14. Decentralized Online Social Networks

Nils Diewald

1. Introduction

Social Network Sites (SNSs) are becoming an increasingly important communication platform on the World Wide Web. According to Nielsen Media, in June 2010 Americans spent nearly a quarter of their online time on SNSs, which therefore supersede email as the most important communication medium on the Internet (Martin 2010). As of September 2011 *Facebook*[1], at this time the biggest SNS worldwide with more than 750 million users (Facebook 2011), was the second most visited site on the web (Alexa 2011).

In this chapter we will discuss the benefits of SNSs as well as potential difficulties for their users, especially associated with the centralized nature of current SNSs.

SNSs allow for the establishment of direct relations to other members of the service, and hence creating an online social network (OSN)[2]. These networks have known benefits regarding efficiency in the dissemination of information, often associated with the so-called "small world" phenomenon proposed by Milgram (1967): Travers and Milgram (1969) conducted a study, asking random selected individuals to send letters to unknown target persons, mediated only by chains of persons they personally know. They found these chains to be unexpectedly short on average (a little greater than five; Travers and Milgram 1969, pp. 432,437), in case they were completed[3]. The assumption was that there is only a small distance between any two individuals in a social network in terms of direct acquaintanceship, which leads to potentially good target-oriented dissemination of information (Dodds, Muhamad, and Watts 2003). A popular hypothesis in social science claims an approximated average value of "six degrees of separation" between any two people on earth[4]. And recent analyses of global technical communication networks – like Email (Dodds, Muhamad, and Watts 2003) or contact lists in Instant Messaging systems (Leskovec and Horvitz 2008) – surprisingly supported this number roughly.

The "six degrees" also gave one of the first Social Network Sites on the World Wide Web its name: *SixDegrees.com* was launched in 1997. It allowed its users to build personal profiles, to send direct messages to other users, to create a list of contacts and – starting in 1998 – to surf the so established OSN (boyd and Ellison 2007). After SixDegrees.com was shut down in 2001, services like *Friendster*[5] (2002), *MySpace*[6] (2003), *Orkut*[7], Facebook (both 2004), *Twitter*[8]

(2006), or *Google+*[9] (2011) adapted its basic principles and introduced new features and forms of relationships and communication.

Boyd and Ellison (2007) define SNSs as

> … web-based services that allow individuals to (1) construct a public or semi-public profile within a bounded system, (2) articulate a list of other users with whom they share a connection, and (3) view and traverse their list of connections and those made by others within the system. (boyd and Ellison 2007, p. 211)

While this definition may be arguable (Beer 2008), it can serve as a blueprint for the architecture of prototypical SNSs as examined in this chapter: A SNS provides tools for the construction of an OSN, with users as nodes and social relationships as edges, the presentation of the user by means of profile pages, and the ability to explore the network along these links. However, this definition may lack a significant aspect of SNSs, which makes them important communication platforms and should be introduced as a fourth item: The ability to interact with each other within the social network[10]. Popular channels for interaction in SNSs are, among others, direct and instant messaging, micro-blogging, sharing of multimedia content, and profile pages. Some of these channels are interwoven in the user profiles, and all are embedded in the context of the egocentric OSN. In addition to this modification, the limitation of "web-based services" seems to be outdated as non-web applications become more and more popular in recent years to participate in OSNs, especially on mobile devices (Ziv and Mulloth 2006; Lugano 2007).

In the first part of this chapter, we will illustrate the characteristics of SNSs, OSNs, and social networks in general from a sociological point of view and discuss their importance as growing communication platforms (Section 2).

Despite their short history, SNSs have become the most popular and dominant communication tool of many users online. But unlike preceding technical communication systems, for example email or telephone, their infrastructure is closed and centralized. Individuals who do not participate are not able to communicate with members. And if they participate, they are not able to communicate with members of other sites. Furthermore, they have not much control on their personal information and how it is disseminated. All information presented and exchanged is under the control of the website's service provider, which may result in serious privacy concerns. This turns these sites into "information silos" (Au Yeung et al. 2009) and their underlying OSNs into "walled gardens" (Fitzpatrick and Recordon 2007).

In the second part of this chapter, we will examine these difficulties regarding the closed and centralized architecture of current SNSs in both technical and privacy related terms, and will discuss the different network topologies (Section 3).

Tim Berners-Lee, one of the inventors of the World Wide Web, made use of the 20th anniversary of the web in 2010 to warn about this, in his eyes, threat to the open web – and talked about "continued grassroots innovations" to anticipate this development, mentioning projects like *GNU social*[11], *StatusNet*[12] and *Diaspora*[13] (Berners-Lee 2010). The latter was announced only a couple of months before, asking for funding to create a decentralized SNS on the open crowdfunding platform *Kickstarter* (Kickstarter 2010). While it was not the first project of its kind, it raised a lot of media attention (including an article in "The New York Times") and at the end of its fundraising round it had accumulated twenty times its goal of $10,000 dollars capital, proclaiming the funders' need for the decentralization of OSN based communication.

In the third part of this chapter, we will discuss these ongoing developments. Open and royalty-free formats and protocols, that are necessary for interoperable and vendor independent systems, are presented (Section 4) as well as projects focusing on decentralizing OSNs (Section 5).

We will conclude with a summary on the topic (Section 6).

2. Characteristics and sociometrics of Social Network Sites

> "The web is more a social creation than a technical one."
> Berners-Lee (2000, p. 123)

The socialization of the web has many forms: In addition to social networking there are applications of social sharing, social news, social bookmarking, social gaming, or social commerce (Schneider 2008). These applications of "social software" have one special thing in common: they support group interactions (cf. Allen 2004). Users of social software interact with each other to the benefit of the service. Take, for example, the collaborations and discussions on the website *Wikipedia* and other wikis (Mehler and Sutter 2008). SNSs, as a subcategory of social software, focus on these interactions (rather than on the object the interactions are about like in, e.g., online bulletin boards; James, Wotring, and Forrest 1995) and allow for an explicit construction of the social relations.

The OSN, based on these relations, can be seen as part of the topmost conceptual layer of a technical communication network (see Figure 1)[14]. The basic layer, as described by Berners-Lee (2007), is the Internet, which he calls the "International Information Infrastructure" (III) (see Figure 1, bottom). Starting in the 1980s[15], it changed the perspective on digital information exchange, realizing "It isn't the cables, it is the computers which are interesting" (Berners-Lee 2007). The underlying communication network was formed by computers as nodes and cables as the edges. The "World Wide Web" (WWW), as the second technical layer (see Figure 1, center), then sharpens the view to "It isn't the computers, but the documents which are interesting" (Berners-Lee 2007). In the

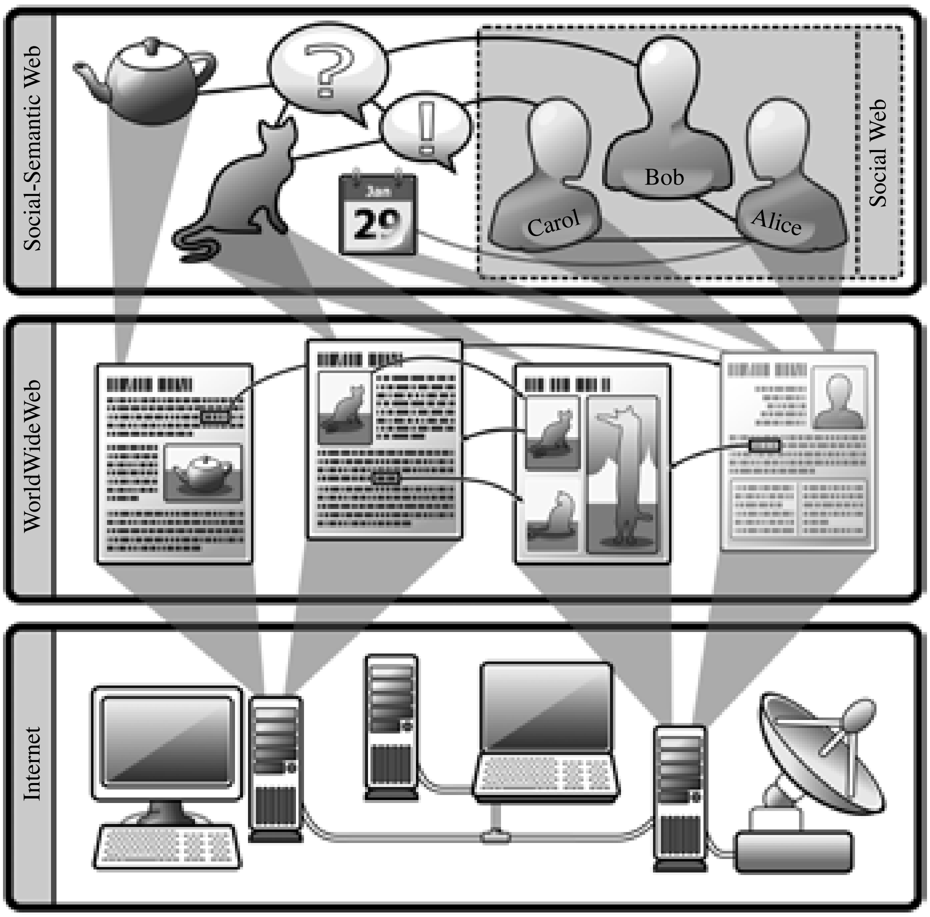

Figure 1. The historically evolved three layers of linked data: The internet (*III*), representing a network of computers, the web (*WWW*), representing hyper-linked documents, and the social-semantic web (*GGG*), representing interlinked data of objects. The social web is an application of the semantic web.

WWW, documents form the nodes of the network with hyperlinks as the edges. Now, the semantic web (see Figure 1, top) is meant to model the realization "It's not the documents, it is the things they are about which are important" (Berners-Lee 2007), for which Berners-Lee coins the term *Giant Global Graph* (GGG). In this technical and conceptual layer, all "things" form nodes in the graph and are related to each other: Texts and photographs as well as humans, products, dates, and thoughts.

There are two perspectives on what the nodes and edges of the social graph as embedded in the GGG can be: A narrow and explicit as well as a wide and im-

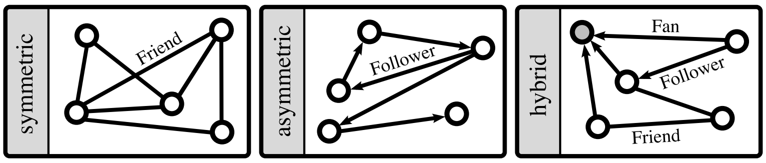

Figure 2. Symmetric and asymmetric relations in SNSs.

plicit one. From the explicit perspective, the social graph is the subgraph of the GGG where all nodes are humans or institutions and their relations are manually established by the members of the social network (e.g., by adding a "friend" to the list of friends on a SNS). In Figure 1 (top), Alice and Bob are connected in this explicit manner, while Carol and Bob are not.

From the implicit perspective, two individuals can also be mediated by different objects in the GGG, forming an "object-centered social network" (Engeström 2005; Breslin and Decker 2007; Breslin, Passant, and Decker 2009). That means, although Bob and Carol are not explicitly connected, they have a mediated relation by taking part in the same online discussion (see Figure 1, top).

When talking about OSNs in the domain of SNSs in this chapter, we will refer to the narrow, explicit perspective, where all relations are direct and manually established by the individuals in the network.

2.1. Profiles, relations, and interaction tools

The information provided by SNSs consist of three basic components: *profiles*, *relations*, and *interactions*. Users of SNSs provide a huge amount of such information on themselves, their social network and their activities[16].

Profile pages represent meta information on the nodes of the social graph, connected via relations that form the paths on which interactions like direct messaging can happen. These relations are manually created by the members of the SNS. Their relation type can form different shapes of networks (see Figure 2): In most cases they are symmetric, as for example in Facebook's relationship model (see Figure 2, left). If the user Alice adds the user Bob to her list of "friends", Bob is asked for acceptance of this friendship invitation. In the case of rejection, there is no relationship between both of them established. In case of acceptance, the contacts are displayed in each others' "friends" lists. Twitter, a microblogging[17] based SNS, on the other hand, has an asymmetric relationship model (see Figure 2, center). Whenever the user Alice wants to read status updates (or "tweets") of the user Bob, she simply "follows" him – his short notes then will be part of Alice' news stream, unless Bob has protected his status updates from being displayed to the public. In that case, Bob has to accept or reject the request of Alice for "following". After that, Alice has Bob in her "following" list, while Bob has Alice as a new member in his "follower" list. Some SNSs allow for both relationship models: *ResearchGate*[18], for example, a SNS for academics, allows users to symmetrically relate with collaborators as well as to follow scientists in whose work the user is interested (see Figure 2, right). Facebook allows partial asymmetric relations with the ability to be a "fan" of special nodes in the social network, such as celebrities, shows, or other objects or events.

As for the wide diversity of SNSs, in the following sections we will focus on symmetric OSNs and refer to Facebook as being a prototypical SNS of this type, due to its concept of reflecting real life social networks: "A social graph is a model for Facebook, we're not trying to make new connections, but mirror the real world", says Mark Zuckerberg, founder and CEO of Facebook (Riley 2007). This is a new model of contemporary SNSs (Lampe, Ellison, and Steinfield 2006). Early services like Friendster had their origin in online dating platforms and thus were aiming at meeting new acquaintances, relying on the idea that an existing social network based on real life acquaintanceship is a good basis for making new connections (boyd 2004).[19] This leads boyd and Ellison (2007) to the preferred term of "Social Network Site" instead of the commonly used "Networking Site", which in their minds emphasizes on the creation of new connections in the social graph.

While meeting new friends still can be part of a user's activity in a SNS, the actual variety of activities on these platforms is huge. As discussing this variety in detail is beyond the scope of this chapter (refer to Thimm 2008; and Waltinger and Breuing 2012, in this issue, for different forms of online communication), we will focus on the impact of the embedding social layer on the different forms of interaction in SNSs.

In Facebook the tools for interaction can be subdivided into three groups: *Communication tools* (including "Wall" postings, status updates, chat, direct messages, comments, and events), *presentation tools* (including profile data, groups, and photo albums), and *entertainment tools* (including games, tests, pokes, and gifts) (Kneidinger 2010).

The *communication tools* vary in the size of the addressed audience as well as regarding their synchronism, from inter-personal (one-to-one, e.g., direct messages) to public communication (one-to-many, e.g., "wall" postings with no specific addressee), and from nearly synchronous (e.g., chats) to asynchronous communication (e.g., status updates). Most of the tools, mainly because of the extent of short messages, bare specific communication characteristics, such as informal use of language, non-orthographical use of punctuation and capitalization, and wide use of abbreviations and emoticons, as known in online communication (Werry 1996).

The *presentation tools* form the basic elements of the profile pages (see Figure 3). Most noticeable elements include the profile data, usually enriched by a

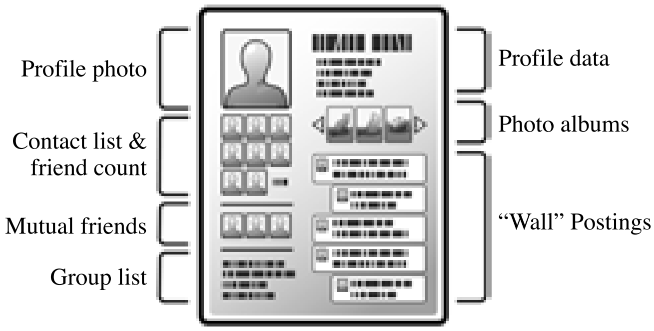

Figure 3. Prototypical elements of SNS profile pages.

photograph, contact and personal information like age, birthday, location, interests, and a short “about me” prose text. Additionally, photo albums and groups – if existing – are part of the presentation of a user’s online identity.

The *entertainment tools* make use of the different communication channels and data provided by the presentation tools of the user and other members of the OSN.

In more and more SNSs the profile sphere aggregates further elements, as part of the communication and entertainment tools, as well as information about the user’s position in the social network. The so-called “activity stream” merges various status updates of a user, including short messages addressed to friends, messages from friends to the user’s “wall”, notifications on activities of the user (e.g., changes of profile data), or information from external services (e.g., games and polls the user participates in).

Profile information is public by a certain degree: The position of the user in her egocentric OSN can provide access authorization to this data. In Facebook, the user is able to adjust the privacy level, saying that only direct friends can retrieve certain information. An initial function of Friendster was the restriction to be disabled to view profiles which are more than three mediating friends away from the observing user (boyd and Ellison 2007). This authorizing principle also applies to the various communication tools on these platforms, as a user is only able to write direct messages or comment on status updates she is allowed to view.

The connections themselves are part of the profile, too, and, as already noted, their visibility and traversability are crucial aspects of SNSs. In Facebook, a random part of the user’s friends is displayed by thumbnail sized images of their photographs, associated with a number indicating the amount of friends the user has (see Figure 3). In addition to that, some SNSs visualize the path between the observer and the owner of a profile by means of mediated connections, or a list of mutual friends.

2.2. Sociometric popularity

A main difference between SNSs and other forms of social software is the embedding of the user's profile in social and communicational contexts. The visibility of the egocentric network is supposed to have an important impact on the user's online reputation (Donath and boyd 2004): While the owner of a profile is in control of her profile data, like name, age, photograph, or her membership in groups, her influence regarding the surrounding social environment and the public communication (e.g., "wall" postings of friends) is rather weak. These contributions from persons other than the profile owner distinguish SNS profiles from other applications of internet communication, like web pages, emails, or chats, where the owner is in full control of her creation (Walther et al. 2008).

To separate aspects on this visibility in SNSs, we will refer to different perspectives a user can have on displayed elements: An *owner-centric view*, applied when watching the user's own profile, and an *observer-centric view*, applied when watching the profile of another user. The display of connections on the profile pages has different benefits depending on these perspectives. The display of one's own contact list can help to stay in touch with friends and acquaintances and the display of a foreign person's contact list gains her credibility (Donath and boyd 2004).

Based on the aforementioned assumption that most connections reflect relationships in the real world, facts in a user's profile data are validated by the companionship of her friends, and are barely to manipulate in this way. In consequence, this makes SNSs easy for the exploration of a person's real life sociometric data, leading to the assumption *"I am whom and how many I'm connected to"*. If a user is married, for example, it is nearly impossible to pretend being single. The same is true for gender, age and other claims, often doubtful in online communication (cf., e.g., Stoll 1995, pp. 56–59). Hence, friendship links can serve as "identity markers" (Donath and boyd 2004). Due to this, profile pages in SNSs like Facebook and the German *StudiVZ*[20] have shown to be close depictions of the persons in real life (Back et al. 2010), rather than presentations of idealized views on their selves (as suggested by, e.g., Manago et al. (2008) in the context of MySpace).

Thus, the online behaviour of the user is connected to her real life social reputation: By embedding herself in real life context, the user signals the "willingness to risk one's reputation" (Donath and boyd 2004), online as well as offline. In anonymous contexts, like in online guestbooks, the user does not risk any reputation by her behaviour. This can be an important advantage when expressing opinions or asking awkward questions (McKenna and Bargh 2000). In pseudonymous contexts, for example in online bulletin boards, a user is expressing the will to only risk her online reputation that is connected with the corresponding pseudonym. The negative aspect on anonymous or pseudonymous contexts is that bad behaviour has only small negative effects on the user, because it does not effect real life social reputation (see Levmore and Nussbaum 2011, for a collection of articles on this topic). That's why communication in SNSs is expected to raise more polite behaviour online (cf. Schonfeld 2011).

Beside reliability, contact lists also affect the perception of a user's social and physical attractiveness. The more attractive the friends of a user are, the better is her perception (Walther et al. 2008). This is also true for all influences on the user's profile that are not in her control, for example, "wall" postings or other forms of external content, and the number of friends (see Section 2.4).

2.3. Quality of social relations

The relational term "friend", as used by Facebook, indicates a strong and somehow intimate relationship. But more often, a lot of these relationships, especially when dealing with implausible high numbers, are rather weak (boyd 2004). Beside the aforementioned reputational aspects of contact lists, political and technical reasons may play a role for gathering more and more contacts: Politically, as the rejection of a "friend's" request may seem impolite or may result in a social disprofit, and technically, because the "friend" relationship widens the authority of a user, for example, it allows her to browse more protected areas in the profiles of other members (see Section 2.1) or to advance her level in a social network game (Wohn et al. 2011). Additionally, users rarely remove established "friends" from their contact lists, although their real life relationship may have passed.[21]

That means that although it is rather likely that the contacts of a person in modern SNSs like Facebook are based on real life relationships, the strength of these relationships is arguable. Thus, when talking about the impact of social networks on technical communication in SNSs, the characteristics of the interpersonal relations may be of high importance.

Granovetter (1973) argues that the strength of a social connection is a

> … (probably linear) combination of the amount of time, the emotional intensity, the intimacy (mutual confiding), and the reciprocal services which characterize the tie. (Granovetter 1973, p. 1361)

A strong tie can exist between close friends or family members, with lots of time spent on the maintenance of the relationship, while weak ties exist between persons who are related in a specific context, for example co-workers or persons who share a common interest and spend time together only occasionally.

In the model of Granovetter (1973), strong ties between an individual and two others indicate a high probability of at least a weak tie between the other two. In Figure 4, Alice has a strong tie with Bob as well as with Carol. Now it may be the case that Bob and Carol are related by a strong tie, too, but at least there is a high probability that they know each other and have a weak tie. In a so-

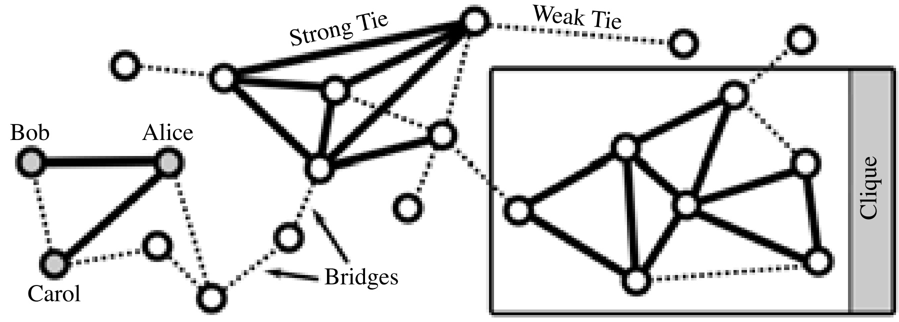

Figure 4. Illustration of a small social network with three cliques connected via bridges. There are strong ties between the individuals Alice and Bob, and Alice and Carol. Based on the definition by Granovetter (1973), there is at least a weak tie between Bob and Carol.

cial network based on this assumption, strong ties form dense, fully connected subgraphs within the social network, so-called “cliques”[22].

Weak ties, on the other hand, are able to connect these clusters. Ties in a network that provide the only path between two individuals by a certain degree (so-called “Local bridges”; by definition always weak), are significant for social networks, as they connect cliques and lead to more and shorter paths in the network (see Figure 4). That means that the better a network is connected by “bridges”, the more effective it is in terms of communication as they provide an important impact to the small world phenomenon. That makes weak ties the more critical connections in social networks: “the removal of the average weak tie would do more ‘damage’ to transmission probabilities than would that of the average strong one” (Granovetter 1973, p. 1366). The weakness of the majority of ties in the egocentric OSN of SNSs can in this way be profitable in terms of dissemination of information. The reason is that cliques gather people that are structurally more equivalent (Burt 1992, pp. 18–19), that is, they have lots of connections in common. In consequence, information will tend to circulate inside the clique. Individuals, that connect otherwise separated cliques and thus fill “structural holes” (Burt 1992) in the network, have a significant control on the flow of information.

For example, when a rumor is told exclusively to close friends and these friends will also retell the rumor exclusively via strong ties, the circulation in the cliques will lead to repetitive transmission of the same information addressed to the same person. By using weak ties, a larger number of people can be reached and a longer path in the social network can be traversed (Granovetter 1973, p. 1366). This is important, when actively intending a widespread dissemination of information as well as for getting novel information (see Section 2.5). Granovetter (1995) showed, for example, that it is a lot more likely to get a new job through weak ties, by means of co-workers or less known acquaintance than by friends or family members.

Weak ties, as they are able to bridge between cliques, are important for informational spread with high social distance (i.e., the path length in social networks), reaching more individuals. On the other hand, strong ties "have greater motivation to be of assistance" (Granovetter 1983, p. 209) and are more likely to be trusted.

Before the advent of SNSs, online communities were often formed by a common interest (James, Wotring, and Forrest 1995), and most members of an online community, as in bulletin boards, newsgroups or chat rooms, did not know each other in person (Wellmann and Gulia 1999, p. 335). These communities were based most completely on weak ties. "Friends" on SNSs nowadays, as they are based on real life relationships, are both: weak and strong. That makes them more effective on the dissemination of information.[23]

2.4. Quantity of social relations

Additionally to the quality of social relations, the quantity has also to be taken into account. Especially as weak ties, by means of local bridges, are important contributors to information flow in social networks by virtue of their numbers – not based on their individual efficiency (Friedkin 1982).

The average member of Facebook has 130 "friends" (Facebook 2011). While this may sound a lot, it is far below the average of 500 to 2.500 acquaintances proposed in Milgram's seminal paper on the small world phenomenon (where acquaintanceship was defined as "known on a first-name basis", Milgram 1967, p. 64).

Anthropologist Robin Dunbar hypothesized that there is a biological limit of social contacts that can be reasonably handled by humans, predicted by around 150 persons (Dunbar 1993, p. 682). The number, Dunbar says, is limited due to the size of the human brain's neocortex, the part of the brain in mammals which deals with complex and logical thoughts. This is meant to be roughly the number of contacts a human "can keep track of within its social group" (Dunbar 1995, p. 287) and is able to have a "genuinely social relationship" (Dunbar 1996, p. 77) with by knowing the other person and knowing how they relate to each other.[24] Dunbar (1993) showed that 150 is a functional size of working communities throughout history. Therefore he claims having more than 200 friends in a SNS can be seen as implausible regarding the term "friend" (Dunbar 2010, p. 22). As the number of friends a user has is displayed in most SNSs, Tong et al. (2008) studied the influence of this sociometric value regarding the influence on her perception. The interesting result was, that the number is not proportional to the user's social attractiveness. Although too few friends indicate less attractiveness (closely related to physical attractiveness), an implausible amount leads to a loss of social attractiveness. The research measured a decrease of social attractiveness by around 300 “friends” (Tong et al. 2008).

Taking the emotional dimension of strong ties into account (following the definition by Granovetter), psychologists argue that there is also a limit on emotional capacity to humans, limiting the number of persons we are strongly emotionally related to. Therefore a person’s “sympathy group” (e.g., a group of “persons whose death would cause you anguish” as defined in a study by Buys and Larson 1979) is rather small, consisting of typically less than 10 to 20 people (Parks 2007; Wellmann and Potter 1999). A similar small subgroup, as a number of active ties with regular interactions and thus greater invested time for maintenance, can be found in Facebook as well (Marlow 2009).

Thus, while there seem to be natural limits of ties a human can have, this does not limit the size of the egocentric social network of a person, as it only holds true for a given point in time (boyd 2005)[25]. Donath and boyd hypothesize, that, although the number of strong ties will not increase by technology provided by SNSs, the number of weak ties that can be maintained “may be able to increase substantially” (Donath and boyd 2004, p. 80). Dunbar concurred with this hypothesis, saying that while biological limits will not be crossed, the communication in SNSs may make the maintenance of relationships more time efficient and less dependent on geographical distance (Dunbar 2010; Krotoski 2010).

Therefore, it is no surprise that keeping in touch with acquaintances and geographically distant friends is the most important benefit of SNSs for the majority of users (Joinson 2008; Kneidinger 2010).

2.5. Commercial use of Social Network Sites

Albeit this user-oriented benefit of SNSs, the most important feature of social networks in general regarding communication is the effective dissemination of information, that is, the acting of a social network as a communication network. It is important in terms of “learning” from trusted friends and acquaintances with implications on various fields, including how individuals “find employment, but also about what movie they see, which products they purchase, which technologies they adopt, whether they participate in government programs, whether they protest, and so forth” (Jackson 2008, pp. 71–72). But – to no surprise – most recent research on diffusion of information in social networks focus on marketing.

Dissemination of information in SNSs happens in a number of ways. Atomic forms include, for example, the “like” button in Facebook, that, by expressing a positive rating on a status message of a friend, a website, a photo or something similar, allows for the quick diffusion of this information with all direct friends in the OSN. The “liked” item then shows up in all friends’ news streams. In Twitter users can “retweet” status messages to make them visible to their followers[26].

In times of online retailers, traditional mechanisms of economics change: Due to the enormous size of potential customers, infinite shelf space and simplified logistics, online retailers can offer a wider variety of products than brick-and-mortar stores. While traditional retailers are most profitable by offering "best-sellers" only[27] online retailers can benefit from selling niche products, making the "long tail" of their product-lineup profitable (Anderson 2006)[28]. To advert niche products effectively, "using traditional advertising approaches is impractical" (Leskovec, Adamic, and Huberman 2006).

Because of its user-centric, information rich approach, and the underlying network structure, SNSs are popular for targeted advertising. Like Google's *AdSense*[29], these sites can provide context sensitive advertisements by analyzing content on profiles, messages, groups etc. So, when reading a message in a group with a computer-related topic, the user may see computer-related ads. But SNSs can additionally rely on *who the consumer is*: The advertisements can be filtered regarding profile information like age, sex, location, and interests. Thus, if the system has further information on the location of the user and her employment status, it can show an advert for a computer-related job when reading in the computer-related group. This user-centric approach to online advertisements can be compared to automated recommendations as on *Amazon*.

By additionally applying social network analysis (SNA), SNSs do not have to rely on the explicit information in the user's profile – it can also rely on the information from the user's contacts. Because users in cliques do not only tend to be structurally equivalent (see Section 2.3), but also tend to be similar regarding several properties like age, education, religion, ethical values, behaviour patterns and so on, the system can guess, who the user is and what she is interested in. This phenomenon is called "homophily" (Lazarsfeld and Merton 1982) and describes "the principle that a contact between similar people occurs at a higher rate than among dissimilar people" (McPherson, Smith-Lovin, and Cook 2001, p. 416). In that way, homophily can be helpful for successfully guessing the background of an individual. On the other hand it can act as a "barrier to diffusion" (Rogers 2003, p. 306), as a high degree of homophily in a subnet of a social network will tend to form circles in information propagation. Bridges in social networks are thus more of a "heterophilous" nature, that means, relations of less similar individuals.

But SNA is not limited to target marketing based on the *intrinsic value* of the user: it also can take her network value into account (Domingos and Richardson 2001). Further filters can be set to target structurally important nodes in the network (see Section 2.3) or individuals with high reputation (see Section 2.2) to identify opinion leaders within the network. Taking in advantage the effective dissemination of information in social networks, these individuals are preferentially triggered to recommend products to their acquaintances, hopefully starting a cascade of positive "word-of-mouth" propagation (Kempe, Kleinberg, and

Tardos 2003). As recommendations by friends and acquaintances are still the most trusted ones (The Nielsen Company 2009), these viral marketing strategies are popular among SNSs[30].

Although these principles are best studied in the field of marketing, the effectiveness of dissemination of information is – as Jackson (2008) noticed – also significant in political discourse. In early 2011, for example, protesters in several countries of Northern Africa were using SNSs to organize their actions. It helped them to quickly diffuse information concerning governmental attacks on demonstrators in form of *Youtube*[31] videos or blog posts.[32]

3. Centralization versus decentralization

> "The trick here, though, is to make sure that each limited mechanical part of the Web, each application, is within itself composed of simple parts that will never get too powerful."
> Berners-Lee (2000, p. 183)

The benefits of SNSs by means of effectivity of information diffusion and maintenance of social relations however may have some drawbacks.

Concerning the maintenance of weak ties, the benefit depends on the participation of all individuals in the same SNS. That is because for now, each of these SNSs are relying on their own separated OSNs. Speaking in terms of social network theory, these sites form cliques with no local bridges – they are "independent, isolated and incompatible" (Mitchell-Wong et al. 2007). Members of a SNS can interact with each other, but not with members of other SNSs. The centralized scenario is often parallelized to the internet's past in the "walled gardens" of *AOL* and *CompuServe* (Recordon 2007; Li 2008). In these early years of the private usage of the Internet, some companies provided email services and discussion forums for their customers, without interoperability with the systems of others – until the emergence of the open, decentralized World Wide Web.

This architecture of the web guarantees the interoperability between different systems by means of open standards (see Section 4) and thus the independence for a customer to choose her provider.

Regarding SNSs, users are free to choose their provider as in the early days of the internet. But furthermore, they can participate in more than one SNS, to be able to connect to as many friends as possible. That means, their identities in the web's "social ecosystem" (Mitchell-Wong et al. 2007) are not unique.

Figure 5 juxtaposes this centralized scenario for SNSs and a decentralized form. In the centralized scenario (Figure 5, top), the user Alice participates in

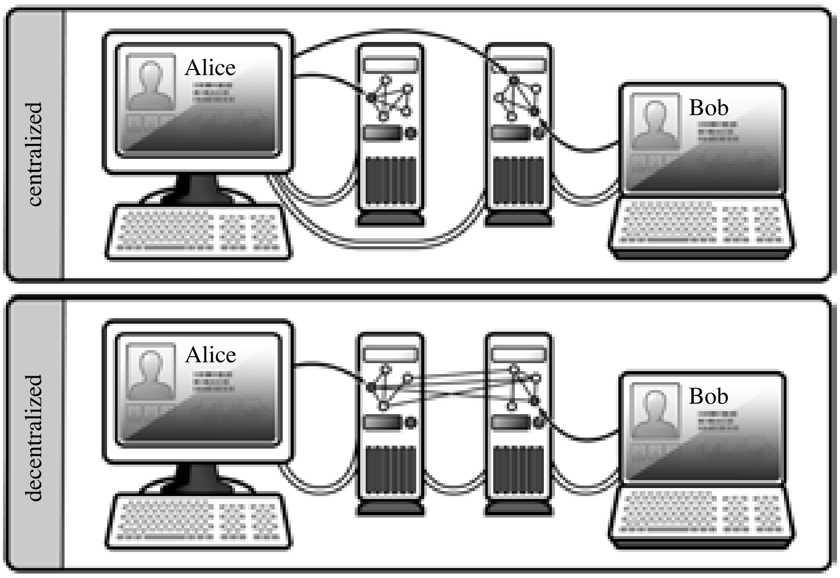

Figure 5. The architecture of centralized and decentralized OSNs. While in both scenarios two SNSs exist, the underlying OSNs in the centralized scenario are separated, while there is an interconnected OSN in the decentralized scenario.

two separated SNSs, having two separated identities with separated profiles and separated contact lists in separated OSNs. Bob participates in one of these SNSs and in this site's OSN he is a friend of Alice – while he is not a friend of Alice in the other one. That means, the OSNs of both SNSs are separated.

In the decentralized scenario (Figure 5, bottom), Alice and Bob participate in one and the same OSN, although they are members of separated SNSs. Their identities in the web's social ecosystem are unique. They each have one profile and one contact list in one common OSN. That means, their SNSs are no "walled gardens" anymore.

As SNSs become more and more important as communication platforms, vulnerabilities regarding *technical* and *privacy* issues gain significance. This Section will discuss these issues in the context of centralized SNSs and will juxtapose centralized and decentralized scenarios, as they have different properties in these aspects.

3.1. Technical issues

The technical architecture of communication networks is always a critical issue. The main objective is to avoid scenarios where failure of small parts of the architecture have a huge impact on the stability of the whole network. When

Paul Baran outlined possible topologies of computer networks in 1964, he stated that a "centralized network is obviously vulnerable as destruction of a single central node destroys communication" (Baran 1964, p. 1). Although Baran was talking primarily about enemy attacks on the communication infrastructure of a country, the nature of single points of failure (SPOFs) in network systems is risky in many ways.

In 2009, during the Iranian election, supporters of the political opposition communicated heavily via SNSs like Twitter or Facebook, to inform about protests and organize their campaign. The communication broke down as the services were blocked by the Iranian regime. Because of their centralized nature, there was only the need to block access to two sites to disrupt the availability of the necessary information and the whole communication structure. Shortly before this blocking action, due to its responsibility regarding the protesters in Iran, Twitter refused to take an operation break for maintenance, that would otherwise have interrupted the communication worldwide (Stone and Cohen 2009).

In September 2010, Facebook went offline for two and a half hours because of a software bug (Johnson 2010), and in the hours right after the death of musician Michael Jackson in June 2009, Twitter almost collapsed[33] because of the high frequency of new tweets on this topic (Bates 2009).

But also enemy attacks can still influence the availability of services in a communication network: On August the 6th, 2009, both Facebook and Twitter were facing "Denial of Service" attacks, forcing Twitter to go even offline (Van Buskirk 2009).

Enemy attacks as well as software bugs, performance problems, maintenance downtime, and governmental blocks make SPOFs critical in terms of technical communication networks. Sometimes services simply go out of business, as the example of the previously mentioned SixDegrees.com has shown, or the defunction of Twitter competitor *Pownce*[34] in 2008. As SNSs become more and more popular, people change their communication behaviour and rely on these centralized communication platforms.

Figure 6 visualizes centralized, decentralized, and distributed scenarios of OSNs following the subdivision of communication networks by Baran (1964).

In the centralized scenario (Figure 6, top-left), Alice participates in the SNSs 1 and 2, while Bob only participates in 2. That means, Bob is not able to connect with users who only participate in SNS 1. In the decentralized and distributed scenarios on the other hand (Figure 6, top-right and bottom-left), every user can connect to every other user, regardless which SNS they participate. The decentralized scenario has Bob participating in SNS 1 and Alice participating in SNS 3. Because these SNSs are technically connected, Alice and Bob can be socially connected in the same OSN, although they participate in different SNSs.

While centralized scenarios are highly vulnerable to SPOFs (think of SNSs 1 and 2 as being Facebook and Twitter), a decentralized scenario is less vulner-

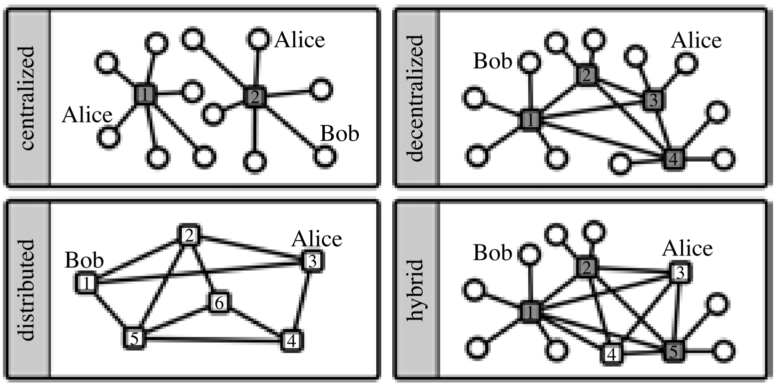

Figure 6. The topologies of centralized, decentralized, distributed, and decentralized-distributed-hybrid SNSs (cf. Baran 1964, p. 2). Circles are representations of participants in the social network, boxes are SNS providers. In the distributed and hybrid scenarios, white boxes indicate no distinction between users and providers.

able, as the defunction of one SNS only affects its users without affecting the communication network as a whole. The distributed scenario is the least vulnerable.

If SNS 2 in the centralized scenario (Figure 6, top-left) goes offline due to technical difficulties, Bob, Alice, and all other users on this SNS are no more able to communicate with each other. If SNS 2 in the distributed scenario (Figure 6, bottom-left) goes offline, this would only have an impact on one participant in the network, while all other participants would still be able to communicate.

The distributed scenario does not follow a *client-server* like model with a distinction of user and provider. Instead, it follows the principles of a *peer-to-peer* model (P2P; see Heyer, Holz, and Teresniak 2012, in this issue), in that all instances are equal in terms of technical connectedness with links based on social relations. Beside these strict architectures, hybrid scenarios of decentralized and distributed SNSs with a common OSN are possible, where, for example, Bob participates as a client of the decentralized SNS 1, while Alice uses the dedicated SNS 3 in a distributed way (see Figure 6, bottom-right).

By following this taxonomy, contemporary SNSs like Facebook can be seen as centralized and separated from other networks. Email services are decentralized, as servers can communicate with each other, allowing for provider independent communication of their clients. *Skype*[35] (in 2011 the most successful Voice-over-IP service on the Internet) or Instant Messaging systems like *ICQ*[36] are distributed, using P2P technology[37]. Weblogs can be seen as hybrid, as there are dedicated blogs as well as popular services like *WordPress.com*[38]. That means in consequence, for example, although when access to the site WordPress.com is limited in China, dedicated instances of WordPress (the open source blogging software running WordPress.com) can still be available (Newey 2009).

Admittedly, as most decentralized architectures allow for dedicated instances as well as servers for multiple clients (e. g., every user is allowed to set up her own email server), decentralization can be seen as a range: From a few interoperable instances, serving as providers for lots of users, to distributed systems with dedicated instances for each user. We will use the term "decentralized" in this chapter in contrast to "centralized" and will refer to "distributed" as being fully decentralized. In recent literature, the term "federated" was used to describe the same concept of an interoperable, decentralized social web (Prodromou 2010).

3.2. Privacy and legal issues

In centralized scenarios, the user is dependent on the separated OSN of the SNS she participates in, as well as on the provider of the service. These providers are in full control of all information on the users, her relations and her interactions. Regarding the diffusion of information under commercial aspects (see Section 2.5) and against the background that SNSs in most cases enable third-party applications use on this information, this can have a significant impact on the members' privacy.

But a lot of the benefits from SNSs depend on the privacy the user can expect. When Facebook launched in 2004, the service was restricted to students having a harvard.edu email address. While this fact limited the value of the network[39], it "contributed to user's perceptions of the site as an intimate, private community" (boyd and Ellison 2007). This privacy, however, is doubtful.

As the amount of data a user provides to the public, her friends, and her SNS provider is immense (see Section 2.1), the protection of this information is a significant challenge. This challenge is not in the user's hands alone but also in the hands of the provider, who (in most cases) has a commercial interest in making use of the data.

The question, to which degree the service provider has the right to make use of the data, is mainly open and can be paraphrased to the question, if the data provided in centralized SNSs is of public or private nature. Due to the recency of SNSs, legal practice in judging the privacy of this new technique is relatively vague. In case of the major SNSs, the protection of privacy and data has to follow the jurisdiction of the USA.[40] Hodge (2006) discusses court decisions regarding (mostly technically) mediated communication based on the Fourth Amendment to the United States Constitution and their impact on privacy issues on Facebook and MySpace[41]. He analyzes that, if a communication act is private or public depends on a couple of factors: The mentioned "expected privacy" of a user is important, but this expectation has to be "one that society is prepared to recognize as reasonable" in order to be protected (Hodge 2006, p. 113). In fact, the Supreme Court "consistently has held that a person has no legitimate expectation of privacy in information turned over to a third person" (Hodge 2006, p. 114), as is the case with centralized SNSs.

Another aspect concerning the privacy of the data is the intended recipient of the communication. While phone numbers are intended to be of value for the phone company to connect the user with the intended conversational partner, the content of the call is meant to be addressed only to the partner. That means, the phone company is the intended recipient of the phone number, while the addressee is the intended recipient of the content. The same is true for the address on a mail envelope in opposite to the letter: The postal service has a legitimate business purpose to use the address on the envelope, as it is necessary for providing the desired service. The user of a mail service thus has no expected privacy regarding the address on the letter's envelope (Hodge 2006).

While a mailman has no business interest in opening and reading a letter, Facebook, Google and the like, on the other hand, have a business purpose to analyze the content of profile information or emails, or apply SNA on the user's contact list to advance their services, including their advertising model. The same aspect is important for storing this information: While an internet provider has no business purpose to store information of their customers aside their needs for billing, Facebook advances its advertising with this knowledge (Hodge 2006). Because of this legitimate business purpose it is arguable if a user has a reasonable expected privacy in these services.

Noticeably, most SNSs allow for changing the degree of publicity of their profiles and contact lists in regards to other users, limiting it to be viewable, for example, only to direct friends (see Section 2.1). By explicitly limiting a profile, an expected privacy may be seen as being expressed. In this case a limited profile "would be more like a phone call or a sealed letter in this aspect" (Hodge 2006, p. 118), and by this matter being protected by the Fourth Amendment.

But, in the end, information on SNSs "can only be known to be private if the information they contain is not at any point given to an intermediate service provider" (Lucas 2007), as restrictions on data access is not effective to the SNS provider. That means, privacy can be best protected in distributed scenarios.

In addition to the use of personal data for commercial interests, SNSs also have control of the provided information. The provider is allowed to ban users if their profiles do not fit its interests. Take, for example, the rebellion of users against Friendster regarding its "Fakester Genocide" politics (boyd 2004), when entertaining fake profiles were rigorously deleted, or the defunction of user accounts with pseudonyms in Google+ (Pfanner 2011). The same can be true for content: The algorithm Facebook uses to rank messages in the "top news" stream (the so-called "EdgeRank" algorithm) is, for example, in full control by the provider to personalize the experience of the SNS[42], as is Facebook's filter mechanism to prevent the transmission of unwanted messages (Singel 2009).

The provider can control the diffusion of information within the centralized OSN of its SNS and has the right to change its general terms and conditions about all data whenever needed to optimize the service. In a distributed OSN, on the other hand, the user has potentially full control on her data and the degree of personalization of her SNS.

Beside already mentioned technical charges like "Denial of service" attacks, censoring, and governmental blocking of SNSs to limit the accessibility of data provided by SNSs (see Section 3.1), there also exist attacks to incriminate the privacy of SNSs' users. Various of these attacks are not restricted to centralized scenarios, as they are based on social engineering mechanisms (see Remark 23.1 in Cutillo, Manulis, and Strufe 2010, p. 510) – however, in distributed SNSs it is up to the user to protect her data and her privacy. And in a decentralized scenario the user can at least choose the provider she trusts the most[43].

4. Open protocols and formats

> "This is not a story of startups and entrepreneurs.
> This is not a story about who will become the next ~363kg gorilla.
> This is not a tale of who will next be crowned king.
> This is a story about … Wait for it …
> Server-side software implementations and open, documented protocols."
> Chisari (2011)[44]

The idea of decentralized OSNs is based on the principles of the decentralized conceptual layers of the technical communication networks (remember Figure 1). The Internet as the first conceptual layer is a decentralized computer network. It relies on open standards for information transmission by means of the Internet Protocol Suite. The World Wide Web as the second conceptual layer is a decentralized document network. It relies on open standards for document linkage by means of HTTP, URIs, and HTML. The third conceptual layer is meant to be a decentralized object network. Like both of the underlying layers, it relies on open, royalty-free standards.

As seen in Section 2.1, a SNS consists of three building blocks: *profiles*, *relations*, and *interaction tools*. To make these components vendor independent interoperable in a decentralized or distributed way, they need to be specified by means of open protocols and formats. In addition to that, secure mechanisms for the authentication of a user and the authorization for the access of resources are necessary.

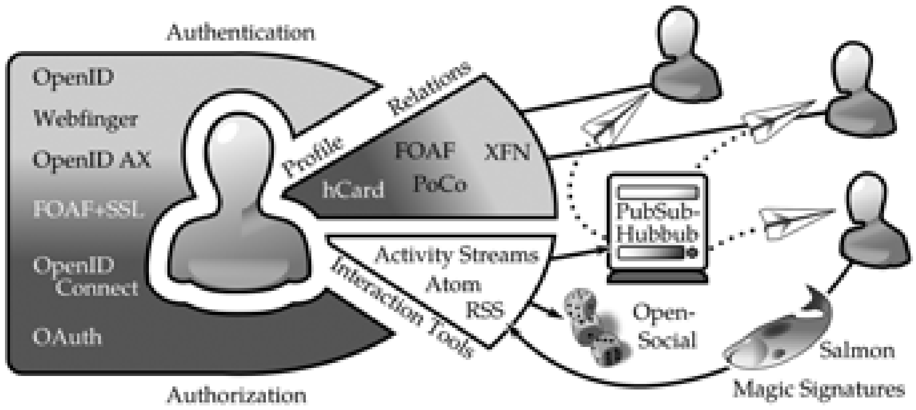

Figure 7. A user in the social web needs mechanisms for authentication and authorization (Section 4.1), tools for presenting profile information and social relations (Section 4.2), and protocols for real-time publishing and interactions (Section 4.3).

Figure 7 outlines the architecture presented in this Section. The following discussion on these topics can only show an excerpt of the wide variety of open protocols and formats in the realm of SNSs. For lots of the discussed use cases there are alternatives – gaining small differences up to completely different approaches.

4.1. *Identification*

Internet Protocol addresses are necessary for the identification of computers in the Internet, and URIs (Uniform Resource Identifier) are necessary for the identification of resources in the WWW. In the same manner identifiers for individuals are crucial for the social web[45]. Nowadays, as most of the social activities on the web happen on SNSs, users have unintentionally multiple identities on the social web: They have accounts on Facebook, Twitter, Google and so on. Beside the aforementioned technical and privacy related issues, this can lead to practical problems. When participating in several SNSs, the user initially has to create an account for each one of these, which means to type in the same personal information over and over again. Additionally, the user has to maintain her multiple accounts occasionally when information changes, like location or relationship status. Status messages (e.g., *Tweets*) have to be send multiple times to multiple SNSs to reach all possible contacts, which can, in consequence, lead to repetitive transmission of information to the same person in different SNSs. Another drawback is to keep track of replies on all these platforms. A lot of users therefore use aggregation services to bundle streams from various

HAL8_014.pod 482
07-07-23 13:50:11 -Administrator- Administrator

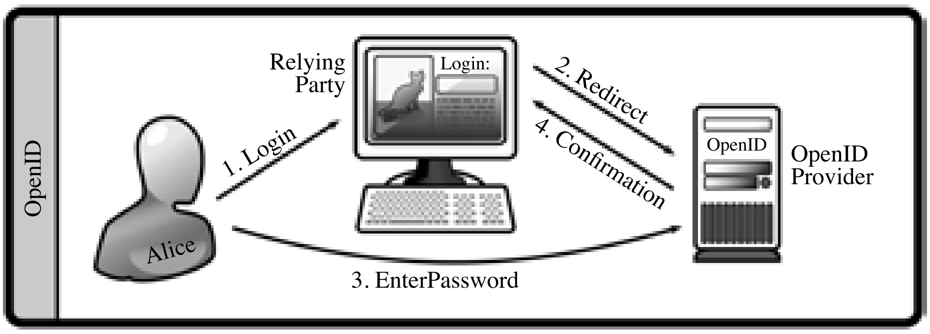

Figure 8. Four basic steps in a (simplified) OpenID authentification: 1) the user types her OpenID into the login form of a relying party site, 2) the relying party site redirects the user to the associated OpenID provider, 3) the user authentifies herself to the provider by inserting, for example, a password, then 4) after authentifying successfully, the OpenID provider tells the relying party that the user is rightfully associated to the given OpenID.

SNSs, showing last tweets from Twitter, recent videos from their YouTube channel, last uploaded pictures on *Flickr*[46] and recent bookmarks on *Delicious*[47].

This practical challenge often also leads to security problems, as users tend to use the same password on several sites (Riley 2006). Security vulnerabilities on one of these sites then can make all other sites vulnerable as well – and identity theft an easy task.

A solution to this problem would be a unique identity in the OSN, that can be used across all sites. To provide such a solution, two aspects have to be taken into account: First, a way for the user to authenticate herself to the service, and second, to grant the service the allowance, for example, to retrieve information about the user, that is, a way for authorization.

OpenID (The OpenID Foundation 2007) is an open standard for decentralized authentication. It is meant to be a single-sign-on solution, that is, the user can apply her OpenID to sign-on for several services instead of creating new identities for each one. The OpenID therefore is an URI. With this mechanism, a user needs only one URI and one password throughout the whole social web, having one single unique identity.

In practice, when using the OpenID to log in to a service (the so-called "relying party"), the user enters her URI first. Alice, for example, has the OpenID https://openid-server.example.net/~alice. The relying party then redirects Alice to her OpenID provider where she inserts her password for authentification. The OpenID provider afterwards redirects back to the relying party and notifies it that the given OpenID is correctly associated with Alice (see Figure 8).

Because it is rather uncommon for users to accept URIs like https://openid-server.example.net/~alice as their unique online identities, the second step in Figure 8 (the redirection to the login form of the OpenID provider) is rarely applied directly. OpenID allows for indirect identifiers, forcing the relying party to discover the OpenID provider of the user based on the OpenID that does not necessarily have to lead to the provider. Assume Alice has a blog at https://example.org/~alice, she can use this URI as her OpenID. In the HTML document of her blog she has to give meta information on where her OpenID provider can be found (by using a <link />-tag in the <head /> section of the HTML document), the relying party then discovers this information and redirects to her provider[48]. In this way, Alice's unique identity is directly related to information about her that can be found on her blog.

Although, URIs are neutral regarding the resource they locate to, people usually don't think of themselves as being represented as URIs. This led to other forms of Identifiers in the discovery process of OpenID, with using email-like addresses as being the preferred variant.

The *Webfinger* protocol (Fitzpatrick et al. 2010; Jones, Salgueiro, and Smarr 2011) provides email like addresses as identifiers and allows for the discovery of *OpenID*. It was designed based on the *Finger* protocol (Harrenstien 1977), that was used to provide information on user accounts on different computers in a network. Webfinger introduces a new scheme prefix "acct": (to differ from the email scheme prefix "mailto":) and allows for the discovery of meta information on an account name like acct:alice@example.org by requesting a document from the given domain called host-meta (Hammer-Lahav and Cook 2011) that can be found in a known location on the server (the "/.well-known" location; Nottingham and Hammer-Lahav 2010). The returned document is an *Extensible Resource Descriptor* file (XRD; Hammer-Lahav and Norris 2010), that contains meta information on the requested domain[49].

A possible link of type *lrdd* (*Link-based Resource Descriptor*) in this document can contain a template for the account URI to be requested, for example http://example.org/webfinger?q={uri}. By retrieving http://example.org/webfinger?q=acct:alice@example.org then, a new XRD file is returned, containing account specific information like the user's OpenID endpoint or her profile information.

While OpenID is the dominant decentralized single-sign-on system for authentication on the web, it has many drawbacks, mainly due to the diversity of specifications for implementers and the minor awareness and acceptance by users. Proprietary centralized approaches like *Facebook Connect* or *Sign in with Twitter* are currently more successful and widely adopted. In addition to OpenID, they do not limit their functionality to authentication but also allow for authorization in the same step, using an open protocol called *OAuth* (Hammer-Lahav, Recordon, and Hardt 2011). Facebook and Twitter are using this protocol also for their application programming interfaces (APIs). OAuth enables a user to authorize a third party with limited access to her data without sharing password information.

OpenID Attribute Exchange (OpenID AX; Hardt, Bufu, and Hoyt 2007) is an extension to OpenID to combine authentification and data exchange in a similar way to, for example, Facebook Connect. A more recent approach is *OpenID Connect*[50].

The World Wide Web Consortium summarizes solutions to authentication under the term *WebID*[51]. A current approach in this workspace is *FOAF+SSL* (Story et al. 2009), that uses SSL (*Secure Sockets Layer*) and *FOAF* (*Friend of a Friend*; see next Section) for the establishing of a *web of trust* based authentication infrastructure.

4.2. Profiles and relations

Information on both the profiles and the relations has to be accessible in a human as well as in a machine readable format. The World Wide Web introduced HTML as a standard for hypertext documents for this purpose. In the semantic web, now, there are several different formats to define different resources (Waltinger and Breuing 2012, in this issue). In this Section we will give a brief overview on formats relating to profile and relationship data in the social web (cf. Mika 2007). These formats differ in their expressiveness, their objective, and their embeddedness in the WWW.

Early electronic standards for personal data sets were defined independent from the web. *vCard* (Internet Mail Consortium 1996), for example, defined an electronic business card format. Listing 1 shows an example vCard of the user Alice.

Listing 1. vCard of Alice Example.

```
BEGIN:VCARD
VERSION:4.0
FN:Alice Example
ORG:Example Inc.
URL:https://example.org/~alice
EMAIL;PREF=1:alice@example.org
END:VCARD
```

To place this electronic business card information on the WWW, *hCard* (Çelik and Suda 2005) was developed as a 1:1 representation of vCard by means of microformats[52]. Microformats are semantic annotations in HTML, using established HTML attributes like "class" or "rel" to formulate relations between elements and contents on a webpage, or between the document and linked resources. Listing 2 shows the vCard of Alice as an HTML-embedded hCard.

Listing 2. hCard of Alice Example.

```
<div class="vcard">
<a class="url fn" href="https://example.org/~alice">
AliceExample</a>
<a class="email" href=
"mailto:alice@example.org">alice@example.org</a>
<div class="org">Example Inc.</div>
</div>
```

Microformats provide vocabularies for a wide range of domains. Regarding relations in OSNs they define the *XHTML Friends Network* vocabulary (XFN; Global Multimedia Protocols Group 2003). The declared target of XFN is the annotation of links, especially as part of “blogrolls” (see Lenhart 2005, pp. 122–133), to form social networks in the so-called “blogosphere” with elaborated relationships.

XFN allows for fine grained annotations in respect of the type of the tie between two individuals, regarding the strength (defined values are “Friend”, “Acquaintance”, and “Contact”), the domain of relationship (e.g., “Professional”, “Romantic”, or “Family”) and even types of relationships within the domain (e.g., “Sibling” in the “Family” domain). Additional to the basic directed and undirected graph models of SNSs, this introduces asymmetric relations, as a “Child” relationship is inverse to a “Parent” relationship.

Microformats were invented to enhance HTML with semantic information instead of rebuilding the web by means of new semantic technology, primarily the *Resource Description Framework* (RDF; Brickley and Guha 2004). RDF is one of the fundamental components of the semantic web. It is a formal language to model decentralized knowledge by means of <subject, predicate, object> triples, like “Alice knows Bob”. With this method, RDF allows for defining directed, labeled graphs with multiple edges. The distributional character is introduced by allowing URIs for the graph nodes and namespaces for different predicate vocabularies.

The *Friend of a Friend* (FOAF; Brickley and Miller 2010) namespace defines an RDF vocabulary to provide knowledge on an individual. On the one hand, this is profile-like information, as the name, title, gender, homepage, or the workplace. On the other hand, FOAF enables to formulate relationships with other individuals.

In a decentralized SNS the user is in control of her FOAF information. With the knows predicate she is only able to define an asymmetric relation: If “Alice knows Bob” there is no conclusion that “Bob knows Alice”. This is similar to the relationship model in Twitter. To reason a symmetric or bidirectional relation between Alice and Bob (like Facebook’s “Friendship”), a system has to follow the URI of the object, analyze the FOAF information of Bob and has to check for the triple “Bob knows Alice” [53].

Additional namespaces for personal information that can be embedded in RDF are biographical (Davis and Galbraith 2002), calendaric (Connolly and Miller 2005), or geographical information (Brickley 2003).

With RDFa (Adida et al. 2008), an extension to the syntax of XHTML[54], a specification was suggested that makes it possible to enrich current webpages with semantic information using these RDF triples likewise to microformats.

A similar approach to the same data but with a different focus is the *Portable Contacts* specification (PoCo; Smarr 2008). While it deals with profile data and contact data in a comparable fashion like FOAF (with using a vocabulary widely borrowed by vCard for profile data and XFN for contact relation types), the main objective is to provide a standard mechanism for the secure access and exchange of this information between different services, for example, to allow a SNS to access the address book of a user's email provider to search for known contacts in the OSN or for the export of a user's digital address book.

4.3. Interaction

Most interactions in SNSs are time-aligned, that means, the information is shared and aggregated in chronological order of publishing, for example, status updates or "wall" postings. A common way to distribute time-aligned information in the semantic web are so-called feeds, for example, in RSS or Atom formats (Winer 2009b; Gregorio and de hOra 2007). These formats are based on XML and serialize entries of small information. A specification to describe entries typical in the context of SNSs is *Activity Streams* (Atkins et al. 2011). It is an Atom or JSON (Crockford 2006) based format, where each entry holds information on the activity's author, the kind of activity (e.g., "post"), the object of activity (e.g., a "note"), and possibly the target (e.g., a blog).

For SNSs, real-time notifications of new activity events like these are important. When, for example, the user Bob is a friend of the user Alice and writes a new status message on his activity stream, Alice is immediately notified by her news stream. In centralized scenarios, all information is stored at one point, so the stream of information Alice gets is directly served by her SNS provider. In a decentralized scenario, the activity streams of Alice' friends can be stored completely separated, which makes synchronization of all feeds more complicated. The SNS needs to fetch all her friends' activity streams from the web to aggregate it in her news stream. When combining this with real-time information, the server has to fetch all streams regularly, which results in bad performance if Alice has a lot of friends (see Figure 9, top). In favour of regular requests to Bob's server ("pull"), the system can alternatively send notifications to all subscribers ("push"), which are, in a SNSs context, Bob's "friends" or "followers". These server-to-server notifications in favour of regular pulling have lately been named *WebHooks*[55]. *PubSubHubbub* (or *PuSH*) (Fitzpatrick, Slatkin, and At-

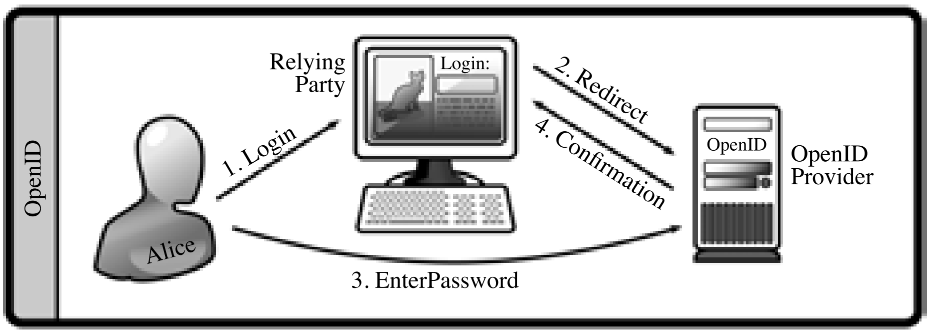

Figure 9. Regular request mechanism and PubSubHubbub.

kins 2010) is a push service using webhooks with a mediating hub server[56]. Instead of fetching all streams of Alice' friends regularly, Bob's server, after he published a new status message, sends a notification to a hub, where all his friends subscribed to his activity stream (see Figure 9, bottom). The hub then fetches Bob's new status message and forwards it to all subscribers. Afterwards the subscribers are able to update their news stream in real-time. In this way, PubSubHubbub delegates time-consuming distribution mechanisms to a dedicated system. A similar approach to real-time feed publishing with mediating hubs is *rssCloud* (Winer 2009a).

For user-to-user interactions (e.g., sending responses to status updates or to "like" a posting) in a decentralized way an additional mechanism is needed, as a system has to know, where and how to send a response. The *Salmon* protocol (Panzer 2010) defines a specification for such a mechanism. It allows for sending Atom entries to specified endpoints as, for example, replies to feed entries by another user. If the user Bob wants to respond to an Activity Streams entry by Alice, and this entry serves a Salmon endpoint in form of an URI, he can post the entry directly to Alice' feed[57].

For some events, like the notification a user was tagged in a photo on an otherwise non-related resource, the user can be notified without responding to a resource by using a Salmon endpoint directly associated to the user's account, discovered using Webfinger. If the user Bob, for example, wants to mention Alice in a posting, the Salmon generator discovers her Salmon endpoint by applying Webfinger and posts the message to Alice.

To authenticate Bob as the author of the message, Salmon allows for signing the message with *Magic Envelopes* (Panzer, Laurie, and Balfanz 2011). Magic Envelopes provide a Public Key Infrastructure (PKI) with a private key for signing messages and public keys for author verification. By applying Webfinger to discover the public key of Bob and verifying the signature of the Magic Envelope of the message, Alice can ensure that Bob was the original author of the message. This helps to establish a reliable association between an authenticatable author (see Section 4.1) and her publication.

The Diaspora project as well as *Friendika*[58] provide additional envelope format specifications for the Salmon Magic Envelopes to fully encrypt the messages, based on PKI as well.

All these protocols and formats are able to provide the functionality of both communication as well as presentation tools for decentralized SNSs (see Section 2.1).

Regarding decentralized entertainment tools, the *OpenSocial* (OpenSocial and Gadgets Specification Group 2010) framework provides a bundle of standardized APIs to create social applications, games and widgets (e.g., gifts) with access to profile information, contacts and several other features of SNSs (LeBlanc 2011).

For a more comprehensive overview regarding the technical architecture of decentralized SNSs, including various use cases and further information on aspects like privacy standards, refer to the publications of the W3C Social Web Incubator Group (2010).

5. Projects

Although necessary building blocks for the infrastructure of a decentralized OSN by means of open protocols and formats already exist, the social web is still dominated by centralized SNSs. In this Section, we want to give an overview on several projects (currently) working on decentralizing SNSs. This list is not meant to be comprehensive, nor does it focus on approaches to decentralized SNSs only, but it shall reflect different flavours and directions of ongoing work in this field with a special emphasize on the aforementioned protocols and formats.

In 2010, *StatusNet Inc* – the company behind the microblogging SNS *Identi.ca*[59] – proposed an open standard for distributed status updates as a suite of open protocols called *OStatus* (Prodromou et al. 2010)[60]. It included the previously introduced specifications of the Salmon protocol, Activity Streams, Webfinger, a subset of Portable Contacts, and PubSubHubbub for publishing of and subscribing to status updates in real-time.

Nowadays OStatus is implemented in several software products[61], considerably in the StatusNet open source software, that runs several instances on the web – with Identi.ca being the most popular among the public ones. While it was originally designed for the decentralization of SNSs based on the asymmetric model, projects like GNU social extend its functionality, aiming for decentralized, symmetric, Facebook-like SNSs. The already mentioned Diaspora project was launched in 2010 with the identical goal. While initially starting with specialized protocols and formats, in recent development stages Diaspora adapted the specifications of OStatus as well, allowing to interact with users of StatusNet or Friendika, which is another OStatus compliant SNS.

The *DiSo*[62] project does not aim on creating a SNS, but provides plug-ins for blogging software and content management systems like WordPress, *Movable Type*[63], or *Drupal*[64] to support features for the social web in terms of open protocols and formats. This is closely related to numerous efforts to provide integration of (decentralized) social networking functions into existing blog and content management software, for example *socialriver*[65], a WordPress package based on OStatus.

These approaches are embedded in the basic infrastructure of the World Wide Web, using URIs, HTML, and HTTP. *OneSocialWeb*[66], a decentralized SNS effort by *Vodafone*, supports a lot of the aforementioned open formats and protocols (including OStatus), but has a different approach regarding server-to-server communication: The communication does not rely on HTTP but on *XMPP* (Jabber Software Foundation 2004), an open protocol for decentralized instant messaging formerly known as "Jabber". As the XMPP infrastructure is build for decentralized real-time communication, this setup gains more and more popularity. Another project using XMPP for SNSs is *buddycloud*[67].

Although most of the current projects working on decentralized SNSs aim to support the OStatus specification, competing mature protocols exist as well. For example the *Appleseed*[68] project uses its own specification (called *QuickSocial*) as does *NoseRub*[69].

Most projects in the field currently focus on decentralization in favor of distribution. That is, hubs in forms of SNSs provide an entrance to the social network for multiple users, while not every user is in need for a dedicated SNS portal (see Section 3). This is along the lines with email, as not every user has to set up her own email server. In some ways, this can be risky as, for example, the provider still has control of the user's data. As seen in Section 3, full distribution gives a better protection regarding privacy concerns as well as regarding technical issues. Projects trying to establish real distributed SNSs focus on private servers for every individual (like the *FreedomBox*[70] project) or use applications on mobile devices (Tramp et al. 2011), that even work without a connection to the Internet.

Some of these systems even emphasize full distribution of the OSN over embedding the social network decentralized in the World Wide Web[71]. Systems of this focus make use of P2P technologies (see Heyer, Holz, and Teresniak 2012, in this issue) and mostly emphasize privacy issues with the use of encryption. Projects include, for example, *Safebook*[72] (Cutillo, Molva, and Strufe 2009) and *PeerSoN*[73] (Buchegger et al. 2009).

Beside these projects, major companies now implement several of the illustrated specifications in their services and in some cases even initiated the development. For example, accounts on Google.com or Yahoo.com can be used as OpenIDs and are discoverable via Webfinger; *Google Buzz*[74] had a similar architecture to OStatus; Facebook's stream API provides the Activity Streams standard; Orkut uses XFN for some annotated relations in a user's profile; and, together with MySpace and several others, it relies on OpenSocial for its applications.

6. Conclusion

In recent years, the social web is gaining momentum on the internet. Especially social network sites (SNSs) like Facebook made online social interactions immensely popular to a wide range of online users.

This chapter outlined the characteristics of SNSs from both a sociological as well as a technical point of view (see Section 2). SNSs were introduced as services that allow for interaction within an online social network (OSN). The success of these platforms was shown to be reasonable due to social benefits like keeping in touch with friends or acquaintances, and being able to monitor their activities without much effort.

Currently, most of the social activities on the World Wide Web happen on centralized SNSs. Critical aspects regarding this architecture were presented, especially the implications regarding technical vulnerabilities and privacy (see Section 3). SNSs based on decentralized OSNs were introduced as a less vulnerable and privacy-aware alternative approach. Open protocols and formats were illustrated as necessary building blocks for vendor independent interoperable SNSs in a decentralized scenario (see Section 4) and a brief overview on currently developed projects in this field was given (see Section 5). These projects try to offer the benefits of SNSs without having most of their drawbacks.

For the moment, future development in this field is not foreseeable. Mostly all specifications of protocols and formats shown in this chapter are still in development or even in draft status. Projects are in early stages to implement common specifications for interoperability in the social web, and although major companies support these developments, the future of a decentralized OSN is open.

But the attention in the Diaspora project has shown that online users are interested in alternatives to centralized SNSs. And the movement within the pool of projects to come up with an interoperable standard, like the mentioned OStatus, is promising. The diversity of all these projects has the potential to result in a wide variety of interoperable clients of one OSN – instead of one platform – that could be able to allow each user to individually choose her wanted level of privacy and features of her SNS. This development may lead to new forms of communication in OSNs other than described in this chapter, with new possibilities for the diffusion of information, the maintenance of social ties, and the forms of collaboration.

The SNSs described in this chapter can be seen as only one specific application of this social web. New social software may be developed based on a decentralized OSN, that is less vulnerable regarding technical and privacy related issues, and could be more useful for target groups, for example, with a business or dating focus, for different ages, or with a focus on barrier-free access (see Kubina and Lücking 2012, in this issue) without the need for separated OSNs.

This scenario – while at this moment highly speculative – would possibly replace the "walled gardens" of the current social web and lead to a decentralized and open "new social web" (Salzberg et al. 2011).

Notes

1. https://www.facebook.com/
2. In this chapter we will distinguish between the terms "social network site" (SNS), as introduced by boyd and Ellison (2007), and "online social network" (OSN), as the more recent term for – in most publications – the same subject (see, e.g., Datta et al. 2010). We use the term SNS to refer to the service portals (e.g., Facebook or Twitter) that allow for participation in a digital social network of individuals and social relations, which we will refer to as an OSN.
3. Similar studies confirmed these findings (see, e.g., Dodds, Muhamad, and Watts 2003, for an email-based approach). However, there is some critique (e.g., Kleinfeld 2002) regarding the conclusion of a *"small world"* based on the results of the experiments by Travers and Milgram (1969) and others, as the communication paths were broken in the majority of experiment runs, so only successful acquaintance chains were taken into account.
4. The term "Six Degrees of Separation" was especially popularized as the title of a play written by John Guare (1990).
5. http://www.friendster.com/
6. http://www.myspace.com/
7. http://www.orkut.com/
8. https://twitter.com/
9. https://plus.google.com/
10. This extension is along the lines with Datta et al. (2010).
11. http://foocorp.org/projects/social/
12. http://status.net/
13. http://joindiaspora.com/
14. In *Weaving the Web*, Berners-Lee conceptualized a four layer infrastructure of the

web, consisting of "the transition medium, the computer hardware, the software, and the content" (Berners-Lee 2000, p. 130).
15. We refer to the advent of standards of the Internet Protocol Suite.
16. For a discussion of the types of information provided by users of SNSs, refer to Cutillo, Manulis, and Strufe (2010, pp. 503–506).
17. "Microblogging" refers to a blogging service specialized in short texts. Twitter, for example, has a limit on 140 characters (McFedries 2007).
18. http://www.researchgate.net/
19. For a survey on the history of SNSs, see boyd and Ellison (2007).
20. http://www.studivz.net/
21. A fact, boyd (2004) and boyd (2005) state for the symmetric SNS Friendster, while it seems to be quite common to unfollow someone on asymmetric SNSs like Twitter, as this does not imply any social or (unwanted) technical disprofits (Kwak, Chun, and Moon 2011; Kivran-Swaine, Govindan, and Naaman 2011).
22. For a model that formalizes a network which allows for cliques – in this case called the *clustering coefficient* –, see Watts and Strogatz (1998). The model says that not only the average path length between any two nodes in a small world network is small, but there is also a high clustering coefficient.
23. Ties, as discussed in Granovetter (1973), are symmetric and positive – like relations in Facebook rather than in asymmetric SNSs like Twitter.
24. Dunbar's number was an inspiration for the limitation of 150 friends of the mobile SNS *Path* (https://path.com).
25. For a discussion on the number of persons an individual knows during her lifetime, see Killworth et al. (1990).
26. Although the "favorite" function in Twitter is semantically closer to the "like" function of Facebook, it has not the same relevance for the diffusion of information, as these items are shown separated to the main stream of information.
27. This principle follows the "80/20 rule", that says, that a small proportion of offered products generate a large proportion of sales (for example, 20 % of the products generate 80 % of the sales).
28. *Amazon.com* (http://www.amazon.com/), for example, makes more than 20 % of their book sales with products below the rank of their top 100,000 products, while most traditional book stores are limited to 100,000 products at all (Brynjolfsson, Hu, and Smith 2003; Fenner, Levene, and Loizou 2010).
29. https://www.google.com/adsense/
30. For further information regarding SNA, see Wasserman and Faust (2008) and Jackson (2008).
31. http://www.youtube.com/
32. The mechanism is closely connected to the phenomenon of *Internet Memes*. Originally based on a term coined by Dawkins (1976, pp. 203–215), it references to all kinds of popular ideas and content diffused via social software and especially SNSs (Hodge 2000).
33. The frequent performance issues of Twitter led to the popularity of the infamous "fail whale", Twitter's mascot for server related problems.
34. http://www.pownce.com/
35. http://www.skype.com/
36. http://icq.com/

37. For several services, P2P systems also depend on central servers and thus are not purely distributed. For a taxonomy regarding the centralization of P2P systems, refer to Vu, Lupu, and Ooi (2010).
38. http://www.wordpress.com/
39. The value of the network is limited according to "Metcalfe's law", that roughly says, the value of a communication network increases more than linear as the number of nodes increase, because of the increased number of potential links for every node (Hendler and Golbeck 2008).
40. In theory, some of these companies participate in the "safe harbour" agreement between the European Union (EU) and the United States of America, that should assure citizens of the EU getting the same private data protection in the USA as in their home country regarding self-certified companies. But according to negative reviews of the EU and recent studies, the implementation is rather weak and misleading, and even representing "a new and significant privacy risk to consumers" (see Connolly 2008). In 2008 Facebook established a new headquarter in Dublin (Facebook 2008), which changed the legal base of privacy protection.
41. Due to the aforementioned recency and the ongoing debate regarding privacy in OSNs, this chapter will be limited to a shallow legal view on the topic.
42. Personalization in this way is believed to have serious impact on the diffusion of information as it prefers information from within cliques rather than weak ties. This effect, among other ways of personalization, was coined the "Filter Bubble" by Eli Pariser (2011).
43. For a survey on privacy attacks on SNSs, see Cutillo, Manulis, and Strufe (2010).
44. Michael Chisari is lead developer of the Appleseed project (see Section 5).
45. Individuals mostly prefer to have multiple identities in different contexts, that means sometimes they deliberately represent themselves with multiple accounts on different OSNs. We will refer to identity as being one of possibly many different identities of one individual. For more information on identity in the social web, refer to Maheswaran et al. (2010) and Farnham and Churchill (2011).
46. http://www.flickr.com/
47. http://www.delicious.com/
48. As OpenID is an open specification, a user can, of course, be her own provider.
49. Because most of the open formats and protocols in this workflow were invented or co-developed by Eran Hammer-Lahav, this is called the "Hammer Stack".
50. https://openid.net/connect/
51. http://esw.w3.org/WebID
52. http://microformats.org/
53. RDF data can be accessed using the powerful query language *SPARQL* (SPARQL Protocol and RDF Query Language).
54. XHTML is a variant of HTML based on XML rather than SGML.
55. http://www.webhooks.org/
56. The hub server in PubSubHubbub can be seen as a SPOF (see Section 3.1), as there are only a few services online providing the services to choose from. However, if the hub is shut down, the availability of data is still assured.
57. To indicate a reply, Atom entries can use the *Atom Threading Extension* (Snell 2006).
58. http://info.dfrn.org/

59. http://identi.ca/
60. This approach was formerly known under the name of “OpenMicroBlogging”.
61. For an overview on OStatus compliant software, refer to Status.Net (2011).
62. https://code.google.com/p/diso/
63. http://www.movabletype.org/
64. http://www.drupal.org/
65. http://socialriver.org/
66. http://onesocialweb.org/
67. http://buddycloud.com/
68. http://appleseedproject.org/
69. http://noserub.com/
70. http://freedomboxfoundation.org/
71. For a survey on distributed SNSs on peer-to-peer basis, see Datta et al. (2010).
72. http://www.safebook.us/
73. http://www.peerson.net/
74. http://www.google.com/buzz; Google Buzz was shut down in 2011 in favor of Google+.

References

Adida, Ben, Mark Birbeck, Shane McCarron and Steven Pemberton
2008 *RDFa in XHTML: Syntax and Processing*. Specification.
→ http://www.w3.org/TR/rdfa-syntax/ [Last accessed 09/08/2011].

Alexa
2011 *Top Sites. The top 500 sites on the web*. Website. September 2011.
→ http://www.alexa.com/topsites [Last accessed 09/08/2011].

Allen, Christopher
2004 *Tracing the Evolution of Social Software*. Blog Post.
→ http://www.lifewithalacrity.com/2004/10/tracing_the_evo.html [Last accessed 09/08/2011].

Anderson, Chris
2006 *The Long Tail: Why the Future of Business Is Selling Less of More*. Hyperion.

Atkins, Martin, Will Norris, Chris Messina, Monica Wilkinson, and Rob Dolin
2011 *Atom Activity Extensions 1.0*. Specification.
→ http://activitystrea.ms/specs/atom/1.0/ [Last accessed 09/08/2011].

Au Yeung, Chingman, Ilaria Liccardi, Kanghao Lu, Oshani Seneviratne and Tim Berners-Lee
2009 “Decentralization: The Future of Online Social Networking”. In: *W3C Workshop on the Future of Social Networking*. Barcelona, Spain.

Back, Mitja D., Juliane M. Stopfer, Simine Vazire, Sam Gaddis, Stefan C. Schmukle, Boris Egloff, and Samuel D. Gosling
2010 “Facebook Profiles Reflect Actual Personality, Not Self-Idealization”. In: *Psychological Science* 21.3, pp. 372–374.

Baran, Paul
1964 *On Distributed Communications*. Tech. rep. Memorandum, RM-3420-PR. Santa Monica, CA, USA: The RAND Corporation.

Bates, Claire
2009 *How Michael Jackson's death shut down Twitter, brought chaos to Google … and 'killed off' Jeff Goldblum*. The Daily Mail Online. 26 June 2009. → http://www.dailymail.co.uk/sciencetech/article-1195651/How-Michael-Jacksons-death-shut-Twitter-overwhelmed-Google--killed-Jeff-Goldblum.html [Last accessed 04/05/2012].

Beer, David
2008 "Social network(ing) sites … revisiting the story so far: A response to danah boyd & Nicole Ellison". In: *Journal of Computer-Mediated Communication* 13, pp. 516–529.

Berners-Lee, Tim
2000 *Weaving the Web. The Original Design and Ultimate Destiny of the World Wide Web*. With Mark Fischetti. HarperCollins.
2007 *Giant Global Graph*. Blog Post. → http://dig.csail.mit.edu/breadcrumbs/node/215 [Last accessed 09/08/2011].
2010 "Long Live the Web". December 2010. In: *Scientific American*.

boyd, danah m.
2004 "Friendster and Publicly Articulated Social Networking". In: *Conference on Human Factors and Computing Systems (CHI 2004)*. ACM. Vienna, Austria.
2005 *Revenge of the Social Network: Lessons from Friendster*. Talk at Stanford's HCI Seminar. Palo Alto, California. → http://www.danah.org/papers/2005.0204.Stanford.txt.

boyd, danah m. and Nicole B. Ellison
2007 "Social Network Sites: Definition, History, and Scholarship". In: *Journal of Computer-Mediated Communication* 13.1.

Breslin, John G. and Stefan Decker
2007 "The Future of Social Networks on the Internet: The Need for Semantics". In: *IEEE Internet Computing* 11, pp. 86–90.

Breslin, John G., Alexandre Passant, and Stefan Decker
2009 *The Social Semantic Web*. Berlin/Heidelberg: Springer.

Brickley, Dan
2003 *Basic Geo (WGS84 lat/long) Vocabulary*. Specification. → http://www.w3.org/2003/01/geo/ [Last accessed 09/08/2011].

Brickley, Dan and R. V. Guha
2004 *RDF Vocabulary Description Language 1.0: RDF Schema*. Specification. → http://www.w3.org/TR/rdf-schema/ [Last accessed 09/08/2011].

Brickley, Dan and Libby Miller
2010 *FOAF Vocabulary Specification 0.98*. Specification. → http://xmlns.com/foaf/spec/ [Last accessed 09/08/2011].

Brynjolfsson, Erik, Yu (Jeffrey) Hu, and Michael D. Smith
2003 "Consumer Surplus in the Digital Economy: Estimating the Value of Increased Product Variety at Online Booksellers". In: *Management Science* 49.11, pp. 1580–1596.

Buchegger, Sonja, Doris Schiöberg, Le-Hung Vu, and Anwitaman Datta
2009 "PeerSoN: P2P Social Networking – Early Experiences and Insights". In: *Proceedings of the ACM Workshop on Social Network Systems*. Nuremberg, Germany

Burt, Ronald S.
1992 *Structural Holes. The Social Structure of Competition*. Harvard University Press.

Buys, Christian J. and Kenneth L. Larson
1979 "Human Sympathy Groups". In: *Psychological Reports* 45, pp. 547–553.

Çelik, Tantek and Brian Suda
2005 *hCard 1.0*. Specification.
→ http://microformats.org/wiki/hcard [Last accessed 09/08/2011].

Chisari, Michael
2011 *The End Of Facebook and Free Software's Quiet Revolution*. Blog Post.
→ http://developer.appleseedproject.org/profile/michael.chisari/journal/the-end-of-facebook-and-free-software's-quiet-revolution [Last accessed 09/08/2011].

Connolly, Chris
2008 *The US Safe Harbor – Fact or Fiction?*
→ http://www.galexia.com/public/research/assets/safe_harbor_fact_or_fiction_2008/safe_harbor_fact_or_fiction.pdf [Last accessed 09/08/2011].

Connolly, Dan and Libby Miller
2005 *RDF Calendar – an application of the Resource Description Framework to iCalendar Data*. Specification.
→ http://www.w3.org/TR/rdfcal/ [Last accessed 09/08/2011].

Crockford, Douglas
2006 *The application/json Media Type for JavaScript Object Notation (JSON)*. Specification.
→ http://www.ietf.org/rfc/rfc4627.txt [Last accessed 09/08/2011].

Cutillo, Leucio Antonio, Mark Manulis, and Thorsten Strufe
2010 "Security and Privacy in Online Social Networks". In: *Handbook of Social Network Technologies and Applications*. Ed. by Borko Furht. Berlin: Springer Science+Business Media. Chap. 23, pp. 497–522.

Cutillo, Leucio Antonio, Refik Molva, and Thorsten Strufe
2009 "Safebook: A Privacy Preserving Online Social Network Leveraging on Real-Life Trust". In: *Communications Magazine, IEEE* 47.12, pp. 94–101.

Datta, Anwitaman, Sonja Buchegger, Le-Hung Vu, Thorsten Strufe, and Krzysztof Rzadca
2010 "Decentralized Online Social Networks". In: *Handbook of Social Network Technologies and Applications*. Ed. by Borko Furht. Berlin: Springer Science+Business Media. Chap. 17, pp. 349–378.

Davis, Ian and David Galbraith
2002 *BIO: A vocabulary for biographical information*. Specification.
→ http://purl.org/vocab/bio/ [Last accessed 09/08/2011].

Dawkins, Richard
1976 *The Selfish Gene*. Oxford University Press.

Dodds, Peter Sheridan, Roby Muhamad, and Duncan J. Watts
2003 "An Experimental Study on Search in Global Social Networks". In: *Science* 301, pp. 827–829.

Domingos, Pedro and Matt Richardson
2001 "Mining the Network Value of Customers". In: *Proceedings of the 7th ACM SIGKDD international conference on Knowledge discovery and data mining*. New York, NY, USA, pp. 57–66. San Francisco, CA, USA.

Donath, Judith and danah m. boyd
2004 "Public Displays of Connection". In: *BT Technology Journal* 22.4, pp. 71–82.

Dunbar, Robin I. M.
1993 "Coevolution of neocortical size, group size and language in humans". In: *Behavioral and Brain Sciences* 16.4, pp. 681–735.
1995 "Neocortex size and group size in primates: a test of the hypothesis". In: *Journal of Human Evolution* 28, pp. 287–296.
1996 *Grooming, Gossip and the Evolution of Language*. 6th ed. Harvard University Press.
2010 *How Many Friends Does One Person Need? Dunbar's Number and other evolutionary quirks*. Faber and Faber Limited.

Engeström, Jyri
2005 *Why some social network services work and others don't – Or: the case for object-centered sociality*. Blog Post.
→ http://www.zengestrom.com/blog/2005/04/why-some-social-network-services-work-and-others-dont-or-the-case-for-object-centered-sociality.html [Last accessed 09/08/2011].

Facebook
2008 Facebook to Establish International Headquarters in Dublin, Ireland. Press Release.
→ https://newsroom.fb.com/Announcements/Facebook-to-Establish-International-Headquarters-in-Dublin-Ireland-cf.aspx [Last accessed 04/03/2012].
2011 *Statistics*. Website.
→ http://www.facebook.com/press/info.php?statistics [Last accessed 09/08/2011].

Farnham, Shelly D. and Elizabeth Churchill
2011 "Faceted Identity, Faceted Lives: Social and Technical Issues with Being Yourself Online". In: Proceedings of the ACM 2011 conference on Computer supported cooperative work. New York, NY, USA: ACM, pp. 359–368.

Fenner, Trevor, Mark Levene, and George Loizou
2010 "Predicting the long tail of book sales: unearthing the power-law exponent". In: *Physica A: Statistical Mechanics and its Applications* 389.12, pp. 2416–2421.

Fitzpatrick, Brad and David Recordon
2007 *Thoughts on the Social Graph*. Website.
→ http://bradfitz.com/socialgraph-problem/ [Last accessed 09/08/2011].

Fitzpatrick, Brad, Brett Slatkin, and Martin Atkins
2010 *PubSubHubbub Core 0.3 – Working Draft*. Specification.
→ http://pubsubhubbub.googlecode.com/svn/trunk/pubsubhubbub-core-0.3.html [Last accessed 09/08/2011].
Fitzpatrick, Brad, Eran Hammer-Lahav, Blaine Cook, John Panzer, and Joe Gregorio
2010 *The WebFinger protocol*. Specification.
→ http://code.google.com/p/webfinger/wiki/WebFingerProtocol [Last accessed 09/08/2011].
Friedkin, Noah E.
1982 "Information Flow Through Strong and Weak Ties in Intraorganizational Social Networks". In: *Social Networks* 3, pp. 273–285.
Global Multimedia Protocols Group
2003 *Xhtml Friends Network*. Specification.
→ http://gmpg.org/xfn/ [Last accessed 09/08/2011].
Granovetter, Mark S.
1973 "The Strength of Weak Ties". In: *American Journal of Sociology* 78.6, pp. 1360–1380.
1983 "The Strength of Weak Ties: A Network Theory Revisited". In: *Sociological Theory* 1, pp. 201–233.
1995 *Getting A Job. A Study of Contacts and Careers*. 2nd ed. Chicago/London: The University of Chicago Press.
Gregorio, Joe and Bill de hOra
2007 *The Atom Publishing Protocol*. Specification.
→ http://www.rfc-editor.org/rfc/rfc5023.txt [Last accessed 09/08/2011].
Guare, John
1990 *Six Degrees of Separation*. New York: Vintage Books.
Hammer-Lahav, Eran and Blaine Cook
2011 *Web Host Metadata*. Specification.
→ http://tools.ietf.org/html/rfc6415 [Last accessed 12/22/2011].
Hammer-Lahav, Eran and Will Norris
2010 *Extensible Resource Descriptor (XRD) Version 1.0*. Specification.
→ http://docs.oasis-open.org/xri/xrd/v1.0/xrd-1.0.html [Last accessed 09/08/2011].
Hammer-Lahav, Eran, David Recordon and Dick Hardt
2011 *The OAuth 2.0 Authorization Protocol*. Specification. This refers to Version 2.0.
→ http://tools.ietf.org/html/draft-ietf-oauth-v2 [Last accessed 09/08/2011].
Hardt, Dick, Johnny Bufu, and Josh Hoyt
2007 *OpenID Attribute Exchange 1.0 – Final*. Specification.
→ http://openid.net/specs/openid-attribute-exchange-1_0.html [Last accessed 09/08/2011].
Harrenstien, Ken
1977 *NAME/FINGER*. Specification.
→ http://tools.ietf.org/html/rfc742 [Last accessed 09/08/2011].
Hendler, James and Jennifer Golbeck
2008 "Metcalfe's law, Web 2.0, and the Semantic Web". In: *Web Semantics: Science, Services and Agents on the World Wide Web* 6.1, pp. 14–20.

Heyer, Gerhard, Florian Holz, and Sven Teresniak
2012 "P2P-based communication". In: *Handbook of Technical Communication*. Ed. by Alexander Mehler, Laurent Romary, and Dafydd Gibbon. Handbooks of Applied Linguistics 8. In this issue. Berlin/Boston: Mouton de Gruyter.

Hodge, Karl
2000 "It's all in the memes. Is the internet spreading a virus through our heads?" In: *guardian.co.uk*.
→ http://www.guardian.co.uk/science/2000/aug/10/technology [Last accessed 09/08/2011].

Hodge, Matthew J.
2006 "The Fourth Amendment and Privacy Issues on the "New" Internet: Facebook.com and MySpace.com". In: *Southern Illinois University Law Journal* 31, pp. 95–123.

Internet Mail Consortium
1996 *vCard – The Electronic Business Card Version 2.1*. Specification.
→ http://www.imc.org/pdi/vcard-21.txt [Last accessed 09/08/2011].

Jabber Software Foundation
2004 *Extensible Messaging and Presence Protocol (XMPP): Core*. Specification.
→ http://tools.ietf.org/html/rfc3920 [Last accessed 09/08/2011].

Jackson, Matthew O.
2008 *Social and Economic Networks*. Princeton, New Jersey: Princeton University Press.

James, Michael L., C. Edward Wotring, and Edward J. Forrest
1995 "An Exploratory Study of the Perceived Benefits of Electronic Bulletin Board Use and Their Impact on Other Communication Activities". In: *Journal of Broadcasting & Electronic Media* 39.1, pp. 30–50.

Johnson, Robert
2010 *More Details on Today's Outage*. Official Facebook Blog Post.
→ http://www.facebook.com/note.php?note_id=431441338919&id=9445547199 [Last accessed 09/08/2011].

Joinson, Adam N.
2008 "'Looking at', 'Looking up' or 'Keeping up with' People? Motives and Uses of Facebook". In: *Conference on Human Factors and Computing Systems (CHI 2008)*. ACM. Florence, Italy.

Jones, Paul E., Gonzalo Salgueiro, and Joseph Smarr
2011 "Webfinger (Draft). Specification.
→ http://datatracker.ietf.org/doc/draft-jones-appsawg-webfinger/ [Last accessed 04/05/2012].

Kempe, David, Jon Kleinberg, and Éva Tardos
2003 "Maximizing the Spread of Influence through a Social Network". In: *Proceedings of the ninth ACM SIGKDD international conference on Knowledge discovery and data mining*. KDD '03. New York, NY, USA, pp. 137–146. Washington, D.C., USA.

Kickstarter
2010 *Decentralize the web with Diaspora. An Open Software project in New York, NY by Daniel G. Maxwell S. Raphael S. Ilya Z.* Website.

→ http://www.kickstarter.com/projects/196017994/diaspora-the-personally-controlled-do-it-all-distr [Last accessed 09/08/2011].

Killworth, Peter D., Eugene C. Johnsen, H. Russel Bernard, Gene Ann Shelley and Christopher McCarty
1990 "Estimating the Size of Personal Networks". In: *Social Networks* 12, pp. 289–312.

Kivran-Swaine, Funda, Priya Govindan, and Mor Naaman
2011 "The Impact of Network Structure on Breaking Ties in Online Social Networks: Unfollowing on Twitter". In: Proceedings of the 2011 annual Conference on Human Factors in Computing Systems. New York, NY, USA: ACM: 1101–1104. Vancouver, Canada.

Kleinfeld, Judith
2002 "Six Degrees of Separation: Urban Myth?" In: *Psychology Today* 35.2, p. 74.

Kneidinger, Bernadette
2010 *Facebook und Co. Eine soziologische Analyse von Interaktionsformen in Online Social Networks*. In German, Wiesbaden, Germany: VS Verlag für Sozialwissenschaften.

Krotoski, Aleks
2010 *Robin Dunbar: we can only ever have 150 friends at most …* Interview with Aleks Krotoski and Robin Dunbar.
→ http://www.guardian.co.uk/technology/2010/mar/14/my-bright-idea-robin-dunbar [Last accessed 09/08/2011].

Kubina, Petra and Andy Lücking
2012 "Barrier-free Communication". In: *Handbook of Technical Communication*. Ed. by Alexander Mehler, Laurent Romary, and Dafydd Gibbon. Handbooks of Applied Linguistics 8. In this issue. Berlin/Boston: Mouton de Gruyter.

Kwak, Haewoon, Hyunwoo Chun, and Sue Moon
2011 "Fragile Online Relationship: A First Look at Unfollow Dynamics in Twitter". In: Proceedings of the 2011 annual Conference on Human Factors in Computing Systems. New York, NY, USA: ACM: 1091–1100. Vancouver, Canada.

Lampe, Cliff, Nicole B. Ellison, and Charles Steinfield
2006 "A Face(book) in the Crowd: Social Searching vs. Social Browsing". In: *Proceedings of the 2006 20th anniversary conference on Computer supported cooperative work*. New York, NY, USA. ACM, pp. 167–170. Banff, Alberta, Canada.

Lazarsfeld, Paul F. and Robert K. Merton
1982 "Friendship as Social Process: A Substantive and Methodological Analysis". In: *The Varied Sociology of Paul F. Lazarsfeld*. Ed. by Patricia L. Kendall. Reprinted from Morroe Berger, Theodore Abel, and Charles Page, eds., Freedom and Control in Modern Society, 1954. New York: Columbia University Press, pp. 298–348.

LeBlanc, Jonathan
2011 *Programming Social Applications*. O'Reilly Media.

Lenhart, Amanda B.
2005 "Unstable Texts: An Ethnographic Look at How Bloggers and Their Audience Negotiate Self-Presentation, Authenticity and Norm Formation". MA thesis. Graduate School of Arts and Sciences of Georgetown University.

Leskovec, Jure, Lada A. Adamic, and Bernardo A. Huberman
2006 "The Dynamics of Viral Marketing". In: *Proceedings of the 7th ACM conference on Electronic Commerce*. Vol. 1. EC '06. New York, NY, USA: ACM, pp. 228–237. Xi'an, China.

Leskovec, Jure and Eric Horvitz
2008 "Planetary-Scale Views on a Large Instant-Messaging Network". In: *Proceedings of WWW 2008*. Beijing, China.

Levmore, Saul and Martha C. Nussbaum (eds.)
2011 *The Offensive Internet: Privacy, Speech, and Reputation*. Harvard University Press.

Li, Charlene
2008 *The future of social networks: Social networks will be like air*. Blog Post. A Forrester Research Blog.
→ http://forrester.typepad.com/groundswell/2008/03/the-future-of-s.html [Last accessed 09/08/2011].

Lucas, Matt
2007 *Decentralizing Digital Social Networking Applications*.
→ https://netfiles.uiuc.edu/mmlucas2/www/decentralizingDigitalSocialNetworking.pdf [Last accessed 09/08/2011].

Lugano, Giuseppe
2007 "Mobile Social Software: Definition, Scope and Applications". In: *eChallenges 2007*, pp. 1434–1441. The Hague, Netherlands.

Maheswaran, Muthucumaru, Bader Ali, Hatice Ozguven, and Julien Lord
2010 "Online Identities and Social Networking". In: *Handbook of Social Network Technologies and Applications*. Ed. by Borko Furht. Berlin: Springer Science+Business Media. Chap. 11, pp. 241–267.

Manago, Adriana M., Michael B. Graham, Patricia M. Greenfield, and Goldie Salimkhan
2008 "Self-Presentation and gender on MySpace". In: *Journal of Applied Developmental Psychology* 29.6, pp. 446–458.

Marlow, Cameron
2009 *Maintained Relationships on Facebook*. Blog Post.
→ http://overstated.net/2009/03/09/maintained-relationships-on-facebook [Last accessed 09/08/2011].

Martin, Dave
2010 *Nielsen NetView (June 2009 – June 2010)*. Cited in: What Americans Do Online: Social Media And Games Dominate Activity.
→ http://blog.nielsen.com/nielsenwire/online_mobile/what-americans-do-online-social-media-and-games-dominate-activity/ [Last accessed 09/08/2011].

McFedries, Paul
2007 "Technically Speaking: All A-Twitter". In: *Spectrum* 44.10, p. 84.

McKenna, Katelyn Y. A. and John A. Bargh
2000 "Plan 9 From Cyberspace: The Implications of the Internet for Personality and Social Psychology". In: *Personality and Social Psychology Review* 4.1, pp. 57–75.
McPherson, Miller, Lynn Smith-Lovin, and James M. Cook
2001 "Birds of a Feather: Homophily in Social Networks". In: *Annual Review of Sociology* 27, pp. 415–444.
Mehler, Alexander and Tilmann Sutter
2008 "Interaktive Textproduktion in Wiki-basierten Kommunikationssystemen". In: *Kommunikation, Partizipation und Wirkungen im Social Web*. Ed. by Ansgar Zerfaß, Martin Welker, and Jan Schmidt. In German, pp. 267–298.
Mika, Peter
2007 *Social Networks and the Semantic Web*. Semantic Web and Beyond: Computing for Human Experience. New York, NY, USA: Springer Science+ Business Media.
Milgram, Stanley
1967 "The Small World Problem". In: *Psychology Today* 1, pp. 61–67.
Mitchell-Wong, Juliana, Ryszard Kowalczyk, Albena Roshelova, Bruce Joy, and Henry Tsai
2007 "OpenSocial: From Social Networks to Social Ecosystem". In: *Digital EcoSystems and Technologies Conference, 2007. DEST '07. Inaugural IEEE-IE*. IEEE Computer Society, pp. 361–366. Cairnes, Australia.
Newey, Guy
2009 "Blogging guru chips away at Great Firewall of China". *AFP*.
→ http://www.google.com/hostednews/afp/article/ALeqM5igVn4hcj6ZNWlawSvzLvgEMkZmkQ [Last accessed 09/08/2011].
Nottingham, Mark and Eran Hammer-Lahav
2010 *Defining Well-Known Uniform Resource Identifiers (URIs)*. Specification.
→ http://tools.ietf.org/html/rfc5785 [Last accessed 09/08/2011].
OpenSocial and Gadgets Specification Group
2010 *OpenSocial Specification 2.0 DRAFT*. Specification.
→ http://docs.opensocial.org/display/OSD/Specs [Last accessed 09/08/2011].
Panzer, John
2010 *The Salmon Protocol*. Specification.
→ http://salmon-protocol.googlecode.com/svn/trunk/draft-panzer-salmon-00.html [Last accessed 09/08/2011].
Panzer, John, Ben Laurie, and Dirk Balfanz
2011 *Magic Signatures*. Specification.
→ http://salmon-protocol.googlecode.com/svn/trunk/draft-panzer-magicsig-01.html [Last accessed 09/08/2011].
Pariser, Eli
2011 *The Filter Bubble: What the Internet is Hiding from You*. Penguin Books.
Parks, Malcolm R.
2007 *Personal Relationships & Personal Networks*. Series on Personal Relationships. Mahwah, New Jersey: Lawrence Erlbaum Associates, Inc.

Pfanner, Eric
2011 "Naming Names on the Internet". In: *The International Herald Tribune*. 5 September 2011.

Prodromou, Evan
2010 *What is the federated social web?* Blog Post. → http://status.net/2010/07/13/what-is-the-federated-social-web [Last accessed 09/08/2011].

Prodromou, Evan, Brion Vibber, James Walker, and Zach Copley
2010 *OStatus 1.0 Draft 2*. Specification. → http://ostatus.org/sites/default/files/ostatus-1.0-draft-2-specification.html [Last accessed 09/08/2011].

Recordon, David
2007 *Is Zuckerberg Trying to Own the Social Graph?* Blog Post. → http://daveman692.livejournal.com/313178.html [Last accessed 09/08/2011].

Riley, Duncan
2007 *TC40 Keynote Conversation: Mark Zuckerberg*. Blog Post. Interview with Michael Arrington and Mark Zuckerberg. → http://techcrunch.com/2007/09/17/tc40-keynote-conversation-mark-zuckerberg/ [Last accessed 09/08/2011].

Riley, Shannon
2006 "Password Security: What Users Know and What They Actually Do". In: *Usability News* 8.1.

Rogers, Everett M.
2003 *Diffusion of Innovations*. 5th ed. New York: The Free Press.

Salzberg, Maxwell, Daniel Grippi, Ilya Zhitomirskiy, Sarah Mei, Yosem Companys, and Peter Schurman
2011 *Diaspora* is making a difference*. Blog Post. → http://blog.joindiaspora.com/2011/09/08/we-are-making-a-difference.html [Last accessed 09/15/2011].

Schneider, Roman
2008 "Web 3.0 ante portas? Integration von Social Web und Semantic Web". In: *Kommunikation, Partizipation und Wirkungen im Social Web*. Ed. by Ansgar Zerfaß, Martin Welker, and Jan Schmidt. In German, pp. 112–128.

Schonfeld, Erick
2011 *The Pros And Cons Of Facebook Comments*. Blog Post. → http://techcrunch.com/2011/03/01/pros-cons-facebook-comments/ [Last accessed 09/08/2011].

Singel, Ryan
2009 *Facebooks E-mail Censorship is Legally Dubious, Experts Say*. Blog Post. → http://www.wired.com/epicenter/2009/05/facebooks-e-mail-censorship-is-legally-dubious-experts-say/ [Last accessed 09/08/2011].

Smarr, Joseph
2008 *Portable Contacts 1.0 Draft C*. Specification. → http://portablecontacts.net/draft-spec.html [Last accessed 09/08/2011].

Snell, James M.
2006 *Atom Threading Extensions*. Specification. → http://tools.ietf.org/html/rfc4685 [Last accessed 09/08/2011].

Status.Net
2011 *OStatus/Interop*. Website/Wiki.
→ http://status.net/wiki/OStatus/Interop [Last accessed 09/15/2011].

Stoll, Clifford
1995 *Silicon Snake Oil. Second Thoughts on the Information Highway*. New York, NY, USA: Anchor Books, Doubleday.

Stone, Brad and Noam Cohen
2009 "Social Networks Spread Defiance Online". In: *The New York Times*. 16 June 2009.

Story, Henry, Bruno Harbulot, Ian Jacobi, and Mike Jones
2009 "FOAF+SSL: RESTful Authentication for the Social Web". In: *Proceedings of the ESWC2009 Workshop on Trust and Privacy on the Social and Semantic Web (SPOT2009)*. Heraklion, Greece.

The Nielsen Company
2009 *Global Advertising: Consumers Trust Real Friends and Virtual Strangers the Most*. Nielsen Global Online Consumer Survey.
→ http://blog.nielsen.com/nielsenwire/consumer/global-advertising-consumers-trust-real-friends-and-virtual-strangers-the-most/ [Last accessed 09/08/2011].

The OpenID Foundation
2007 *OpenID Authentication 2.0 – Final*. Specification. This refers to Version 2.0.
→ http://openid.net/specs/openid-authentication-2_0.html [Last accessed 09/08/2011].

Thimm, Caja
2008 "Technically-mediated interpersonal communication". In: *Handbook of Interpersonal Communication*. Ed. by Gerd Antos and Eija Ventola. Handbooks of Applied Linguistics 2. Berlin, Germany: Mouton de Gruyter. Chap. 12, pp. 331–354.

Tong, Stephanie Tom, Brandon Van der Heide, Lindsey Langwell, and Joseph B. Walther
2008 "Too Much of a Good Thing? The Relationship Between Number of Friends and Interpersonal Impressions on Facebook". In: *Journal of Computer-Mediated Communication* 13, pp. 531–549.

Tramp, Sebastian, Philipp Frischmuth, Natanael Arndt, and Sören Auer
2011 "Weaving a Distributed, Semantic Social Network for Mobile Users". Submitted to the Extended Semantic Web Conference (ESWC2011).

Travers, Jeffrey and Stanley Milgram
1969 "An Experimental Study of the Small World Problem". In: *Sociometry* 32.4, pp. 425–443.

Van Buskirk, Eliot
2009 "Denial-of-Service Attack Knocks Twitter Offline". In: *Wired.com*.
→ http://www.wired.com/epicenter/2009/08/twitter-apparently-down/ [Last accessed 09/08/2011].

Vu, Quang Hieu, Mihai Lupu, and Beng Chin Ooi
2010 "Peer-to-Peer Computing. Principles and Applications". In: Architecture of Peer-to-Peer Systems. Springer. Chap. 2, pp. 11–37.

W3C Social Web Incubator Group
2010 *A Standards-based, Open and Privacy-aware Social Web. W3C Incubator Group Report 6th December 2010*. Tech. rep. W3C.
→ http://www.w3.org/2005/Incubator/socialweb/XGR-socialweb-20101206/ [Last accessed 09/08/2011].

Walther, Joseph B., Brandon Van der Heide, Sang-Yeon Kim, David Westerman, and Stephanie Tom Tong
2008 "The Role of Friends' Appearance and Behavior on Evaluations of Individuals on Facebook: Are We Known by the Company We Keep?" In: *Human Communication Research* 34, pp. 28–49.

Waltinger, Ulli and Alexa Breuing
2012 "Internet-Based Communication". In: *Handbook of Technical Communication*. Ed. by Alexander Mehler, Laurent Romary, and Dafydd Gibbon. Handbooks of Applied Linguistics 8. In this issue. Berlin/Boston: Mouton de Gruyter.

Wasserman, Stanley and Katherine Faust
2008 *Social Network Analysis: Methods and Applications*. 17th printing. Cambridge University Press.

Watts, Duncan J. and Steven H. Strogatz
1998 "Collective dynamics of 'small-world' networks". In: *Nature* 393, pp. 440–442.

Wellmann, Barry and Milena Gulia
1999 "Net-Surfers Don't Ride Alone: Virtual Communities as Communities". In: *Networks in the Global Village. Life in Contemporary Communities*. Ed. by Barry Wellmann. Westview Press, pp. 331–366.

Wellmann, Barry and Stephanie Potter
1999 "The Elements of Personal Communities". In: *Networks in the Global Village. Life in Contemporary Communities*. Ed. by Barry Wellmann. Westview Press, pp. 49–81.

Werry, Christopher C.
1996 "Linguistic and Interactional Features of Internet Relay Chat". In: *Computer-Mediated Communication: Linguistic, Social and Cross-Cultural Perspectives*. Ed. by Susan C. Herring. Pragmatics and Beyond. Amsterdam, Netherlands: John Benjamins, pp. 47–63.

Winer, Dave
2009a *Implementor's guide to rssCloud*. Specification.
→ http://rsscloud.org/walkthrough.html [Last accessed 09/08/2011].
2009b *RSS 2.0 Specification*. Specification.
→ http://www.rssboard.org/rss-specification [Last accessed 09/08/2011].

Wohn, Donghee Yvette, Cliff Lampe, Rick Wash, Nicole Ellison, and Jessica Vitak
2011 "The 'S' in Social Network Games: Initiating, Maintaining, and Enhancing Relationships". In: Proceedings of the 44th Hawaii International Conference on System Sciences. Kauai, HI, USA.

Ziv, Nina D. and Bala Mulloth
2006 "An Exploration on Mobile Social Networking: Dodgeball as a Case in Point". In: *Mobile Business Conference 2006*. IEEE. Copenhagen, Denmark.