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Universal Social Network Bus

Towards the Federation of Heterogeneous Online Social Network Services

RAFAEL ANGARITA*, LISITE, ISEP Paris, France

BRUNO LEFÈVRE, SHOHREH AHVAR, EHSAN AHVAR, NIKOLAOS GEORGANTAS,
VALÉRIE ISSARNY, Inria Paris, France

Online Social Network Services (OSNSs) are changing the fabric of our society, impacting almost every aspect of it. Over the last decades, the aggressive market rivalry has led to the emergence of multiple competing, "closed" OSNSs. As a result, users are trapped in the walled gardens of their OSNS, encountering restrictions about what they can do with their personal data, the people they can interact with and the information they get access to. As an alternative to the platform lock-in, "open" OSNSs promote the adoption of open, standardized APIs. However, users still massively adopt closed OSNSs to benefit from the services' advanced functionalities and/or follow their "friends", although the users' virtual social sphere is ultimately limited by the OSNSs they join. Our work aims at overcoming such a limitation by enabling users to meet and interact beyond the boundary of their OSNSs, including reaching out to "friends" of distinct closed OSNSs. We specifically introduce USNB -*Universal Social Network Bus*, which revisits the "service bus" paradigm that enables interoperability across computing systems, to address the requirements of "social interoperability". USNB features *synthetic profiles* and *personae* for interaction across the boundaries of -closed and open-, -profile- and non-profile-based- OSNSs through a *reference social interaction service*. We ran a 1-day workshop with a panel of users who experimented with the USNB prototype to assess the potential benefits of social interoperability for social network users. Results show the positive evaluation of users for USNB, especially as an enabler of applications for civic participation. This further opens up new perspectives for future work, among which, enforcing security and privacy guarantees.

CCS Concepts: • **Information systems ■ Social networks**; *Internet communications tools*; *Service buses*; • **Computer systems organization ■ Distributed architectures**;

Additional Key Words and Phrases: Federation, Decentralization, Interoperability, Middleware.

1 INTRODUCTION

Online Social Network Services (OSNSs) have changed, and keep changing, the fabric of society. There is no doubt of the impact they have had in almost every corner of it. Sometimes they have a positive impact such as in communication during emergencies and disasters [Palen and Hughes 2018], increased job satisfaction [Hanna et al. 2017], and creating and maintaining social relationships [Ellison et al. 2007]; and sometimes, they have negative effects such as increasing anxiety in young adults [Vannucci et al. 2017] and contributing to the spread of fake news during critical democratic processes [Allcott and Gentzkow 2017]. For better or for worse, there exist a multitude of examples of OSNSs transforming the way we live and influencing the offline world, which makes them one of the most disruptive technologies that have emerged in recent times.

*Also with MiMove Team, Inria Paris.

Social networks are social structures made up of a set of social actors, sets of dyadic ties, and other social interactions between actors. A widely accepted definition of the online version of social networks, i.e., OSNSs, is then the one presented in [Danah and Nicole 2007], where authors define them 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*”. Other references, such as [Schneider et al. 2009] and [Armstrong and Hagel 1999], also emphasize the public or semi-public profile notion, which allows users to create a description of themselves, when defining OSNSs. However, these definitions exclude important social interaction services such as, e.g., WhatsApp and email, because these services do not manage detailed profiles. In contrast, other researchers consider that the messages exchanged by email users, and therefore the users of any social interaction service, also form online social networks [Mislove et al. 2007]. In our work, we adopt a similar perspective and consider this kind of social interaction services as OSNSs, although they implement basic profiles and functionalities for the management of relationships between users [Angarita et al. 2017a].

OSNSs have allowed users to massively develop their social networks in the virtual world, spanning the private, professional and public spheres. However, the success of OSNSs has also resulted in the emergence and growth of *closed* OSNSs¹, i.e., services in which a central platform imposes the boundaries of the enabled social interactions. Hence, users get trapped in these OSNSs’ walled gardens. It follows that users need to join multiple OSNSs and find their way across them to be able to meet and interact with all their social peers. To overcome the platform lock-in, *open* OSNSs promote the adoption of open, standardized APIs, which further ease the peer-to-peer federation of the OSNSs. Still, open OSNSs define yet another OSNS and their users cannot interact directly with the users of closed OSNSs nor with the users of a different open OSNS. In general, existing solutions to the federation of OSNSs are quite restrictive regarding the ability for users to interact across the boundaries of OSNSs. Our work aims at overcoming such limitations and enabling users to *network* with their social peers independently of the OSNSs they each belong to. This objective relates to the well-known problem of addressing *interoperability* between digital systems. However, there is a distinctive feature, that is, enabling *social interoperability* between the digital systems under study, as opposed to only dealing with *technical interoperability*.

According to the definition of OSNSs that we have adopted, we say that *social interoperability* between OSNSs holds if their respective users can: (i) *discover* each other, (ii) *display their profiles*, and (iii) *interact*. While open OSNSs offer such social interoperability (although dependent upon the adoption of a common standard), our goal is to enable social interoperability across heterogeneous OSNSs, including the most popular closed ones. For that purpose, we leverage the state of the art on interoperability solutions, which extensively documents how to solve mismatches between application

¹Depending on the literature, authors may qualify such *closed* networks as *centralized*, while the *closed* qualifier may refer to *private* networks. In this paper, we use the terms *open/closed* with same meanings as *decentralized/centralized*, while we use the terms *public/private* if we need to refer to the population who may access a specific OSNS.

data and underlying middleware protocols [Blair et al. 2011]. Our contribution then lies in revisiting these interoperability solutions for the sake of online social networking. More precisely, our paper includes the following contributions:

- **Background on interoperability of OSNSs:** Section 2 reviews existing concrete approaches for enabling interactions across the boundaries of OSNSs. As we outline, these solutions address only part of the social interoperability requirements.
- **Conceptualizing OSNSs and USNB for social interoperability:** Section 3 introduces the principles of our solution to social interoperability. Following and building upon the well-known *service bus* paradigm for interoperability between computing systems, we introduce Universal Social Network Bus (USNB) that captures user interactions across OSNSs according to the users' *social reachability*. USNB features *synthetic profiles* together with the *persona* concept to enable the (virtual) social presence of users beyond their OSNSs and thereby interactions across OSNSs. Such interactions rely on the coordination of personae through a reference social interaction service, which implements a multi-party distributed mediation.
- **Prototype implementation and enabling participatory systems:** Section 4 showcases a working prototype of the proposed USNB, which provides interoperability between well-known closed and open OSNSs. The current prototype focuses on enabling social interaction between users of distinct OSNSs, while its customization paves the way for specialized socially-driven applications such as participatory and collaborative systems.
- **Evaluation and take-away:** Section 5 reports on the evaluation of USNB following a one-day workshop with a panel of users. This allows us to investigate the user perspective about: (1) USNB usability, (2) pros and cons of enabling social interoperability, and (3) envisioned usage of USNB, from which we derive perspectives for future work.

Finally, Section 6 concludes with a summary of our contributions and future research directions.

2 BACKGROUND

Researchers have worked towards the description, characterization, and the study of the future, of OSNSs [Breslin and Decker 2007; Heidemann et al. 2012; Pathak et al. 2014; Quan et al. 2011]. The presentations are narrative, as opposed to introducing models abstracting the key concepts and functions of OSNSs. Another significant line of OSNS research is about understanding the behavior of OSNS users through the analysis of the unprecedented large amount of data they produce. Other research efforts are concerned with understanding the dangers of personal information leakage [Irani et al. 2011], or finding a mapping among the identities of individuals [Zafarani and Liu 2013].

Focusing on the specific concern of enabling interoperability across OSNSs, some approaches promote the adoption of the classical solution to overcome heterogeneity, that is, to introduce relevant standards (spanning data formats, APIs and protocols). This is, e.g., the focus of the W3 Social Web Working Group². However, the OSNS market is too competitive for providers to be willing to adopt a common standard [Hinchcliffe

²<https://www.w3.org/Social/WG>

2014]. On the contrary, many closed OSNSs keep proliferating and gaining popularity. Thus, other approaches have emerged to overcome OSNS heterogeneity; they aim at simplifying the management of multiple user accounts. Summarizing, today's practical solutions to OSNS interoperability fall in the following categories (see Figure 1):

- **Account linkage:** It is a well-known feature to share content across OSNSs. Users must possess accounts in *all the* OSNSs they are interested in and let the OSNS offering the account linkage feature access all the other accounts. The feature is usually limited to sharing content such as information found in news feeds. An example of account linkage is when users enable their Twitter accounts to access their Facebook accounts so that their Facebook wall posts are automatically published on their Twitter Timelines³. The advantage of this approach is that it lets users "stay" in their favorite OSNS and publish content in it while reaching users in other OSNSs.
- **Aggregation service:** The service collects content from multiple OSNSs to exhibit it as one unified presentation. As with account linkage, users have to give the aggregation service access to all the accounts they want to collect information from. In contrast with account linkage, aggregation services are third-party platforms that gather content, forcing users to leave their favorite OSNSs so as to benefit from content aggregation. friend2friend is an example of an aggregation service and brings together social content (photos, videos, stories) from Facebook, Twitter, YouTube, Instagram, etc.
- **Universal instant messaging client:** Similarly to an aggregation service, such client provides a single interface to several messaging systems. This single interface also aggregates contact lists from the different social interaction services added to the client, giving the illusion of using one account to communicate with everybody no matter the social interaction service they are using. As with aggregation services, users not only have to possess accounts in all the social interaction services they are interested in and give the client access to them, but they are also forced to "leave" them to enjoy the advantages of universal messaging. Pidgin is an example of a universal instant messaging client that supports many instant messaging protocols such as Bonjour, IRC, MySpaceIM, MSNP, OSCAR (AIM, ICQ, MobileMe, ...), XMPP/Jingle (Google Talk, LJ Talk, Gizmo5, ...), Yahoo! Messenger, etc.
- **Open social network:** It is an OSNS that provides mechanisms, usually in the form of an API, for other OSNSs to discover its users and interact with them. Open social network projects generally develop software, protocols, or both, which they release as open source most of the time, so that other platforms can adopt them. Open standards such as ActivityPub, OAuth authorization, OpenID authentication, OStatus federation and the Extensible Messaging and Presence Protocol (XMPP) (aka Jabber) are some of the technologies for building open OSNSs⁴. Diaspora⁵ and Mastodon⁶ are examples of open OSNSs.

³https://www.facebook.com/help/1547895645497795?helpref=uf_permalink

⁴See, for example, <https://www.w3.org/TR/2018/REC-activitypub-20180123/>

⁵<https://diaspora-fr.org>

⁶<https://joinmastodon.org>

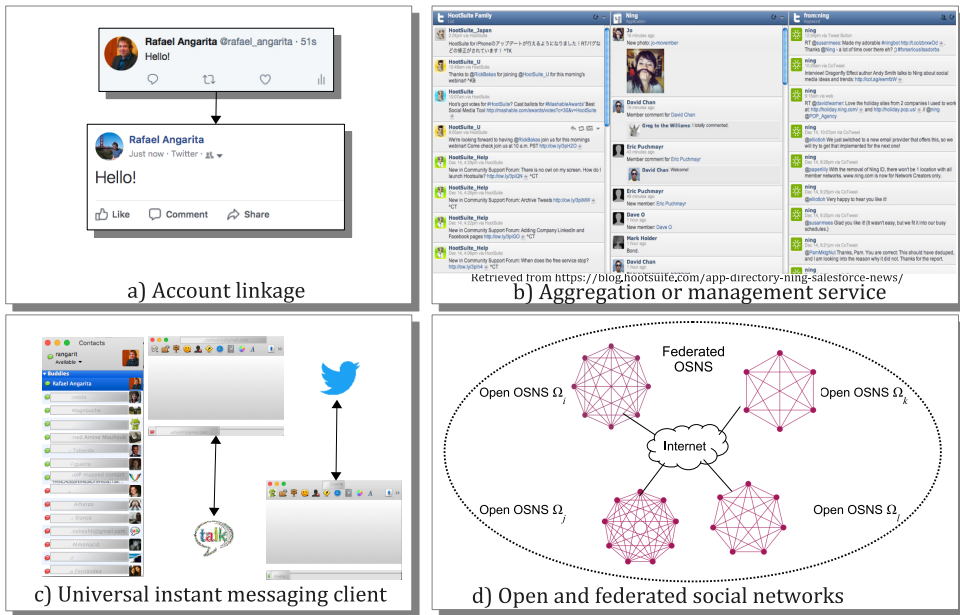


Fig. 1. Existing practical solutions to OSNs interoperability.

- Federated (open) social network:** This consists in the *union* of open OSNs, each from different providers [Esguerra 2011]. A user in a particular OSN can discover other users of any OSN in the federation and interact with them. In the most general case, the federated social network allows the assembly of OSNs that leverage different open technologies. However, in practice, most solutions are limited to the federation of *homogeneous* open OSNs, i.e., services based on the same technologies. For instance, we may find a federation of distributed Diaspora providers/instances or a federation of distributed Mastodon providers/instances; but, we cannot have a federation combining Diaspora and Mastodon providers/instances without modifying the underlying protocols of those OSNs. Few solutions offer the federation of *heterogeneous* open OSNs, such as the one presented in [Silva et al. 2017]; however, they are not well-developed yet and do not consider closed and non-profile-based OSNs.

Account linkage, aggregation services and universal instant messaging clients ease the management of multiple OSNs accounts; however, they do not fully address interoperability across them. For example, they do not support discovering or following users across OSNs. Instead, these solutions either introduce yet another OSN or enable coordinating only a specific subset of functions between OSNs. The nature of open OSNs makes it possible for them to interoperate with other OSNs in a federation; unfortunately, since there is no standard protocol for OSN federations, open OSNs end up being implemented using divergent technologies.

The main goal of our work is to let people interact beyond the boundaries of the OSNs they use while relieving them from the burden of creating and managing multiple accounts and learning how to use new tools. To achieve that, we introduce a dedicated

interoperability solution, which enables the *federation of heterogeneous OSNs*, that is, the federation of open and closed OSNs, as well as profile- and non-profile-based OSNs. Our work builds upon the interoperability work done in the distributed systems community [Issarny et al. 2011]. More specifically, we adopt the *service bus* paradigm [Chappell 2004], which enables existing loosely coupled service components, possibly implemented using different technologies, to exchange messages transparently through an intermediary representation. Further, the connection of service components to the service bus removes the need of solving interoperability problems between every pair of them.

To the best of our knowledge, despite the OSN hype and the extensive research on interoperability, we are the first to introduce an overall approach to the federation of heterogeneous –profile and non-profile-based–, –open and closed– OSNs. In our previous work [Angarita et al. 2017b], we introduced a conceptualization of the human interaction paradigms in the virtual sphere and a service bus-like approach to decouple them and make them interoperate. This previous work introduced an initial idea for social interoperability, showcasing a one-way notification use case. In [Angarita et al. 2017a], we build upon this idea to provide a model for social interaction services, and present an initial interoperability solution to enable users of different closed OSNs to interact. This paper generalizes this work to account for the diverse functionalities of OSNs, spanning *profile management* and *social interactions*, and introduces a new USNB implementation prototype and experimental evaluation as a follow-up of the experimental results we previously presented in [Angarita et al. 2017a].

3 FEDERATING HETEROGENEOUS OSNS WITH USNB

The essential functions of an OSN relate to [Heidemann et al. 2012]:

- (i) The management of *user profiles* so that users may meet their social peers through the advertisement and search of "virtual selves". User profiles are virtual representations of people, companies or any other entity. They are made up by data associated with those entities (e.g., name, profile picture, description, location, interests, contacts, etc.).
- (ii) *Social interaction services* so that social peers may interact directly (e.g., messaging) as well as indirectly (e.g., wall post) in the virtual world.

With enabling the federation of heterogeneous OSNs, which we also refer to as "*social interoperability*", we want to allow OSN users to meet and interact with their "social peers" beyond the boundaries that their respective OSN platforms impose. Regarding the management of profiles, most OSNs follow a similar user model. Hence, we can map profile pictures, name, and other personal information, across OSNs. The same applies to social interaction services. For example, a Facebook wall post can be seen as equivalent to a tweet without the 280-character limit⁷. The same Facebook wall post can be sent by email; in this case, the main concern is to decide what to write as email subject, since a Facebook wall post does not explicitly specify one. This mapping may involve data transformation operations, which is a problem that has been extensively studied within the database community to integrate data from multiple autonomous and heterogeneous sources [Halevy et al. 2006]. There also exist

⁷This restriction was of 140 characters not so long ago.

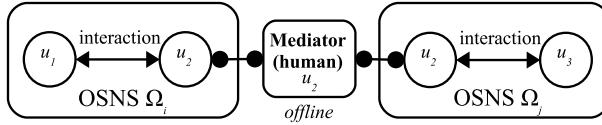


Fig. 2. Human mediation between heterogeneous OSNs.

commercial solutions, such as Mule⁸, providing graphical tools to assist developers in data transformation of messages between components. However, dealing with social interoperability goes beyond leveraging relevant technical interoperability solutions that reconcile mismatches between data formats and protocol messages.

3.1 A Perspective on Social Interoperability

To exploit the full set of OSNS functionalities, people act as "social interoperability" enablers on a daily basis by coordinating functionalities between multiple OSNs. Consider the example depicted in Figure 2, where user u_1 in OSNS Ω_i needs to interact with u_3 in Ω_j although the two users are in different OSNs. Fortunately, u_2 is member of Ω_i and Ω_j , and maintains two profiles, one in each OSNS, where the two profiles most likely contain redundant personal information. Then, u_1 can interact with u_2 and communicate the need of forwarding a message to u_3 ; u_2 can do this by selecting the appropriate interaction services of the respective OSNs and adapting the content of the interaction from one service to the other. This scenario illustrates the best case where u_2 has the time and skills to manage two different OSNS accounts and is willing to help u_1 by forwarding a message to u_3 . In the worst case, this interaction is not possible.

Going back to Figure 2, u_2 acts as a *mediator*. This *human mediator* has profiles in heterogeneous OSNs and is capable of receiving messages, transforming and sending them across the OSNs. We formalize human mediation in OSNs with the notion of *social reachability graph*, which tackles the central question of social communication interoperability: "whom can a user interact with?".

Definition 1. Let U be the universe of OSNS users, within which users are represented/known by their profiles. Notation-wise, a user u_x of OSNS Ω_i is represented with the profile $u_x^{\Omega_i}$ ⁹. U can be partitioned into **social reachability graphs**, such that each one of them is a connected graph and these graphs are disconnected among each other. Each graph is denoted $R = (V, E)$, where $V \subseteq U$, $E \subseteq \{\{v, w\} : v, w \in V\}$, with the following properties:

- Every edge $\langle u_x^{\Omega_i}, u_y^{\Omega_i} \rangle_{x \neq y} \in E$ has an associated social interaction service, s_{Ω_i} ¹⁰, so that u_x and u_y can interact within OSNS Ω_i via s_{Ω_i} .
- Every edge $\langle u_x^{\Omega_i}, u_x^{\Omega_j} \rangle_{i \neq j} \in E$ is such that the two user profiles $u_x^{\Omega_i}, u_x^{\Omega_j}$ belong to the same user u_x .

⁸<https://www.mulesoft.com>

⁹Without loss of generality and to simplify the presentation, we do not account for the case where a given user has more than one profile in a given OSNS.

¹⁰Again without loss of generality, we assume that an OSNS has a single social interaction service.

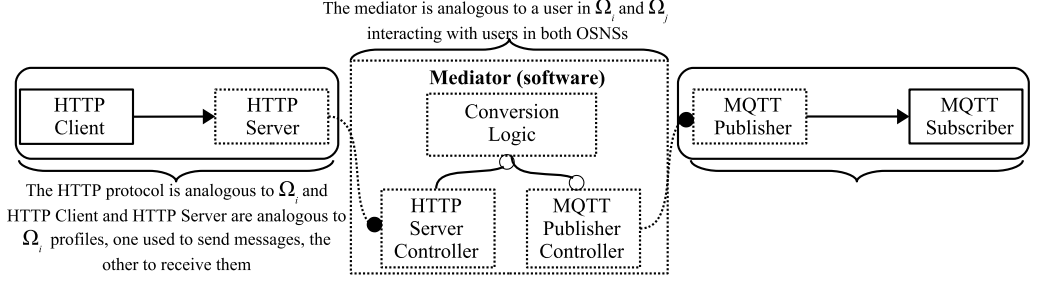


Fig. 3. Example of a software mediator and analogy to OSNS mediation.

- For any given pair of user profiles $u_0^{\Omega_i} \in V$, $u_z^{\Omega_n} \in V$ there exists at least one bidirectional path \mathcal{P} such that:

$$\mathcal{P}(u_0^{\Omega_i}, u_z^{\Omega_n}) = u_0^{\Omega_i} \begin{matrix} \xleftrightarrow{s_{\Omega_i}} \\ \xleftarrow{s_{\Omega_i}} \end{matrix} \dots u_w^{\Omega_i} \begin{matrix} \xleftrightarrow{s_{\Omega_j}} \\ \xleftarrow{s_{\Omega_j}} \end{matrix} u_w^{\Omega_j} \begin{matrix} \xleftrightarrow{s_{\Omega_j}} \\ \xleftarrow{s_{\Omega_j}} \end{matrix} \dots u_x^{\Omega_j} \begin{matrix} \xleftrightarrow{s_{\Omega_n}} \\ \xleftarrow{s_{\Omega_n}} \end{matrix} \dots u_y^{\Omega_n} \begin{matrix} \xleftrightarrow{s_{\Omega_n}} \\ \xleftarrow{s_{\Omega_n}} \end{matrix} \dots u_z^{\Omega_n}$$

where:

- $s_{\Omega_i}, s_{\Omega_j}, \dots, s_{\Omega_n}$ are social interaction services associated to the corresponding edges, and
- $\begin{matrix} \xleftrightarrow{s} \\ \xleftarrow{s} \end{matrix}$ links two profiles of the same user, while it requires to transform data and to coordinate behavior between two different social interaction services.

Following, users in the same social reachability graph can interact. They can act as interaction relayers between one or more users, acting as human mediators.

The distributed systems community has largely studied the concept of mediator -this time in software- [Wiederhold 1992]. We can define a software mediator as an intermediary software entity that enables software components that are not directly compatible to work together without any internal modification to them. In our example, u_2 enables an interaction between u_1 and u_3 by fulfilling the roles of *receiver*, *converter* and *sender*. Traditionally, software engineers who understand the semantics and data models of interacting components have been the ones developing software mediators. More recently, researchers have been working on how to synthesize mediators automatically to face the growing complexity and dynamism of distributed systems [Bennaceur and Issarny 2015]. Figure 3 exemplifies this concept with a software mediator enabling the interoperability between a REST client and an MQTT subscriber. The REST client posts data to a REST server that the mediator exposes. The REST server controller gets this data, transforms it using some conversion logic and sends it to the MQTT publisher controller, which in turns sends it via an MQTT publisher. Finally, an MQTT subscriber receives this data.

Figures 2 and 3 together show how the concept of mediators of distributed systems is analogous to the mediation of OSNSs. Moreover, in both cases, the ultimate goal is to achieve the automatic synthesis of mediators. Still, in the OSNS context, there is the additional -and non-trivial- need for the mediator to synthesize user profiles. Figure 4 illustrates the case where u_1 wants to interact with u_3 ; however, they are not in the same OSNS and none of them are willing to join yet another one. To make this

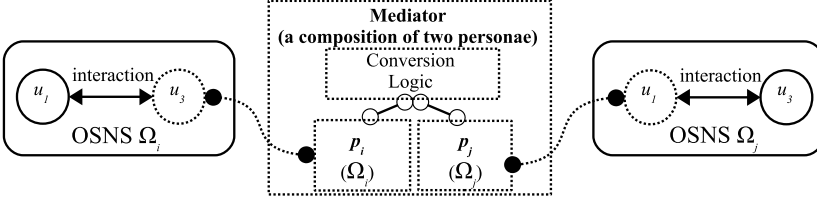


Fig. 4. Users interacting through synthetic OSNS profiles.

interaction possible without relying on a human mediator, two profiles are automatically synthesized (see the dotted circles): one for u_3 in OSNS Ω_i ; and one for u_1 in OSNS Ω_j . These *synthetic profiles* can be generated using known data from existing profiles in other OSNSs or from information provided by the users for that matter. In addition, a mediator enabling the interactions across Ω_i and Ω_j is synthesized as a composition of two *personae*. A *persona* is a software entity that simulates users in a particular OSNS so as to take part in social interactions via *synthetic profiles* on behalf of human users. The combination of two *personae*, each one specialized for a given OSNS, together with the appropriate conversion logic between the two, allows the necessary translation of the messages exchanged between the different social interaction services of the respective OSNSs. We formalize the notion of *persona* in relation to social reachability graphs:

Definition 2. A **persona** for OSNS Ω_i , denoted p_i , is an entity enabling the bridging of users from OSNS Ω_i with users from other OSNSs through the management of synthetic profiles on behalf of the latter users. To this end, p_i is deployed in the social reachability graph R_{Ω_i} of Ω_i . For a given user $u_x^{\Omega_j}$ of OSNS Ω_j , represented in Ω_i via p_i , we note: $u_x^{\Omega_j} \succ p_i \in V(R_{\Omega_i})$

The combination of *personae* p_i and p_j creates a new social reachability graph by connecting R_{Ω_i} and R_{Ω_j} .

3.2 Universal Social Network Bus

Pursuing our analogy between software mediators for distributed systems and OSNS mediation, we introduce Universal Social Network Bus (USNB), which takes inspiration from the concept of service bus [Chappell 2004]. The latter allows the interoperation of heterogeneous and distributed applications, data and devices, by providing a high-level intermediary communication protocol. More formally:

Definition 3. Universal Social Network Bus (USNB), denoted \mathcal{B} , is an entity allowing the interoperation of heterogeneous OSNSs over a service bus-like paradigm by featuring a reference social interaction service, $s_{\mathcal{B}}$, and enacting a social reachability graph, $R_{\mathcal{B}}$.

Figure 5 illustrates how USNB enables social interactions among four users of four different OSNSs, through the implementation of a multi-party, distributed mediator. The (multi-party) USNB mediator embeds a *USNB persona* for each of the OSNSs to include them in the target social reachability graph. A *USNB persona* is a special *persona*: it implements a complete mediator between the OSNS it represents and USNB,

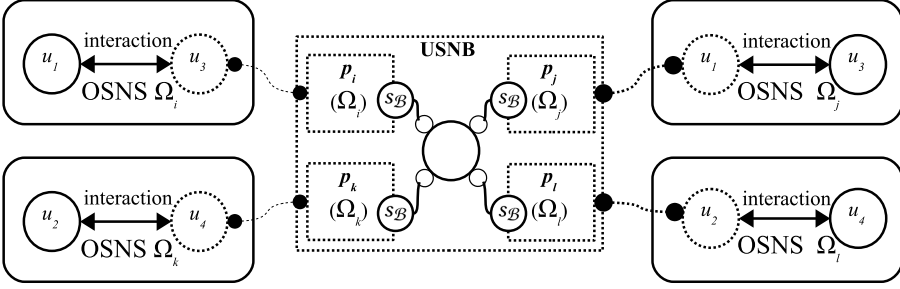


Fig. 5. Multi-party distributed mediation in USNB: The USNB personae implement the bus' reference social interaction service $s_{\mathcal{B}}$.

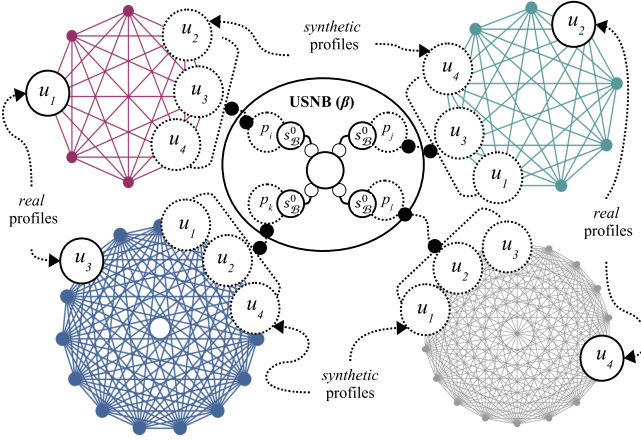


Fig. 6. Federating heterogeneous OSNs via USNB and synthetic profiles. For synthetic profiles, we use the representation of u_x inside a dotted circle as an equivalent to $u_x^{\Omega_a} \succ p_{\mathcal{B}}^a$, $a \in \{i, j, k, l\}$.

including the conversion logic between the OSNS's social interaction service and the bus's reference social interaction service. USNB personae are the main components of USNB and they interact with each other through its reference social interaction service. A USNB persona acts as a bridge between its associated OSNS and USNB. More formally and from Definition 2:

Definition 4. A **USNB persona** for OSNS Ω_i , denoted $p_{\mathcal{B}}^i$, is an entity bridging \mathcal{B} and OSNS Ω_i , such that for any user $u_x^{\Omega_i}$ of Ω_i , we have: $u_x^{\Omega_i} \succ p_{\mathcal{B}}^i \in V(R_{\mathcal{B}})$

The linking of USNB personae allows users from (technically) isolated social reachability graphs to interact independently of their technological choices. Figure 6 illustrates the case of four users: $u_1 \in V(R_{\Omega_i})$, $u_2 \in V(R_{\Omega_j})$, $u_3 \in V(R_{\Omega_k})$ and $u_4 \in V(R_{\Omega_l})$. USNB creates synthetic profiles for each of the users in all the OSNs where they do not have a profile. For example, u_1 has a profile in Ω_i , while USNB creates synthetic profiles for u_1 in Ω_j , Ω_k and Ω_l . The synthetic profiles, which are represented as dotted circles in the figure, enable (remote) users of distinct OSNs to interact via the USNB personae. As a result, all the users in the USNB federation of heterogeneous OSNs can interact. For example,

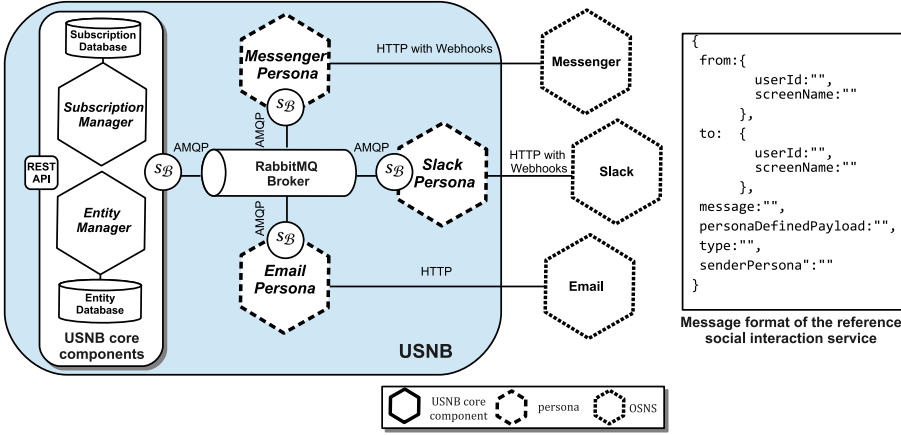


Fig. 7. USNB prototype architecture (**Left**) connecting three OSNs: Facebook Messenger, Slack, and Email (the specific email service is not relevant since email is an open and decentralized OSNs). The related personae coordinate through the USNB reference social interaction service using the associated message format (**Right**).

there exists a path between u_1 and u_4 , where interactions in \mathcal{B} are transparent for u_1 and u_4 :

$$\mathcal{P}(u_1, u_4) = \overbrace{u_1^{\Omega_i} \xleftrightarrow[s_{\Omega_i}]{s_{\Omega_i}} u_4^{\Omega_i} \succ p_{\mathcal{B}}^i}^{\text{Interactions in } \Omega_i} \xleftrightarrow[p_{\mathcal{B}}^i]{p_{\mathcal{B}}^i} p_{\mathcal{B}}^i \xleftrightarrow[s_{\mathcal{B}}]{s_{\mathcal{B}}} p_{\mathcal{B}}^l \xleftrightarrow[p_{\mathcal{B}}^l]{p_{\mathcal{B}}^l} u_1^{\Omega_i} \succ p_{\mathcal{B}}^l \xleftrightarrow[s_{\Omega_i}]{s_{\Omega_i}} u_4^{\Omega_i} \xleftrightarrow[p_{\mathcal{B}}^l]{p_{\mathcal{B}}^l} u_4^{\Omega_i}$$

Interactions in \mathcal{B}

From u_1 's perspective, interactions happen only via s_{Ω_i} ; from u_4 's perspective, only via s_{Ω_i} ; in effect, u_1 and u_4 interact with synthetic profiles managed by $p_{\mathcal{B}}^i$ and $p_{\mathcal{B}}^l$.

4 USNB PROTOTYPE IMPLEMENTATION

The USNB prototype implements the reference social interaction service and the persona concept; it is available under the AGPL license at <https://gitlab.inria.fr/usnb/>. The prototype is an evolution that follows-up the feedback we received from participants of our previous study [Angarita et al. 2017a]. In particular, we implemented a user interface, on top of the lower level one, to improve the usability of our previous prototype and to enhance the way users interact. Further, we present this prototype as a baseline platform for the implementation of participatory systems by supporting collaborative actions at the Internet scale.

4.1 High-level Architecture and Implementation

Figure 7-Left depicts the architecture of the current USNB prototype implementation:

- *Subscription Manager* maintains a list of events, subscriptions to those events, and has an endpoint to send messages related to those events. It can implement group communication or *follow*-like functionalities as we presented in [Angarita

et al. 2017b], where users get notifications about certain events via their favorite social interaction services.

- *Entity Manager* serves as a registry for users, personae, as well as (synthetic and real) profiles and user preferences. For each user that is known to USNB, the registry maintains: the USNB UID `userId`, the set of associated OSNS profiles within the supported OSNSs¹¹, and a preference specifying the preferred profile for interactions.
- *Personae* are in charge of translating messages and coordinating behavior between the connected OSNSs via the USNB reference social interaction service.
- *RabbitMQ Broker* is the message-oriented middleware supporting asynchronous communication between the distributed service components of USNB. As its name suggests, the middleware is implemented using RabbitMQ and its associated AMQP protocol.

We implemented the architecture components, including personae, as Node.js services. They all feature an AMQP endpoint and client –which we implemented using the AMQP library for Node.js¹²– to interact with other USNB components.

Figure 7–Right depicts the message format supported by the reference social interaction service: `to` (resp. `from`) specifies receivers (resp. senders), which are defined by their user ids and can have a screen name; `message` can be used to specify message parts such as text and subject; `personaDefinedPayload` may contain additional information related to the sender persona; `type` specifies the interaction type (i.e., user-to-user or user-to-USNB); and `senderPersona` identifies the persona sending the message to USNB.

4.2 Developing Personae for the Diverse OSNSs

Figure 7 shows the personae that our prototype currently supports:

- *Messenger* is the Facebook’s messaging platform, which, as of the third quarter of 2018, counted approximately 2.27B monthly active users¹³. It is the most popular OSNS in the world and is the perfect example of a closed and centralized OSNS.
- *Slack* is a team-based collaboration tool. As of May 2018, it counted more than 8M daily active users¹⁴, making it another perfect example of a closed and centralized OSNS, while –compared to Messenger– serving a more specific collaboration-oriented purpose.
- *Email* is a more traditional communication tool. In 2017, there were approximately 3.7B e-mail users, and we expect this number to grow to 4.3B in 2022¹⁵. There is no doubt that we will still use email for a long time, while other OSNSs may come and go. Email is also the reference example of an open and decentralized OSNS: no matter the email service provider, users can always interact with users of different providers.

¹¹A user can have multiple profiles for the same OSNS.

¹²<https://www.npmjs.com/package/amqplib>

¹³<https://www.statista.com/statistics/264810/number-of-monthly-active-facebook-users-worldwide/>

¹⁴<https://www.statista.com/statistics/652779/worldwide-slack-users-total-vs-paid/>

¹⁵<https://www.statista.com/statistics/255080/number-of-e-mail-users-worldwide/>

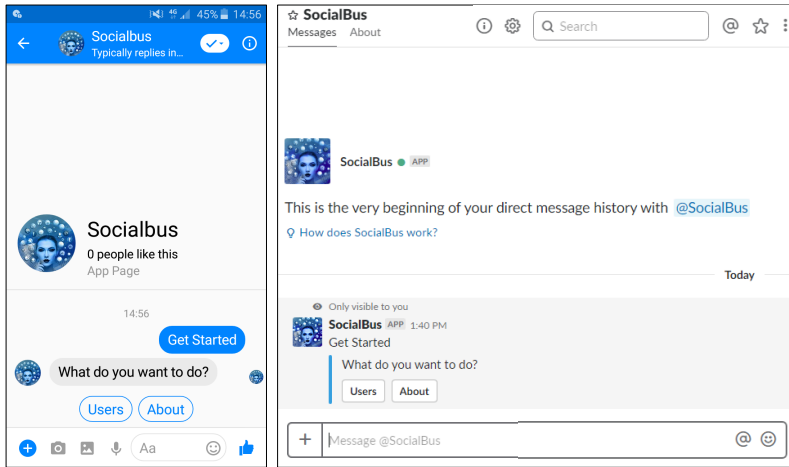


Fig. 8. The SocialBus profile for USNB within Messenger (**Left**) and Slack (**Right**). This profile exposes a homogeneous representation of USNB, and its functionalities, across diverse OSNSs. There is no email profile for USNB, since interacting via USNB is transparent for email users.

The above personae allow us to experiment with representative categories of OSNSs. We (and hopefully third-party developers) will plug other personae into USNB across time. While the current prototype requires the developers to take care of most of the personae implementation, it is our intent to develop tools supporting the systematic synthesis of personae by leveraging the related state of the art [Calinescu et al. 2017].

Closed OSNSs such as Messenger and Slack do not offer a way to create profiles programmatically, which prevents the implementation of software components (in our case, personae) that generate synthetic profiles. Instead, a human user must create the required profiles using Web-based user interfaces, via which they have to fill out their personal information. Users also face a series of challenge-response tests to determine whether or not they are humans. Some well-known and widely used challenge-response tests are CAPTCHA, and email and SMS verification. In general, closed OSNSs forbid software agents -among which USNB personae- to interact on behalf of human users. Thus, the automatic synthesis of OSNS profiles and their usage, by personae, for a closed OSNS, requires a previous agreement between the specific OSNS and USNB. Nonetheless, closed OSNSs provide ways for software agents to interact through special kinds of OSNS profiles. For instance, Facebook offers the *apps* profile¹⁶. Such (synthetic) profiles cannot represent remote users individually. However, they can represent a (synthetic) entity such as USNB. We specifically introduce a USNB profile (linked each time to the related persona), called *SocialBus*, within closed OSNSs. Local users can then discover, visualize and interact with SocialBus within the OSNS they belong to, so as to benefit from social interoperability and thereby be able to reach out to users from remote OSNSs. Figure 8 shows the welcome screens of SocialBus within Messenger and Slack.

Going back to the implementation of personae:

¹⁶<https://developers.facebook.com>

- The *Messenger persona* is available at <https://gitlab.inria.fr/usnb/messenger-persona>. Apart from having an AMQP endpoint and client to communicate with USNB components, it has an HTTP client to interact with the Messenger platform and it exposes a public Webhook to receive HTTP Post notifications from the Messenger platform. These notifications are about events such as when a user starts an interaction with SocialBus in Messenger, writes messages or selects a button. For the Messenger UI, we used quick replies¹⁷ and templates¹⁸.
- The *Slack persona* is available at <https://gitlab.inria.fr/usnb/slack-persona> and is implemented using the Slack Developer Kit for Node.js¹⁹. Interaction with Slack is implemented using the Slack API²⁰ together with the Slack interactive messages library²¹ to improve the user experience. The persona also exposes a public Webhook to receive HTTP Post notifications from the Slack platform. As for Messenger, the notifications inform when a user writes messages or selects a button, etc.
- The *Email persona* is available at <https://gitlab.inria.fr/usnb/gmail-persona>, and is implemented using the Google APIs Node.js library as a client for the Gmail API²². By design, open OSNSs (like Email) enable the discovery and interactions with remote users, i.e., users of distinct OSNSs (see § 3.1). Email users do not have to do anything special to interact with users of different email service providers. USNB can thus set up an email server where it can automatically and dynamically synthesize email identities by creating email addresses for every USNB user who does not have one. The Email persona is then in charge of email synthetic identities on behalf of which it checks for new emails and extracts their content to send it to the corresponding USNB component (e.g., Messenger persona). Dually, this persona receives messages from other USNB components, builds emails from their contents, and sends them using the corresponding email synthetic identity.

4.3 USNB for Participatory and Collaborative Systems

USNB enables users to reach out to their social peers independently of the communication service (and especially underlying platform) each one uses in the virtual world. The success and massive adoption of OSNSs -as magnified by the success of Facebook- shows that online social communication is an essential tool for people. This further paves the way for collective and collaborative actions at the Internet scale. However, existing online collaborative tools come along with their communication platform, which is either a proprietary solution or a third-party OSNS. We argue that USNB contributes to enabling participatory systems at a larger inclusive scale by overcoming the technical boundaries set by existing online communication platforms. In that direction, we investigate the customization of USNB for specific applications, which involves:

- *Delimiting the universe of users*. Instead of considering all the users of all the OSNSs, the participating users can have restrictions according to the characteristics

¹⁷<https://developers.facebook.com/docs/messenger-platform/send-messages/quick-replies>

¹⁸<https://developers.facebook.com/docs/messenger-platform/send-messages/templates>

¹⁹<https://github.com/slackapi/node-slack-sdk>

²⁰<https://api.slack.com>

²¹<https://github.com/slackapi/node-slack-interactive-messages>

²²<https://developers.google.com/gmail/api/>

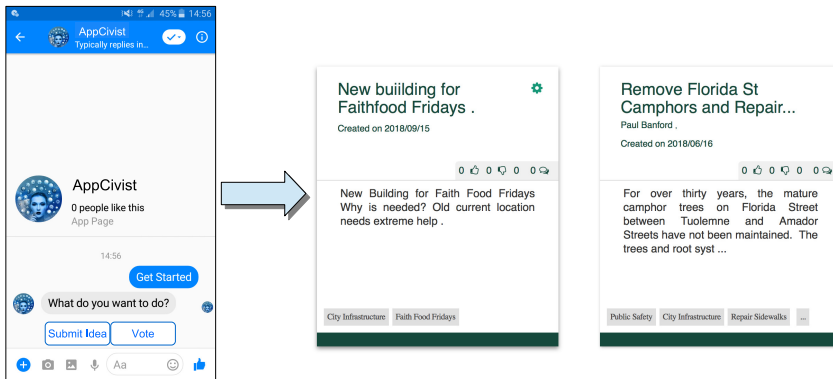


Fig. 9. Thanks to USNB, citizens can take part in participatory budgeting campaigns supported by the AppCivist-PB platform, using the communication platforms they prefer. Here, an AppCivist-PB profile offers Messenger users the possibilities of submitting ideas and voting for ideas (**Left**). Two ideas displayed in the AppCivist-PB platform (**Right**): The idea *New building for Faithfood Fridays* asks for a new location to help neighbors in need with free boxes of food, groceries and other basic necessities; the idea *Remove Florida St Camphors and Repair...* asks for the removal of the invasive camphor trees in Florida St. and the repairing of its pavement damaged by their roots. Citizens can submit these ideas via Messenger, Slack, Email, or any other communication platform, or directly using the AppCivist-PB Web interface. In general, the figure illustrates how we can customize USNB for specific applications beyond the interconnection of heterogeneous OSNSs.

and needs of a given participatory application. For instance, the customization may allow interaction only with the users registered in that application.

- *Functional customization.* USNB personae enable interaction between users across OSNSs through the USNB reference social interaction service (and the SocialBus profile in the case of closed OSNSs). Personae customized for an application will support specialized interactions and will come along with associated USNB profile(s) that provide UIs for users to perform those specialized interactions.

As a first participatory application that leverages USNB, we have been focusing on participatory budgeting, which allows citizens to propose and select projects to be implemented with public funds by their cities. The AppCivist-PB platform²³ [Holston et al. 2016] has been designed to enable citizens to take part –both online and offline– in such processes. We are now studying the customization of personae together with the creation of associated profiles to enable citizens to take part in AppCivist-PB campaigns using the communication platforms they are the most comfortable with (see Figure 9).

5 EVALUATION

The design and prototype we presented in this paper follow from the evaluation of an early design presented in [Angarita et al. 2017a]. This first evaluation work, in particular, resulted in introducing synthetic profiles for improved user experience. Further, following the current maturity of the prototype, we ran a one-day user workshop

²³<http://www.appcivist.org/>

to assess the stated benefit of USNB against the users' perspectives, and further derive recommendations for the evolution of USNB.

5.1 User Workshop

In collaboration with INSEAD²⁴, the Multidisciplinary Center for Behavioral Science of Paris Sorbonne University, we organized a workshop involving 20 users, from 18 to 35 years old and already comfortable with OSNS uses.

After a short general presentation of our USNB prototype, we assigned to each user a profile related to one of the three OSNSs supported by the current prototype: 10 users got a profile on Messenger, 6 on Slack and 4 on Gmail. For 30 minutes, each OSNS user was asked to communicate with users of different OSNSs via USNB, sending and receiving messages. Then, they filled out a survey and participated in a collective discussion about the experiment (see next section).

To exemplify what the participants performed during the workshop, we focus on two users who wish to interact with each other (see Figure 10): Rafael uses Messenger, and Carmen uses Gmail. For Rafael, USNB creates the address "rafaelan-garita.at.bus@gmail.com", which is all we need for a synthetic email identity. For Carmen, USNB creates a Facebook identity showing her name, a short description, and her profile picture. We first concentrate on Rafael's actions, recalling that Facebook Messenger is a closed OSNS. Rafael thus has to look for SocialBus (the USNB synthetic profile) in Messenger in order to interact with Carmen. Then, SocialBus proposes an action menu to Rafael (we already presented this action menu in Figure 8). When Rafael selects "About", SocialBus shows a brief description about itself and two options: going back to the main menu or visiting its official Website. When Rafael selects "Users", SocialBus shows the list of USNB users along with a minimalist version of their profiles. To start an interaction with Carmen, Rafael selects her profile from the list of users. Then, SocialBus starts an interaction context so that Rafael can send and receive messages in Messenger, in a way similar to what he is used to with any Messenger user; messages sent to SocialBus will ultimately reach Carmen. Finally, Rafael can end the interaction by typing "quit". Slack users, or users of any other messaging-based closed OSNS, will follow a similar procedure to interact with USNB-connected users. From Carmen's point of view, nothing changes. She interacts with Rafael as with any other email user, as Figure 10 illustrates. This last example also illustrates what is possible with other open and decentralized OSNSs such as Diaspora or Mastodon, which are alternatives to Facebook and Twitter, respectively.

5.2 Questionnaire and Evaluation Results

We evaluated three main aspects through the survey that is detailed -including the provided responses- at <https://gitlab.inria.fr/usnb/universal-social-network-bus/tree/master/documents> and the follow-up discussion with the workshop participants:

- (1) Smooth functioning of the prototype and related usability.
- (2) Pros and cons of having access to a universal social network that enables interacting with social peers independently of one's OSNS.
- (3) Envisioning user adoption of USNB.

²⁴<https://www.insead.edu/>

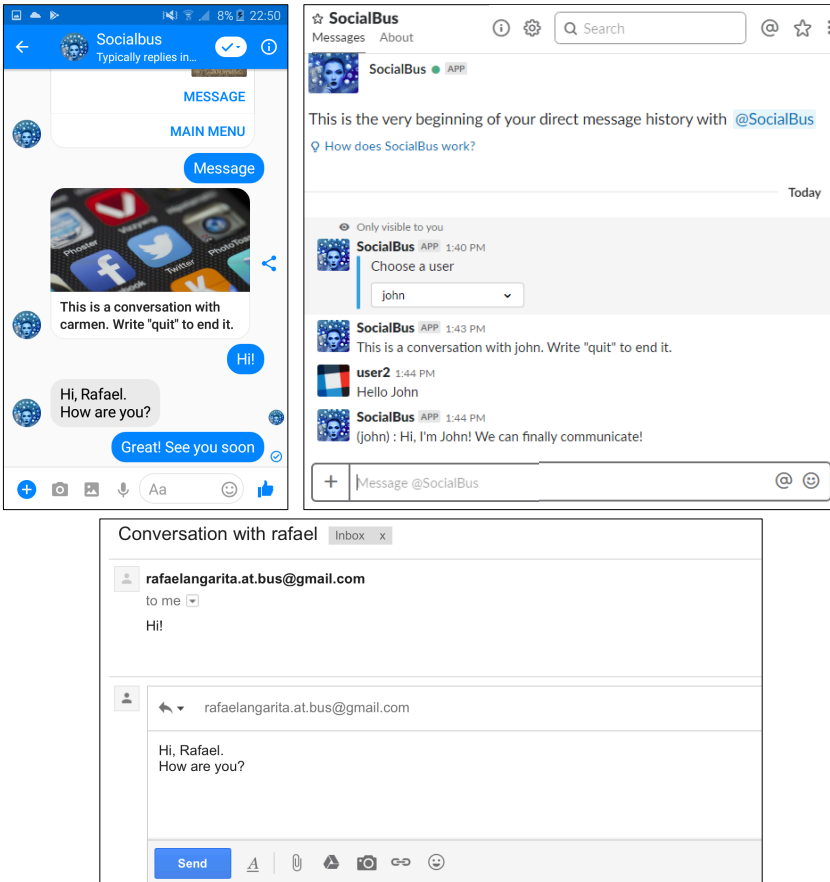


Fig. 10. Rafael who uses Messenger (**Top-Left**), interacts with Carmen who uses email; Rafael interacts with Carmen via SocialBus similarly to the way he interacts with any Messenger user. Carmen replies to the message “Hi!” sent by Rafael (**Bottom**). As we can see, Carmen can interact with Rafael as she normally does with any email user thanks to the open and decentralized nature of email. Finally, user2, a Slack user, interacts with John (**Top-Right**); user2 does not know which OSNS John uses for this interaction.

First, we asked for feedback on the design and the practical use of the USNB prototype. Two-thirds of the participants (67%) considered that the function of sending a message from their assigned OSNS profile is intuitive (48%) or very intuitive (19%). Slightly more participants (72%) declared that the supported interface is convenient for looking up a contact. On another note, 95% of the participants did not identify particular problems in the content or structure of the messages they exchanged; we note, however, that users had to limit message contents to text, as the current prototype does not support other media. Some participants noted that Messenger was slowed down during the test or they observed inactive or crashing actions like when clicking on “Quit” to stop a conversation in Slack. Overall, 90% of the users considered that the USNB prototype is “*efficient for communicating*” with their contacts, and “*although complex to understand at first*”

glance, it's easy and fast", "easy to take part in, even if perfectible". A user further suggested "mentioning at the end of each received message: 'Sent from Facebook or from Gmail...', to make more evident potential formatting issues".

Second, at the level of usages and OSNS culture, we evaluated the deep changes that such a universal tool could induce practically and in terms of mentalities. Indeed, users are not familiar with the open-ended interaction across social networks that USNB enables. Social network services and platforms are mainly closed and centralized, configuring the various usages (specific features related to specific contents) as well as the emotive and practical organization of users' connections in spheres (friends, work, topics) [Stenger and Coutant 2013]. Even if USNB still makes possible the separated use of OSNSs, it disrupts their current silo-based coherence: Rafael will receive through Messenger the emails that Carmen sent. *"Receiving on Messenger the contents of a long email or getting by email a 'Hello' could be irritating over time",* considers one tester. Nevertheless, another one sees in USNB a great tool for younger people, comfortable with social applications, *"to communicate with old people, who mostly use email".* A participant further questions *"what would happen when sending an emoji or using specific features"* or *"does such a system make it possible to connect people from countries not allowed to communicate through usual services like Facebook or WhatsApp?".* Such reactions raise fundamental socio-economical problematics, as they question proprietary media formats vs. open and standard ones, but also the legal agreements each OSNS establishes with governments.

Furthermore, we asked the participants if they would use such a service, with regard to its properties and to security or privacy issues. 40% of the users consider the usage of USNB is more relevant to personal networks, 25% to professional networks, and 35% would use it for both. About 75% of the participants declared that USNB is useful (50% testers) or very useful (25% testers) and that its working principles are easy to understand (90% of the answers), specifically because it allows a user to communicate with users in different OSNSs without having to create and manage personal accounts and profiles in each OSNS. Almost half of the participants think that USNB could be useful to help them *"manage their digital identities thanks to a unique visibility on different social networks".* Even if some consider that *"a break-in period is required",* three-quarters of the testers declared that the OSNS interoperability that USNB offers was *"not disturbing with regards to their actual uses of social networks".* About 40% consider that such a service could be useful to better manage their participation in consultation campaigns, petitions or institutional and administrative processes. In less than 2 hours of discovering and testing this service, users expressed a wide range of possible benefits related to their own experiences and uses of digital networks: *"Having less passwords to remember", "making internship or job applications easier and faster", "being able (because we wouldn't need to give out our personal profiles on some networks) to preserve part of our personal life, when participating in scholar or professional work groups",* and several others. Half of the participants see pros and cons in using such a universal social network service *"with regard to communication security and privacy issues".* As for the others, 40% of the participants consider that USNB, being a *"third party service with few guarantees",* could raise new kinds of such

issues, while 10% see it as helpful and feel more confident. More than 70% of the testers think that such a service could increase the risks of spam and personal data mining.

Third, at a strategic and future development level, we sought to identify the most important reasons of users' motivation or reluctance to effectively use USNB for all or part of their social network interactions. As a result, 20% of the participants expect to use it for all their social communications, while 60% only for part of them. Moreover, 15% of the testers consider that it could be relevant for interacting in the context of collective actions or administrative formalities. This shows that users envision diverse potential uses of such an interoperable system. Finally, nearly 15% of the testers declare that they don't expect to use it at all, particularly because they "*use the same networks as their friends*" or for fear of "*losing parts of their contents or missing specific features*". Having sufficient safeguards for security and message content confidentiality is declared to be the most important condition for testers for using USNB regularly ("*very important*" for 75% of the 20 testers and "*necessary*" for 25% of them).

Overall, the results of the test session encourage us to develop USNB support for more OSNSs and to provide an interface for the configuration of user preferences. They further highlight the relevance of customizing personae for civic applications, which is also one of our principal directions (see Section 4.3). Although the participants mostly consider that USNB's features could make their social communications easier, most of them suggest providing explicit operating rules and trustful information about contacts and contents management: as already pointed out, most of the participants question the security and privacy issues related to such a third-party service.

6 CONCLUSIONS AND FUTURE WORK

Closed OSNSs do not allow their users to interact with users of other OSNSs. To overcome the resulting platform lock-in, existing solutions either focus on the interconnection and duplication of data between accounts of the same user in different OSNSs or promote the adoption of open platforms. All these solutions turn out to be limited. This paper introduced a service bus-inspired solution for building a federation of *heterogeneous*, closed & open, profile- & non-profile-based OSNSs, allowing the users of the diverse OSNSs in the federation to interact. Feedback from users who have experimented with the current prototype of the proposed USNB solution confirms the interest in the "social interoperability" that it enables. The experiment also suggests that social interoperability is deemed especially valuable for civic applications, which is part of our ongoing work.

Our contribution has the potential of influencing the OSNS landscape in the near future. Our work opens thrilling perspectives, such as privacy policy and semantics mapping between OSNSs, evaluation of end-to-end user perception of interactions across OSNSs, and trust management for OSNSs in the federation. From our point of view, it is crucial to take into account the trust of users in the heterogeneous OSNSs involved in their interactions. One solution at the application-level is to let users decide in which OSNS they will be visible (i.e., in which OSNS they trust). This implies that users will also have the possibility of choosing the OSNSs to which USNB can send their messages. Another solution is to warn users when the security and privacy level of the OSNS they use may be compromised by the OSNS at the other end of the interaction

(e.g., messages they are sending in a private interaction are published in some sort of wall, message board or group at the other end). As for USNB itself, we will apply existing mechanisms found in OSNSs to guarantee same levels of security & privacy for USNB users and to earn their trust. Regarding personae, we plan to support their automatic synthesis. We will also further improve user experience when interacting with USNB profiles in the case of closed OSNSs. Last but not least, closed OSNSs may eventually grant USNB full access to synthesized profiles, which will greatly facilitate the participation of those OSNS in the USNB federation of heterogeneous OSNSs. Our hypothesis is that, if USNB manages to federate OSNSs that are successful at attracting a sufficient number of users, other OSNSs will join that federation for fear of user migration towards a new hyper-OSNS connecting an ever-growing population of users.

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