Abstract—In this work we describe the PriSM framework for
decentralized deployment of a federation of autonomous social
networks (ASN). The individual ASNs are centrally managed
by organizations according to their institutional needs, while
cross-ASN interactions are facilitated subject to security and
confidence requirements specified by administrators and
users of the ASNs. Such decentralized deployment, possibly either
on private or public clouds, provides control and ownership
of information/flow to individual organizations. Lack of such
complete control (of third party online social networking services
like Facebook or Yammer were to be used) has so far been a
great barrier in taking full advantage of the novel communication
mechanisms at workplace that have however become common-
place for personal usage with the advent of Web 2.0 platforms
and online social networks. PriSM provides a practical solution
for organizations to harness the advantages of online social
networking both in intra/inter-organizational settings, without
sacrificing individual as well as organizational autonomy, security
and confidentiality needs.

Index Terms—online social networking platform; decentrali-
ation; federation; autonomy; private/public cloud; workplace

I. INTRODUCTION

Online social networking and other Web 2.0 applications
have brought in a paradigm shift in the manner in which people
communicate and interact online. Realizing the versatility,
flexibility and reach of open online social networks such as
Facebook and Twitter, they have been widely embraced by
organizations for public relations as well as marketing and
monitoring purposes. Some relevant Web 2.0 technologies,
such as Wikis are also readily deployed within corporate
Intranets. However, other platforms, particularly social net-
working, despite its preponderance in the Internet setting, are
yet to become an integral part of individual organizations’
internal communication and workflow infrastructure.

While the new modes and (more importantly) opportunities
of interaction that social networking platforms provide can
significantly help improve an organization’s internal dynamics,
there have so far been several barriers in wide-scale adaption
of such infrastructure in workplace. Foremost, a Facebook
like platform which is open to all, or even a more closed
system like Yammer, hosted and controlled by a third party,
is unsuitable for storing and communicating sensitive business
data and information. In contrast to Wiki-engines which can
be privately deployed, there has been a relative lack of out-of-
the-box social networking platform software

Furthermore, each organization is differently structured, and carries out
distinct activities, thus it is essential to be able to map
these organizational structures and processes in the platform.
Ultimately, even if most of the interactions are carried out
within corporate boundaries, ability to interact with outside
entities, for example, with customers or suppliers (or even
across different departments or project groups within same
organization), requires mechanisms enabling easy and flexible
ways to express rules of engagements and enforce and monitor
the same subject to various security and confidentiality needs of
all the stake-holders — particularly that of the organizations
and the individuals.

In this paper we present a framework for deploying au-
tonomous social networks (ASNs) that can be run and adminis-
tered independently, and can further be federated with other
ASNs through trusted peering links. PriSM (Private Social
Mesh) implements such a framework. This results in a hybrid
architecture, where individual ASNs follow traditional OSN’s
client-server model, while the federation is achieved in a peer-
to-peer manner.

An analogy for such decentralized social networking plat-
form deployment may readily be drawn from the way ‘emails’
work. Individual organizations often choose to run their own
private email servers catering to their users, while these users
can also communicate with users using other email services.
Furthermore, organizations may also choose to rent the server
 functionalities or even the whole email service from a cloud
based service provider. Our PriSM implementation allows
similar deployment models, i.e. deployed from scratch on
personal servers/private clouds or on a public cloud service
providing Infrastructure as a Service (IaaS), or alternatively,
get administrative access to a preinstalled configurable in-
stance, akin to Software as a Service (SaaS). However, in con-
trast to email’s any-to-any communication paradigm, PriSM
allows ASN administrators as well as an user’s superiors from
within the organizational hierarchy to determine intra/inter
ASN communication restrictions. Thus, from an operational
point of view, PriSM provides bottom up access control where

\[1\] We note that recent implementations arising from works on decentralized
online social networks are partially filling up the void.
individuals determine which other users have access to specific resources owned by that user, as in traditional online social networks, but it also allows top-down access control, where (sub-)domain administrators/delegates determine the rights and rules determining the possible actions that individuals can carry out. From an infrastructural perspective, PriSM makes similar trust assumptions as typical email server deployments, and each organization (administrators) orchestrates the data storage and flow within individual ASNs.

The main contributions of this work are as follows: (i) A framework for decentralized deployment of autonomous social networks (ASNs) which allow their users to map their respective organizational structures and processes such as departments, project (sub-)groups, etc. is proposed. (ii) The proposed framework supports federation of ASNs with peering mechanisms for inter-ASN user interactions. (iii) It allows to scope intra/inter-ASN interactions flexibly, determined by users (and their superiors) subject to business as well as individual privacy and confidentiality needs. Furthermore, the decentralized architecture naturally allows for deployment of individual ASNs in both private/public server/cloud environments.

The rest of the paper describes the model and implementation of the PriSM framework as follows: Section II describes the network model while Section III describe the “frontier” information propagation & control mechanism. In Section IV we present the access control mechanism deployed in PriSM and Section V presents the architecture of the framework detailing encountered implementation issues and summarizing relevant related works are discussed in Section VI. We draw our conclusions and outline our ongoing and planned extensions of PriSM in Section VII.

II. THE SOCIAL MESH MODEL

We define a social mesh as a network of social networks, described next by borrowing some terminologies from sociology literature [1]. Naturally, the model is rather standard besides the different user groups required by PriSM’s model. Note that in what follows, we assume that a user is employed only in a single organization. Hence, in our model, an individual with multiple accounts across different ASNs is considered as distinct users.

Figure 1 shows a simple example instance of a Social Mesh. As briefly mentioned in Section II, PriSM models what we call a Social Mesh, which is a network interconnecting distinct Autonomous Social Networks (or ASN for short).

Definition 2.1 (Social Mesh): A Social Mesh $SM$ is a tuple

$$\langle \mathcal{ASN}, \mathcal{U}, \mathcal{PG} \rangle$$

where $\mathcal{ASN}$ is the set of autonomous social networks and $\mathcal{U}$ is the set of users. Each user $u \in \mathcal{U}$ belongs to exactly one autonomous social network $asn \in \mathcal{ASN}$. Finally, $\mathcal{PG}$ is the set of public groups defined in $SM$.

An ASN is the social network defined within a given organization. Thus, it defines the members, their privileges and the communication channels which are existing within

the organization. The ASN also enforces the organization’s policies in terms of information flow, beside the users’ ones.

Definition 2.2 (Autonomous Social Network): Given a social mesh $SM$, an autonomous social network $asn \in \mathcal{ASN}(SM)$ is a tuple of the form

$$\langle a, \mathcal{UD}, \mathcal{SD}, \mathcal{rsd}, \mathcal{R} \rangle$$

where $\mathcal{UD} \subset \mathcal{U}(SM)$ is the set of users of $asn$ and $a \in \mathcal{UD}$ is the administrator of the autonomous social network. Moreover, $\mathcal{SD}$ is the set of subdomains defined in $asn$, $\mathcal{rsd} \in \mathcal{SD}$ is the main subdomain and $\mathcal{R}$ is the set of roles defined in $asn$.

The information flow across different users of an ASN and across different ASNs is managed by means of circles. A circle is a group of users of the social mesh and an associated set of rules controlling how information – messages – associated to such circle can be accessed by users not belonging to the circle itself. Thus, we assume that, in general, information associated to a circle are accessible by members of the circle. In PriSM, one may associate different circles to a message by means of so called tag set (denoted by $T(m)$), which is the set of circles controlling who is entitled to access the message, and a conflict set (denoted by $I(m)$), which is the set of circles whose members cannot access the message.

PriSM allows the specification of different types of circles to represent the different types of users’ groups existing within real world organizations. Because of that, we need circles representing both the internal structure of complex organizations, as well as other circles not directly mapping formal structure of an organization. We call circles materializing structures of an organization as subdomains.

Definition 2.3 (Subdomain): Given a social mesh $SM$ and an autonomous social network $asn \in \mathcal{ASN}(SM)$, a subdomain $sd \in \mathcal{SD}(asn)$ is a tuple of the form

$$\langle n, \mathcal{M}, \mathcal{PR}, \mathcal{P}, a, f \rangle$$

where $n$ is the identifier of the subdomain, $\mathcal{M} \subseteq \mathcal{UD}(asn)$ is the set of members of $sd$, $\mathcal{PR}$ is the set of privileges granted

\footnote{We use the notation $P(O)$ to refer to the property $P$ of the object $O
by the administrator to the members of the subdomain $sd$, $P$ is the set of rules defining the constraints a user must satisfy in order to access messages tagged with $sd$ (or any circle which is a child of $sd$, see Definition 2.4 Definition 2.7 and Definition 2.9) and $a \in M(sd)$ is the administrator of $sd$. More than one user may have administrative privileges on a given subdomain $sd$, as we discuss in Section IV $a(sd)$ is the user who initially received the charge of managing $sd$. We assume that $a(sd)$ does not change over time even if administrative privileges may be granted and revoked to other users. Thus, we assume that $a(sd)$ will always be granted administrative privileges over $sd$.

Example of subdomains may be departments of a university or branches of a company. Subdomains are organized in a hierarchy representing the parent-child relationship existing among the different departments of the company. PriSM does not restrict the number of children of a subdomain, on the other hand, we restrict the number of father of a subdomain to at most one. Similarly, we will later assume similar restrictions to circles. The reason is related to how PriSM’s information propagation mechanism works, see Section III.

Definition 2.4 (Subdomain hierarchy): Let $SD$ be the set of subdomains for an autonomous social network $asn$. The subdomain hierarchy

$$\phi_{SD}: SD \rightarrow SD \cup \{\bot\}$$

is the function defining the hierarchy among the subdomains.

The root of the subdomains’ hierarchy is called main subdomain. Such subdomain represents the organization itself. Therefore, it is required to be defined and unique.

Definition 2.5 (Main subdomain): Given a set of subdomains $SD$ for a given autonomous social network $asn$ we define as main subdomain for $asn$ the subdomain $msd \in SD$ such that $\phi_{SD}(msd) = \bot$. We further assume that $msd$ exists and is unique for each $asn$, which means that $\forall sd \in SD$ if $\phi_{SD}(sd) = \bot$ then $sd = msd$.

On the other hand, circles representing groups created for official purposes, but without a direct mapping into the organization’s structure, are called public groups.

Definition 2.6 (Public Group): Given a social mesh $SM$, a public group $PG \in PRG(SM)$ is a tuple of the form

$$\langle o, M, B, P \rangle$$

where $o \in U$ is the user who created the public group, $M \subseteq U$ is the set of users who are member of $c$, $B \subseteq M$ is the set of “bosses” of $c$, i.e. the users who can modify $P$, the set of rules associated to the public group.

As an example, a public group may be a team of physicians and nurses working on a specific disease. The different cases related to that disease may be handled by users belonging to different departments of the hospital, such as users from the Cardiology Department (a subdomain) and users from the Elderly Service Department (another subdomain). Hence, the main feature characterizing a public group is the purpose for which it has been created. Some ASNs may allow users to create and join public groups created for purposes not directly work-related, such as a group created to simplify the communication among the players of the Nurse’s Soccer Team. As opposed to subdomains, members of a public group may belong to different ASNs, such as a research project carried out by researchers and professors from different universities. Similarly to subdomains, public groups may be organized hierarchically. More precisely, in PriSM, a public group may specify a public group or a subdomain as parent.

Definition 2.7 (Public Group hierarchy): Let $PG$ be the set of public groups and let $SD$ be the set of subdomains of a social mesh $SM$. The public group hierarchy

$$\phi_{PG}: PG \rightarrow PG \cup SD \cup \{\bot\}$$

is the function defining the parent-child relationship for public groups.

Finally, PriSM allows users to define personalized circles called private groups in which users are categorized according to the preferences of the creator of the circle.

Definition 2.8 (Private Group): Given a user $u$, a private circle $prg \in PRG(u)$ is a couple of the form

$$\langle M, P \rangle$$

where $M \subseteq U$ is the set of users who are member of $prg$. $P$ is the set of rules associated to the private group.

Again, private groups can be organized hierarchically but only among private groups of the same creator.

Definition 2.9 (Private Group hierarchy): Let $PRG(u)$ be the set of private group for a given user $u$. The private group hierarchy

$$\phi_{PRG}: PRG(u) \rightarrow PRG(u) \cup \{\bot\}$$

is a function defining the parent-child relationship among the private groups of $u$.

Such private groups are strictly private to the creator of the circle, and thus unknown to the users who are categorized. Private groups provide a tool to control the flow of an individual’s messages in a fine-grained manner (akin to the use of circles in Google+), for example specifying that a message is visible only to the user categorized to a specific private circle.

As a concrete example, consider a physician working on a very sensitive case. She/he may create a private group of “untrusted colleagues” to avoid such users from receiving messages pertaining that sensitive case exchanged within the remaining members of the department.

Beside information flow, ASNs require a way to manage the privileges of their members. In the following we define as privileges the operations that a user is allowed to perform in an ASN. To do that PriSM uses an approach similar to [2]. PriSM uses the roles assigned to user by the ASN administrator. In the presented model a role is a job function/title within the organization with some associated semantics regarding the authority and responsibility conferred on a member role.

Definition 2.10 (Role): Given an autonomous social network $asn \in ASN$, a role $r \in R(asn)$ is a couple of the
form 
$$\langle n, PR \rangle$$

where $n$ is the (unique) identifier of the role and $PR$ is the set of privileges granted and/or denied to the members of the role $r$.

As for groups, role may be organized hierarchically.

Definition 2.11 (Role hierarchy): Let $R$ be a set of roles defined for an autonomous social network $asn$. A role hierarchy

$$\phi_R: R \rightarrow R \cup \{\perp\}$$

is the function which defines the child-parent relationship among the roles.

A user may be associated with multiple roles, according to the functions she/he is performing within the organization. Furthermore, PriSM allows the administrator to further refine the privileges available to a given user according to “where” (in which context) she/he is operating. In fact the privileges granted to a given user at a given moment are defined combining the roles to which the user has been assigned and the subdomain in which she/he is operating. Thus, the subdomains contribute to identify the available privileges, refining the privileges of a role (both granting or revoking privileges) or even granting/revoke permissions directly to specific users.

Beside that, a group creator may wish to restrict the membership to the group, for example not granting the membership to those users who are member of another specific group. Moreover, one may need to moderate the communication among the roles.

Definition 2.12 (Circle): Given a social mesh $SM$, the set of circles $C$ is defined as follows:

$$C = \mathcal{PG}(SM) \cup_{asn \in ASN(SM)} \mathcal{SD}(asn) \cup_{u \in \mathcal{U}(SM)} \mathcal{PRG}(u)$$

To wrap up, we define “a message”, which is the entity of data created by and shared among the users of the social mesh.

Definition 2.13 (Message): A message $m$ is a tuple $\langle u, t, T, I \rangle$ where $u \in \mathcal{U}$ is the author of the message, $t$ is the content. $T, I \subseteq C(u)$ are respectively called the tag and the conflict set.

III. FRONTIER INFORMATION PROPAGATION MECHANISM

It is fairly complex to manage the communication within large organizations. In particular, sometimes it is not completely clear who are the users entitled to access certain information. The complexity increases rapidly when dealing with the communication between users belonging to different organizations. In the following, we will present a mechanism to handle such complexity, by taking advantage of the model defined in Section II. In our model, information propagation is performed with respect to circles but not to domains since domains deal with privileges of users, while circles have been specifically designed to deal with information flow.

The Frontier Information Propagation Mechanism ensures that a given message $m$ is accessible by all the users who are member of at least a circle in $T(m)$ but who are not member of any circle in $I(m)$. In addition, other users may read the message $m$ satisfying the policies of at least a circle $c \in T(m)$. Moreover, it is also possible for a user to access $m$ if there exists a sequence of circles $CSeq = c_1, \ldots, c_n$ where $c_n \in T(m)$ and $\forall i \in [2, n], \phi(c_i) = c_{i-1}$. The user $u$ is allowed to access $m$ if and only if she/he satisfies the policies defined for all the circles in $CSeq$.

The syntax to describe the policies is outside the scope of this work and treated in works such as [3].

Informally, policies are of the form:

$$a \leftarrow pred_1 \land \ldots \land pred_k$$

where $a \in \{\text{allow, deny}\}$ and each predicate $pred_i$ verifies properties of the message, the author of the message or the user reading the message. The properties verified by the predicates currently supported by PriSM comprehend: author/reader identity, author/reader membership, tags of the message, etc.

The enforcement mechanism is described in Alg. 1.

Algorithm 1: The Frontier Information Propagation Mechanism.

Consider an example scenario shown in Figure 2. In such a scenario, the users Bob, Charlie and Ellen are following Alice. Alice is member of the circle $C_1$ which is in turn an inner circle of $C_2$. Suppose Alice creates a message $m$ such that $T(m) = \{C_1\}$ and that $I(m) = \emptyset$. As previously defined, the Frontier Information Propagation mechanism states that if $\exists c \in T(m)$ such that $reader \in M(c)$ then $reader$ is allowed to access the message. Thus Bob is allowed to access $m$ since he is a member of $C_1$. On the other hand the other users will satisfy the policies of $C_1$ to access $m$. Assuming that both Charlie and Ellen satisfy such policies, only Charlie will access $m$ because he is a member of $C_2$. Hence, Ellen will be
required to satisfy also the policies of \( C_2 \) before being able to read content from the circle \( C_2 \).

If the collision set \( \mathcal{I}(m) \) is not empty, then it needs to be verified whether the reader is member of any of the circles in such a set. If this is the case, then the reader is not allowed to access \( m \).

Fig. 2: An example for the frontier information propagation mechanism.

IV. MANAGEMENT OF PRIVILEGES

PriSM supports what we call group and domain privileges. The former are those privileges which define the actions users can perform within a group, such as the privileges of joining the group, to tag a message with the current group or the requirement of the messages tagged with a group to be moderated by a boss of the group. The latter are those privileges granting to users administrative powers, such as the privileges to create public circles, to create subdomains, to create roles and so on and so forth.

Group privileges are specific for the group in which they are defined and therefore their enforcement is straightforward: once a user is operating in a specific group, the group privileges are enforced.

In contrast, domain privileges require a more complex mechanism to be enforced. Note that the PriSM framework manages and enforces access control at ASN’s level, in the sense that the domain privileges are defined in groups characteristics of a ASN – such are roles and subdomains – and they can be enforced only within the specific ASN.

As presented in Section II, the operations a user is granted to perform are defined by a combination of her/his roles and the subdomain in which she/he is operating. Because of that, the PriSM framework enforces access control differently according to the action performed by the user.

The enforcement algorithm works as follows (also see Figure 3). Let us assume a given ASN \( \text{asn} \) and the user \( u \in \mathcal{U}((\text{asn}) \) who is associated with the roles \( r_1, \ldots, r_n \in R((\text{asd})) \). Thus, \( u \) is granted the privileges \( u_{PR} = \bigcup_{i=1}^{n} \mathcal{PR}(r_i) \). When \( u \) operates within a subdomain \( sd \in SD((\text{asn}) \) the privileges actually granted to \( u \) are computed as:

\[
u_{PR} \otimes \mathcal{PR}(sd)\]

Recall that the predicate \( \otimes \) refines the privileges in \( u_{PR} \) with the ones defined in \( \mathcal{PR}(sd) \).

Fig. 3: Access control model.

V. PRIISM ARCHITECTURE

In order to provide the services required by an ASN, each domain deploys PriSM locally. Figure 4 shows the architecture of an independent ASN deployment comprising several interconnected modules. Each module is in charge of managing a specific subset of the features provided by the system. Many of these features are ‘standard’ in any state-of-the-art online social network platform while a few others are novel, specific to PriSM’s distributed/federated nature and its access and information flow controls:

- **User Manager**: This module provides an interface to the operations directly related to the users, such as registration, profile management, relations and subscription of messages from other users, etc.

- **Circle Manager**: This component controls the circles related information such as the lists of members and the propagation policies for each circle other than any relationships between them (See Definition 2.4 and Definition 2.9).

- **Access Control Manager**: This module regulates both the actions performed by the users of a PriSM ASN with respect to the privileges assigned to them by the domains administrators and enforces the policies defined in the circles (the later is elaborated in Section V-A).

The functionalities of this module are: (i) to store and propagate the messages (and content) generated by the ASN’s users and (ii) to grant access only to those users who are allowed according to the rules.

The PriSM Web Interface exposes the services orchestrated by all these constituent modules to the ASN users.

A final module manages the interconnections between the different ASN instances of PriSM.

- **Remote Interface**: This module is in charge of performing the operations of exchanging information with other ASNs. For example, the Remote Interface retrieves the required data when a user is accessing the profile of some user \( u' \) in some other domain \( D' \). It also sends to the interested domains the updates involving shared data, such as those regarding the members and/or the policies of shared circles.
The present PriSM implementation allows communication between only ASNs which have been manually paired by the domains’ administrators. Paired ASNs are considered trusted in the current model. Additionally, at present we assume the existence of a service to correctly discover other ASNs and their trustworthiness. These assumptions need further consideration in future. We will also like to remark that individual ASN deployments are free to tweak the constituent modules, to add or modify functionalities as deemed appropriate.

A. Message propagation

The primary objective of the PriSM system is to allow users to exchange information. In order to provide the users a satisfactory experience, the architecture of PriSM has been designed to reduce the time elapsing between when the information is created and when it is actually available to the final user.

Figure 5 shows the steps required to post a message through the system to all the users potentially interested in it. First of all the user $u_s$ sends the message $m$ to the Content Manager (1), which stores the message in the local database. Afterwards, the Content Manager retrieves the set of followers $\hat{F} = \{u_1, \ldots, u_k\}$ from the User Manager (2). The Content Manager requests to the Access Control Manager for each local user $u_i \in L \subseteq \hat{F}$, if $u_i$ is allowed to access $m$ (3). The verification is performed by Access Control Manager according to both the tag set, the conflict set (see Definition 2.13), the set of circles to which $u_i'$ is member of and the list of propagation polices. Such information are retrieved by the Access Control Manager querying the Circle Manager (4). If the verification (3) holds then the Content Manager will notify the user $u_i$, immediately if the user is currently online or delivered in the user’s ‘inbox’ to be retrieved as soon as she/he logs into the system (9). At the same time, the Content Manager sends the set of remote users $RU = \hat{F} \setminus L$ to the Remote Interface (6) which will, in turn, extract the set of domains $RD = \{d_1, \ldots, d_q\}$, with $q \leq |RU|$, to be notified of the existence of $m$ (6).

B. Implementation of the framework

The model described in Section II and the architecture previously presented have been implemented in a prototype using Java 6 and GWT [4] for the user interface. A MySQL [5] database is used for the persistency of the data. The communication protocol between the different deployed ASN instances occurs using a well defined REST interface [6].

The current prototype is structured as a modular server, in which each component is directly connected with the others as shown in Figure 4. Nevertheless, the server modules can be easily separated on different machines, to take advantage of such parallelism.

A final remark we will like to make, to repeat what has been stated elsewhere, is that the individual modules can be modified, or additional modules added, as deemed essential for an ASN instance. Furthermore, we are working on exposing a set of interfaces so that other “apps” can be deployed on top of PriSM by leveraging on its existing functionalities.

C. Evaluation and discussion of the architecture

From our observations, the PriSM architecture presents mainly three possible scalability bottlenecks (i) the Web Interface (ii) the Remote Interface and (iii) the database. More precisely, increasing the number of the users of a ASN increases the probability of users connected simultaneously to the system. Such a condition will require an ever increasing amount of computational resources. Similarly, more resources are required to provide the same promptness of the system with the increase of the number of interconnected ASNs.
The three previously mentioned issues can be addressed using standard distributed systems techniques, such as replicating the appropriate modules of the architecture.

Each module of the PriSM’s architecture is stateless and internally highly parallelized, specifically with the intent to simplify its replication. Similarly, the database can be replicated and distributed as well. However, such operation will have a cost in terms of an increased complexity to manage the consistency of the data.

We benchmarked the performances of the remote operations to empirically verify the scalability of the proposed architecture. We evaluated the execution time of each remote operation varying the number of involved ASNs. The experiments have been executed in a network of two computers (Linux 3.0.1 running on a Intel Core 2 Duo 2.53GHz with 4GB of RAM). On the first machine we ran the PriSM prototype, while on the other machine ran a ‘light weight’ version, which did not provide the Web Interface. The results are shown in Figure 6. As one may notice, the time required for the execution of each operation is negligible except for sending messages to the remote ASNs – the Post operation. We observed that PriSM prototype requires on an average 8780 milliseconds to propagate a message to 250 distinct ASNs. Note that, normally an individual has 100s of contacts. Thus, even if each of these contacts were to belong to a different ASN, the delays introduced for scaling the message propagation over very many ASNS is reasonable, showcasing the scalability of our PriSM implementation.

![Fig. 6: Empirical evaluation of the architecture’s scalability, the y-axis uses a logarithmic scale.](image)

Given the result of the previous experiments, we also evaluated the scalability of the software itself. This was done by evaluating the capacity level of a single PriSM instance. Thus, we measured the number of operations per second that a PriSM instance is able to handle under different stress levels. In this experiment we executed only the Post operations because, as we previously showed, it is the most expensive in term of resources required. To create different load levels we set as a parameter the number of parallel clients (from 50 to 300). Figure 7 shows the results. Our first implementation was not really able to scale that well (see the HouseMade series in Figure 7). In fact we obtained several database-related error messages when we hit the prototype with 150 clients. Initially we imagined that the errors were caused by bad performances of our house-made connection pool. Hence, we changed to the one provided by Apache Tomcat. The results using the default configuration were even worse (see the ConnectionPool series). We changed then the configuration increasing the minimum number of pooled connections (from 100 to 300) and the results increased (ConnectionPool(300) in the graph) but not as much as we expected. Finally, we realized that the bottleneck was caused by the configuration of the database server instead of the connection pool. This was caused mainly by the fact that the messages generated by MySQL are fairly cryptic.

Hence, we extended the log mechanism of PriSM to better observe the usage of the connection pool and of the various connections. The primary outcome was a better understanding of the errors. MySQL is by default configured to handle 100 parallel connections through the network. Increasing such value to 1000 partially improved the performances because the machine’s operating system (Linux Ubuntu 12.04) has a fairly long TIME-WAIT for actually closing connections (see [8]).

Once we modified the corresponding configuration, both increasing the number of parallel connection and setting the configuration of the OS to reuse connections in TIME-WAIT state, we were able to measure the real capacity of the system (as shown in Figure 7, ConnectionPool(1000)).

![Fig. 7: Number of varying the number of requesting users, with the 10th and 90th percentile.](image)

Furthermore, we evaluated the time taken to post a message to different ASNs. To do that, we took advantage of a real cloud provider. Namely, we rented 5 EC2 instances in 5 different datacenters across the globe (see Table I). All the instances have the same (virtual) hardware configuration: m1.large, 7.5 GiB memory, 4 EC2 Compute Units (2 virtual cores with 2 EC2 Compute Units each), 850 GB instance storage, 64-bit platform. We configured the virtual machines to run Ubuntu 12.04 LTS and we installed on them the strictly required software (OpenJDK 7, Apache Tomcat 7, MySQL 5.1). The experiments run as follows: we simulated that a user posed a message in the Singaporean ASN and we measured...
the time required to the message to reach all the other ASNs.

| Name     | Location                     | Avg ping |
|----------|------------------------------|----------|
| asia_sg  | Asia Pacific (Singapore)     | 0ms      |
| eu_west  | Europe (Ireland)             | 550ms    |
| s_america| South America (Brazil)       | 737ms    |
| us_east  | US East (N. Virginia)        | 526ms    |
| us_west  | US West (Oregon)             | 445ms    |

TABLE I: Characteristics of the EC2 instances.

The parameter for these series of experiment was the number of threads handling the delivery of the messages.

The results of each experiment are shown in Figure 8a, Figure 8b, Figure 8c and Figure 8d respectively. As we expected increasing the number of working threads decreased the time required to deliver the messages to remote sites.

We also benchmarked the time required for a user to access a given message. In particular we evaluated two aspects: the length of the sequence of circles that the reader has to cross in order to access a message (see Section III) and the number of rules to be evaluated to access messages of a given circle. In both scenarios we assume a ASN with 100 circles hierarchically organized and a user who wants to access a message is member of 50 random circles and \( T(m) \) contains 10 (random) circles \( c_1, \ldots, c_{10} \) with \( \forall i \in [1, 10], u \notin \mathcal{M}(c_i) \). We also define 10 rules composed by 10 random predicates for each circle. As shown in Figure 9, the time required for a user to access the message \( m \) is linear to the length of the sequence of circles separating \( u \) from \( m \). We observed that on average 115 milliseconds were required to access a message tagged with the last circle of a sequence of 50 circles. We also observed that the number of tags associated with \( m \) has a lesser impact on the performances. The main reason is because the evaluation of the different possible sequences of circles is performed in parallel and, more importantly, distinct sequences are merged if during their evaluations common circles are found.

In the second series of experiments, we investigate another aspect, that of the time required by a user \( u \) to access messages contained in a given circle \( c \), with \( u \notin \mathcal{M}(c) \) and \( \phi(c) = \perp \) (see Section III). As expected, the time required is linear with the number of rules associated with \( c \). We observed that on average 187 microseconds were required to evaluate 1000 rules. The results are shown in Figure 10. Based on observations, the jitter trend in Figure 10 is caused by the memory allocation of the JVM and noises from background processes running on the testing machine.

VI. RELATED WORKS

In the current section we briefly discuss some works related to the proposed framework.

**Decentralized Social Network.** There has been recent interests in deploying decentralized online social networking (DOSN) as an alternative to the centralized third party services such as Facebook in order to avoid big brotherly controls and monitoring. Different architectures have been proposed by open-source as well as academic communities, which include Diaspora [10], Appleseed [11], Vis-à-Vis [12], SuperNova [13] among others [14]. Traditional anonymous communication and file sharing networks such as Freenet [15] have also been adapted to support friend-to-friend darknet subnetworks. A more detailed survey on DOSNs can be found at [16]. The main motivation of these works is privacy, anonymity and free-speech of individuals. The deployment models are predominantly peer-to-peer in nature, where most (all) individual participants contribute resources to the system and control their individual data, and hence the infrastructure provides best effort service, and the design focus are towards dealing with system churn, fairness & incentives, etc.

**Federated Social Network.** Another criticism of centralized social networks like Facebook and LinkedIn is that users are tied-in, and cannot communicate across networks. Social network interoperability has been advocated to address such barriers [17], [18] for users to communicate across social networks and achieve portability. In achieving federation of such social networks, the main challenge is to specify data format and protocol for exchanging information across different platforms - dealing with both technical issues (originating from the different existing implementations) and legal and commercial issues (e.g., companies are unwilling to expose user data to competitors).

PriSM is instead designed for deployment in workplaces, and works with similar assumptions of trust as do organiza-
tional email services. Specifically, in PriSM autonomous social networks (ASN) are deployed and managed in a centralized manner on well provisioned infrastructure. It gives its users privacy privileges with respect to other fellow users, but not necessarily from the organization whose infrastructure the users are using. Instead, it is designed to provide the organizations a means to manage their users’ interactions flexibly and subject to the organizations’ security and confidentiality needs. The goals of federation are also distinct, in that the federation is among multiple ASN instances with a common set of communication interfaces, but the objective is to enable flexible specification and control of information across ASNs, as determined by organizational business logic and confidentiality needs. Cross-platform federation of PriSM ASNs with other social networks will still need extrinsic mechanisms [18].

**Commercial alternatives.** Oracle Social Network [19], Yammer [20] and SalesForce [21] are a few commercial services providing some analogous functionalities by facilitating inter-department and inter-organization information exchange. These services reside in third party cloud infrastructures, in contrast to PriSM, which owing to its decentralized architecture allows multiple deployment models, including third party public cloud as well as fully controlled private cloud hosting. Furthermore, PriSM allows customized mapping of organizational hierarchy & workflows and finer grained specification of who is entitled to access certain information, a feature which is lacking in the existing general purpose services.

**Security and Privacy.** OSNs and DOSNs are often criticized for the currently provided protection mechanisms. To overcome such restrictions several works has been done, mainly focusing on protecting private and sensible information while performing social network analysis (see [22], [23]). One of the common characteristics of almost all the newly defined access control models is that access control is *relationship-based* [24], that is, authorized users are denoted on the basis of constraints on the relationships the requester should have with other network users and/or the trust level associated with a relationship [25]. Following such trend, PriSM natively supports an efficient relationship-based security mechanism based on relationships specified by means of circles, mimicking the security rules of work environments. Such mechanism can be easily extended to include more advanced constraints like the ones previously presented.

**Access control.** With respect to “pure” access control, the most widespread family of access control model is RBAC.
(Role-Based Access Control), proposed in [26] and in subsequent publications. PriSM provides management of privileges as in [26], taking advantage of the role concept with the objective to simplify the management of the privileges assigned to users. Our approach is also inspired by the works [27], [2]. These works extend the RBAC model such that: the roles define the actions that a user may perform while the “team” defines the object on which such actions can be performed. In PriSM, this idea has been further extended using teams for refining the privileges associated to roles. Practically, in PriSM it is possible for an administrator to create roles that are more general than in a pure RBAC model, and therefore fewer number of roles suffice. The context, defined by the team, can be used both to identify the objects on which the user is allowed to operate and to slightly change the privileges of the role. As a result, PriSM provides a way to reduce the increasing number of defined roles in order to identify the right set of privileges for a given task. This is a common and well known issue in systems deploying the RBAC model. To balance that, PriSM allows the operational context, the team or in our case the subdomain, to grant/revoke privileges when required.

VII. CONCLUSION AND FUTURE WORK

In this paper we presented PriSM, a framework for peer-to-peer interactions among autonomous social networks. The PriSM framework is supported by a formal model defining relationships and interactions among the different users. In particular the framework allows delegated declaration/administration of (sub-)domains which allow the possibility to define inherited privileges and restrictions on individuals and groups of users, and provides easy to form communication groups for the members to interact among themselves subject to the constraints. While PriSM facilitates confidentiality and privacy aware communication across autonomous entities, thus allowing organizations to retain ownership of data and control the flow of information, it does not provide confidentiality to individual users from the organization to which an user belongs. Additional cryptographic techniques would be necessary for the same. The modular architecture of our implementation will allow such solutions to be plugged in.

The proposed framework (and the prototype implementation) provides a flexible solution for the deployment of collaborative network in different application scenarios. These include (1) health sector, where different kinds of entities and interactions are involved - such as internal communication within and across hospitals, supply chain management with pharmaceutical companies as well as public relations, outreach and patient support groups, (2) customer relationship management and enterprise resource planning for private and public companies allowing collaboration for the fulfillment of joint operations but still ensuring that the exchanged information abide management policies, (3) educational environment complementing existing e-learning tools for better intra/inter-institute communication, (4) local/city-level administration, etc. We are at the moment engaged in exploratory discussions with stake-holders from several of these application scenarios to customize and deploy PriSM instances.

As part of future work, we aim to define a user API allowing the deploying organizations to create personalized extensions to the framework, taking advantage of all the features of the communication infrastructure.

Finally, we also intend to formally define and verify the frontier information propagation mechanism, with respect to both the policy definition language and the corresponding enforcing protocols.

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