Intra and Inter Domain Social Information Service (IIDSIS): Definition and Evaluation of a Supporting Architecture

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Abstract— **We present a platform for Intra and Inter Domain Social Information Service (IIDSIS), able to identify, analyse and exploit (complex) relationships emerging from the use of multiple pervasive Internet services, offered in different domains. The computed social information is offered as a service to the domain applications, both to improve their effectiveness and to increase end-users' awareness of their broader social context. In particular, we introduce an abstract framework for expressing high-level requirements for IIDSIS and propose a reference architecture for distributed implementations. We discuss a specific implementation, called PASION, that proved the platform effectiveness in extensive trial campaigns.**

Keywords: reference architecture, Web services, information mining, ocial network analysis, online social networks

I. INTRODUCTION

Internet services, such as e-mail, blogs, wikis, instant messaging and social networks can be considered as complex systems that pervade our everyday activities and significantly change the way we communicate and interact. While some effort has been done to evaluate the way users interact and social structures emerge within a single service domain (e.g. [1][2]), not much attention has been paid to the analysis of the combined effects and interplay of complementary Internet services across domains. Most scientific work and research on complex social networks have been focused to date on two main goals. Firstly, the characterization of statistical properties related to structure and behaviour of networked systems. Several parameters of interest have been studied and observed such as path lengths, degree distributions, clustering coefficients and the small world phenomenon [3]. These parameters have been considered and measured for a number of networks in many different scenarios and domains (e.g. [4], [5]). The second goal has been about the definition of network models to investigate and verify the above properties towards a better assessment and understanding of the meaning, origin and interplay of communications and relationships [6]. Defining network models is important as it leads to possible predictions of a complex network's behaviour and to the identification of specific (social) patterns on the basis of its measured structural properties [7]. While this surely applies to single networks and relevant properties, since structure and form can be observed within each pertaining domain, we consider it interesting and complementary to investigate inter-networks connections, relationships and patterns emerging across these domains [7][9]. Inspired by existing approaches in the social Web 2.0 (e.g. mashups [10] and social aggregators [11]) and by the progressive availability of public social APIs (e.g. [12], [13]), our investigation is concerned with further combining interoperability of pervasive applications and services with the possibility of computing and revealing emerging non obvious regularities typical of complex social systems. This extra information may then be used to give novel feedback cues to Internet services/applications and their users. In this paper we present an Intra and Inter Domain Social Information Service (IIDSIS) to identify, analyse and exploit (complex) relationships emerging from the use of multiple pervasive Internet services, possibly at the same time and on different media. The benefits of this include providing further insights on intra and inter domain individual and group behaviour, communication and information exchange; and offering new feedback, both to improve applications and increase awareness of users' social context.

II. KEY ARCHITECTURAL REQUIREMENTS

An IIDSIS is built in the context of multiple Internet social services, which increasingly offer Web and mobile access via multiple media. This raises interesting issues in an inherently multidimensional space. For instance: what's an individual's role in a group/organisation in terms of communication and interaction on a specific service domain? Do service domains and contexts have an impact on the way people communicate? Are there emerging group/network structures that can be observed and measured via ad-hoc social metrics? Are there any correlations between different individual and group communication behaviours and attitudes? What type of combination/aggregation of these metrics can be more significant to offer new social "inter domain" value added services? In order to tackle the aforementioned issues and answer (some of) the above raised questions and following an approach adopted in a different research [14], the following key architectural requirements for an IIDSIS are identified.

R1: Inter domain social identity management and reconciliation. We need to track groups of users and their authorization settings on every supported application and service domain. In general, users have many profiles, identities, roles and sets of contacts on different service domains. A key requirement to enable an IIDSIS is to support a single management of people's and groups' multiple identities to

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track their activities across domain and properly correlate information on both individuals and groups coming from heterogeneous service environments. The need to maintain a user's single global identity and to reconcile it with multiple "views" on different service domains is an important precondition for the specific objectives of an IIDSIS (e.g. [12]).

R2: Social communication and interaction management. An IIDSIS is required to properly handle social interactions generated by groups of users on every supported service domain (e.g. a Web-based social network, a telecommunication provider's mobile game) by possibly using multiple communication media (e.g. chat, phone call, email, SMS text). Ideally, interaction instances should be analysed and described according to common formats and semantics. Interactions occurring within or between different domains must be properly linked to individuals and groups and possibly filtered according to specific policies (e.g. time constraints) and/or manipulated on the basis of predefined conditions (e.g. incompleteness of information, transmission errors or repetition).

R3: Social patterns detection, description and provision. An IIDSIS must be able to capture "social patterns" reflecting social interactions between users. For instance, Social Network Analysis (SNA) defines specific indices expressing a single user's properties (e.g. prestige and influence) as well as group-level characteristics (e.g. hierarchy, cohesion, collaboration). Further structural properties (e.g. in/out degree distribution, clustering degree, reciprocity) of social networks [3][4] can also be studied to infer useful information communities. As long as a specific model is established, social patterns can be "detected" through computation of the relevant measures. Descriptors of social patterns can be computed depending on many free parameters: length of the observation time, inclusion of one or more service domains (i.e. intra-domain or inter-domain descriptors), focus on either single users, their first friends or a wider community. Descriptors and parameters should also be compliant with a semantic model, shared and accessible to potentially interested parties. An IIDSIS must be able to aggregate multiple "intra domain social patterns" into "inter domain social patterns" to further reveal hidden, non-obvious behaviours/relationships and emerging regularities reflecting the combined effects of using multiple "complementary" applications and services. This crucial requirement recognises the need and potential for an IIDSIS to help investigate how individual and group microscopic interactions on single domains can have impacts on macroscopic social systems.

R4: Social information service provision in a distributed networked environment. Applications are considered as IIDSIS's clients, being capable of receiving properly represented meaningful descriptors of social patterns (prepared as per R3). Service parameters should be allowed for client setup so that representation of social patterns is flexible and tailored on human vs. non-human users under consideration. Scale of observation should also be tuned, including at least: time scale, regarding the memory of past instances and their impact on present; social scale, regarding the "social distance" of people to be considered for measures.

R5: Trust, security and privacy management. Due to its role as a third party intermediate value added social service provider, an IIDSIS must be concerned with security and privacy related matters. In order to be perceived as a trusted counterpart by existing Internet services and applications and their users, end-to-end security must be guaranteed all across supported processes. Depending on specific implementations, an IIDSIS supporting system must protect event communications and service requests from harmful attacks by adhering to well-established security protocols. By the same token, single services and applications' users who want to exploit an IIDSIS should be assured that their privacy is completely preserved by advanced mechanisms and technologies (see [15] for a survey).

III. GENERAL FRAMEWORK

Let us introduce a few concepts that allow for the deployment of the high level requirements into functional specifications. We define *communication media* as the set S of communication capabilities enabled by a specific Internet service domain, such as chat, email, SMS, instant messaging, audio/video conference, Facebook posts, etc. The end-user we consider in an IIDSIS scenario is a member of at least a persistent group (represented by the set V in the following), whose members communicate using the available communication media. Any instance of *mediated-communication* involves identified users from V and a medium from S, having a beginning and an evolution in time. The R2 requirement can be rephrased as the need to collect and store the most updated set of mediated-communication events. So far, an operational definition of *domain D* can be given as the couple $D \equiv (V,S)$, i.e. an user group and the available media set. As a remark let us note that the content of the communication exchanged between the users is disregarded by the IIDSIS architecture. After requirement R3, we need to detect social patterns according to an algorithm. This service needs to be computationally affordable and should give back descriptors meaningful to the several classes of service users. Relations between users can be modelled using a social graph resulting from social interactions in the period $[t-T,t]$, with T the observation time, that we call $G_T(t)$. These interactions occur and develop over time, according to the characteristics of the domain. Capturing temporal properties of the evolving social graph through suitable descriptors will fulfil the R3 requirements.We define an IIDSIS service for a user group in a domain D as the computation and provisioning of social information $I(t,T)$, computed as a function of the social graph

$$I(t,T):\ \left\{ G_T(t) \right\} \rightarrow \Sigma \qquad (1)$$

Where Σ is a convenient set of values, meaningful to the user group and usually consisting of real numbers. We are now in the condition to define the intra-domain social activity of the user v. Let v belong to the user sets of both domain A and domain B. The intra-domain activity of the user v in A, at time t over a certain observation time T, is the set of events occurred in the period $[t-T,t]$ between v and other users of A through the media available in the domain A. The inter-domain social activity of the user $v$at the same time is the set of events that includes the previous set and events occurred between v and users of the domain *B* through the media available in the domain *B*. According to requirements R2 and R3 an IIDSIS system should be able to consider both type of social activities for each user, and to allow for the appropriate social information, as in the focus of the present paper. As a simple rule, (1) can be used for computing both intra and inter-domain information services after the appropriate social graph has been built, i.e. including only intra-domain social activities of the users, or adding inter-domain activities between two or more domains.Let us consider two traditional SNA indices: the user centrality [16] a local indicator of social activity defined in literature as in (2), with A_{ij} the generic element of the adjacency matrix of the social graph *G* and *N* the number of users:

$$C_i(G) = \frac{1}{N-1}\sum_{j=1}^{N} A_{ij} \tag{2}$$

and the group centrality [16]defined in literature as in (3),averaged on all the users, being a global indicator of social activity:

$$C^*(G) = \frac{1}{(N-1)(N-2)}\sum_{j=1}^{N} \left| C_{\max} - C_j \right| \tag{3}$$

$$with \qquad C_{\max} = \max(\{C_1,\ldots,C_N\})$$

It is straightforward to note that (2) and (3) are instances of (1) with $T=t$ as long as a specific domain is declared. For most purposes, most possible specification of the social information *I* can be computed as a function applied to the appropriate social graph.

IV. A REFERENCE ARCHITECTURE FOR IIDSIS

Following an approach proposed by [14] and in order to meet the key requirements introduced in section II and rephrased in terms as in section III, we have conceived a reference architecture for IIDSIS. The general framework is shown in Fig.1: we consider an IIDSIS as composed of a main logical block called Social Information Support (SIS) exposing its functionalities to domain applications via standard APIs.

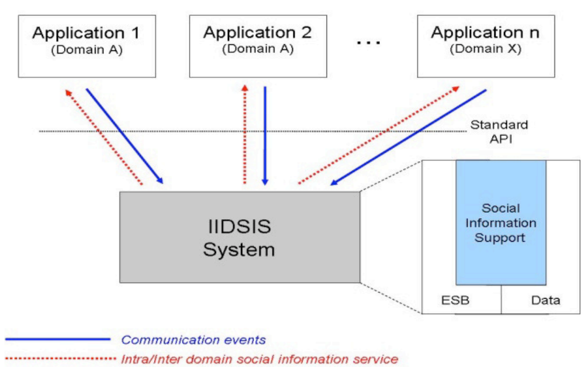

Figure 1. General framework for IIDSIS: applications for domain users are IIDSIS's clients.

This core block is concerned with the identification and exploitation of complex intra-domain and inter-domain relationships, communications and collaborations in line with the theoretical approach of the previous section. It relies on lower level services provided by an Enterprise Service Bus (ESB) and a Data management operational block to support system distribution and persistence management respectively. From here, SIS is further exploded to identify layers and functional modules pertaining to its peculiar structure.

A. Layers

Fig. 2 shows a layered architectural design for the SIS. The first is the *Task* Layer where all the building blocks of social collaboration are located. The second is the *Workflow* Layer, which is responsible for the execution and monitoring of business processes. The separation of the Workflow Layer from the Task Layer liberates workflow scheduling from task execution and promotes flexibility in model representation, thus improving the performance and scalability. The third layer is the *Presentation* Layer, which contains tools to turn the social information measures into support to social collaboration.

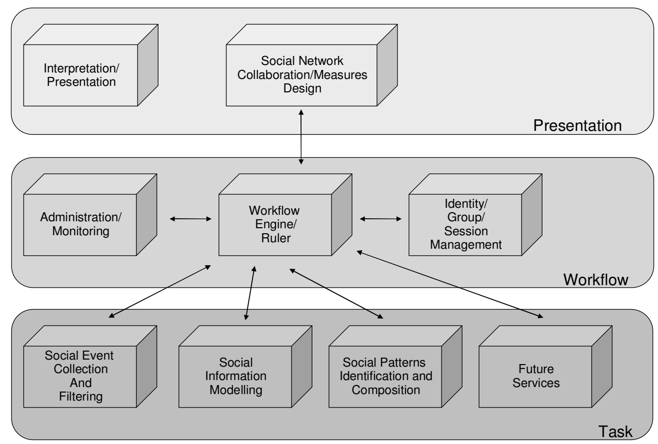

Figure 2. Reference architecture for the Social Information Support.

B. Modules

The *Social Network Collaboration/Measures Design* module is responsible for the definition and the selection of metrics, measures and algorithms to be applied on social groups' and networks' interaction and communication. Customisations of aggregation operations on domain dependent measures towards inter domain ones are to be performed in this module to specifically address R4. The *Interpretation/Presentation* module deals with a proper representation of social network measures to ultimately build feedback information that can be handed back to applications' users. To achieve this objective and address requirement R4, final feedback information must always be interpreted and represented in meaningful and suitable formats, for instance intuitive visual cues. The *Workflow Engine/Ruler* and the *Administration/Monitoring* modules provide the system's execution and control rules. In particular, a general orchestration process is at the heart of the proposed SIS. Such process is executed in alternative configurable working modes and is concerned with the coordination of underlying modules operating at task level. Specific administration and monitoring activities are performed to customise, configure and control the orchestration process execution both before and at runtime and provide tools for failure handling if required. The *Identity/Group/Session Management* module properly keeps track of groups of users and their possible authorisation set on applications' domains and other services of interest.

Essentially, it is meant to address requirement R1, R5 and partially R2. General individual and group identities are generated and maintained to correlate information, communication and behaviours across heterogeneous environments and domains. Sessions of users are created between applications and the SIS at runtime. Specific session identifiers are maintained to associate groups of user with general identities, generated communication events (on multiple domains) and corresponding identified intra domain and inter domain social patterns measures. According to R2 requirement, the *Social Event Collection and Filtering* module deals with social communication events generated by users groups in their domains when using communication media. These events must be always time framed and properly linked to the previously described sessions. This module supports alternative working modes (e.g. polling vs. publish/subscribe) to retrieve communication events from their sources. It is crucial for the system to maintain a clear and precise conceptual association between sessions, time intervals, communication events and computations executed towards identification of exhibited social patterns by groups of users. For every active group of users (and their associated sessions), the *Social Information Modelling* module is concerned with the definition and fine-tuning of adequate representations of their (dynamic) social activity as observed through communication and interaction events. Meaningful data models of social communications offer a basis to perform "increasingly sophisticated" computations revealing significant properties of social structures, as per requirement R3. Any IIDSIS service computed according to our definition of the social information *I* (see (1)) can be provided by the *Social Patterns Identification and Composition* module by applying specific algorithms (e.g. (2) and (3) for SNA indices, or other graphs' structural properties) either directly on these models or after possible requested transformation. Frequency of data gathering impacts at "social event" level, therefore having relevance in the *Social Event Collection and Filtering* module. Time elapse for intra domain and inter domain social patterns identification and composition impacts at "social collaboration property" level on the *Social Patterns Identification and Composition* module's computations. Times of final feedback information provision are relevant at "social collaboration service" level as they ultimately affect external application and services using IIDSIS. We need the *Workflow Engine/Ruler*'s general orchestration function to be able to successfully cope with all these time constraints and therefore need to track time settings for every application service session on every supported domain accordingly. Towards this end, the association of identity and internal sessions (each having its own specific time related parameters) maintained for each group of users by the *Identity/Group/Session Management* module plays quite an important role.

V. THE PASION SYSTEM IMPLEMENTATION

The main goal of this section is to describe how the proposed architecture has been successfully implemented. The implementation in discussion is named PASION (after the international PASION consortium): its components and the relevant interfaces are shown in Fig. 3 [17].While all three layers have been successfully implemented, some components were aggregated or not required, and therefore unused, by the implementation. The presentation layer has been simplified compared with what has been specified in the reference architecture. The task layer has been specialised on the time-evolving social graphs paradigm. For the sake of clarity, an additional data layer that assures data exchange and persistency has been made explicit.

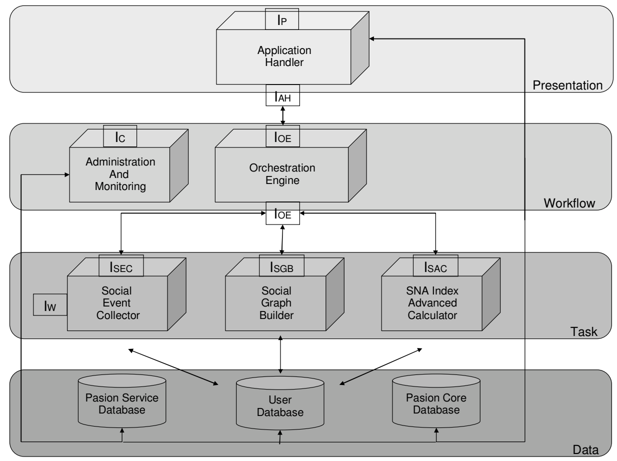

Figure 3. Components of the Pasion implementation of IIDSIS

The SNA Index Advanced Calculator computes algorithms derived from (1) on social graphs dynamically built by the Social Graph Builder. In case an inter-domain social information measure is requested the Social Graph Builder is able to make a fusion out of the two domain-specific graphs thus generating a unified inter-domain graph to be processed. In the field trial campaign that we describe further on in the section, components and corresponding interfaces have been installed in specific configurations in the context of nearly a thousand users and more than ten different contemporaneous domains. Basically, the applications have been of two types, social games and collaborative work applications, and have been able to build on the added-value provided by the IIDSIS without an in-depth knowledge of the inner workings of the system. More in detail, *Orchestration Engine* and *Administration and Monitoring* were unique; the *Orchestration Engine* instantiated a *Social Event Collector*, a *Social Graph Builder* and *SNA Index Advanced Calculator* per domain. Furthermore, it were deployed a sub-component of the *Social Graph Builder* per application that required inter-domain social information. In practice a task layer deployed per supported domain and application-specific instances of subcomponents for inter-domain social activity. By allowing a completely distributed computation of intra and inter-domain specific information measures via dedicated components, our first implementation has shown acceptable resilience and performance while dealing with an increasing number of users generating events across domains. The web service implementation has provided a transparent service to client applications that conceals its complexities behind clear and simple interfaces. Since our solution has been conceived to be deployed in a distributed network environment, we have to be concerned with alternative communication and interaction approaches across any number of hosts and domains on a network. In other words, in order to further support and achieve a higher degree of module independence, system robustness, scalability and general component distribution over the Web, we have designed and advocate also an additional REST-based [18] PASION implementation. By implementing more up-to-date Web interaction paradigms, protocols and data formats over time, we envision to gain performance benefits of the devised system, especially when a higher number of supported domains comes into play.

A. *Field trials*

In the context of PASION, the implementation of IIDSIS serves a wide spectrum of social applications with its social information services. Field trials of IIDSIS and applications engaged several user groups with the need to collaborate in order to fulfil their own tasks. Here we focus on a small subset of the trials, as summarized in Table I. The application in discussion is a social game called Pasion Fruit, provided with a number of internal communication media. Out of the trials held from 18 January to 25 March 2010 three domains are here discussed (the code being a session identifier): *General*1-G, *Frullati di mente*19-G, *noozono*7-G.Table I reports per domain the observation time (equal to 1 day), the number of active users, the number of the mediated communication events and their rates. The goal for players was to build up virtual gardens with collections of diverse fruit trees. Each player was assigned a certain type of "home fruit" based on their location. In order to collect more fruit for their garden, players needed to receive them from other players. There were no formal trading mechanisms included in the game, the central social interaction was instead through gifting. Initially, a handful of participants were recruited in Italy and the UK and asked to play the game. Since registration was publicly open on Facebook, the player-base was permitted to grow as a natural viral, or snowballing, effect as would be experienced by a typical social game. The purpose of the trial was to investigate personal patterns of social behaviour based on social feedback received in the game. The application used the PASION – IIDSIS to provide social network indices as feedback to players about their performance in the game.

TABLE I. TRIALS OF INTER-DOMAIN SOCIAL INFORMATION SERVICES.

Session ID	Observation time	No. of users	Total User Interactions	Eventdaily rate per user (average)	Eventdaily rate per user (peak)	Group centrality final value	Group reciprocity final value	Group density final value
1-G (General)	1	143	3817	0,398	1,321	0,1163	0,4391	0,0217
19-G (Frullati di mente)	1	19	595	0,467	1,789	0,1471	0,7500	0,0234
7-G (noozono)	1	17	206	0,180	1.412	0,0542	0,5000	0,0147

These trials allowed for the testing of the IIDSIS end-to-end functionalities in a scenario with real users who operate in real life conditions and produce a large number of interactions. The IIDSIS allowed for a fast and efficient method of generating large amounts of feedback for all the domains transparently within the interface of the game. All the described technical requirements have been successfully implemented and tested. About the genesis of the domains, *Frullati di mente* and *no ozono* were generated separately by different founders. Afterwards other users were aggregated and some of them began to interact between groups to exchange fruits. Most of the following new users aggregated to the super-group, called *General*, but not to *Frullati di mente* and *noozono*. In synthesis: the communication media are the same for the three domains; the users of *Frullati di mente* belong also to *General,* as much as the users of *noozono do*; there are few users that belong to both *Frullati di mente* and *noozono*, and many users of *General* that do not belong to neither *Frullati di mente* or *noozono*. Thus we have some noticeable consequences: all intra-domain social activity in *Frullati di mente* is also a (part of the) social activity of *General*; all inter-domain social activity between *Frullati di mente* and *General* is also a (part of the) social activity of *General*; all inter-domain social activity between *Frullati di mente* and *noozono* is also a (part of the) social activity of *General*. The experimental approach was the observation of the patterns of social activity that originate and evolve within and between the application domains, as measured by a number of intra and inter-domain information measures. Table I reports three measures, group centrality, reciprocity and density for the three domains, valued at the end of the trials. These values allow for a comparison between single and multiple domain views, and summarize information about the social structure and activity.

B. *Discussion*

For evaluation of the system let us focus on measures of group centrality [16], (see (3)), because centrality is a good indicator of presence of a social hierarchy in the group and the nonlinear character of its definition is strong. We expect domain calculations C*(*General*), C*(*Frullati di mente*) and C*(*noozono*) to have different dynamics over time because, given a certain probability that after a certain time a hierarchy has been developed within a group, it is far less likely to have a hierarchy in *General*, that is much larger super-group. Fig. 4 matches the expectations and clearly shows uncorrelated dynamics: centrality of *Frullati di mente* and *noozono* show a clear tendency to converge to constant values, to be interpreted as a tendency to hierarchization; the group in *General*, instead, shows an oscillating behavior. An analysis of (3) shows that it is not possible to analytically express the centrality of *General* as a mere function of the instantaneous values of group centrality of *Frullati di mente* and *noozono*, given the intrinsic nonlinear character of the chosen social information measure. If it had been possible, C*(*General*) would have stabilized as much as C*(*Frullati di mente*) and C*(*noozono*). In practice the nonlinear character forces a time-dependency of C*(*General*) from past values, keeping the oscillations alive. Fig 4 straightforwardly demonstrates the importance of multi-domain social information, revealing the qualitatively different information contained in the social activity developed by overlapping groups of users operating in different domains. As to the scalability of the system versus the number of domains, in case we had an incremental new domain becoming active after *n-1*, we might instantiate a new Task Layer and *n-1* new inter-domain components. So far the number of components might scale up as the number of domains plus a quantity due to inter-domain that starts far smaller than one but increases fast and can potentially become intractable. On the contrary in the trials we followed a smarter approach that exploits the nested nature of the domains. The Social Graph Builder worked on the widest possible inter-domain social graphs and derived the intra-domain graphs on request by pruning. As a result the effort ratio, computed starting from *General* to include all the three domains scales fairly less than linearly, and nearly linearly starting from a nested domain and ending up to all.

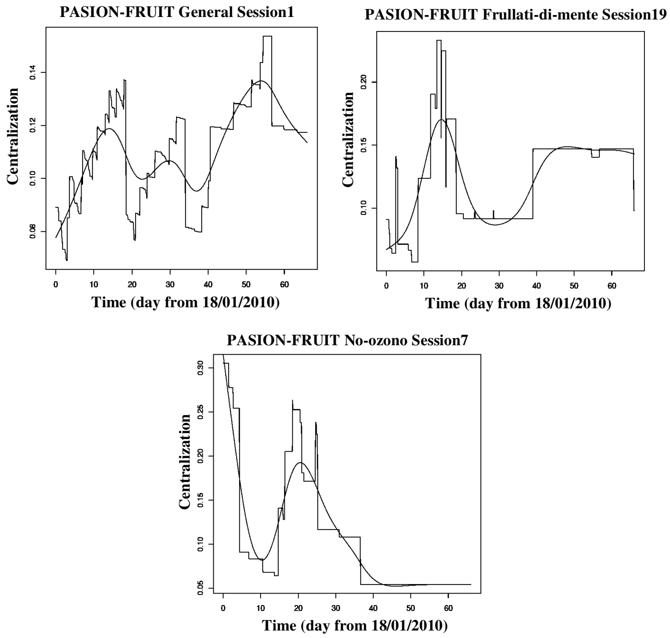

Figure 4. The time evolution of the group centrality index (also called centralization) for two domains in the days of trials.

Although this does not hold in all possible scenarios it is applicable when social structures develop in terms of nested processes and those processes can be often recognised analysing appropriate temporal social information measures. This situation is very likely to happen, for example when we have users of a portal and a subset of them joining a community of practice open in the portal, or when two groups in Facebook are nested one in the other. In other trials we have been able to verify a good promise and viability of the reported architectural and implementation approach as far as the evolving social structure is considered in order to dimension and dynamically adapt the computational deployment.

VI. CONCLUSIONS

Understanding on-line social networks and services and analysing their structures and dynamics have been a focus of intense research both in Social Science and Computer Science (e.g. [19][20]). However most studies and investigations in the field have been carried out on single service domains, in this paper we have recognised the need for social information measures when users act in different domains, and presented a platform for Intra and Inter Domain Social Information Service, able to identify, analyse and exploit complex social relationships emerging from the use of multiple pervasive Internet services, offered in different domains. We have identified an abstract framework for expressing high-level requirements for an IIDSIS and proposed a reference architecture. A specific implementation, called PASION, has helped to demonstrate the capability of the IIDSIS platform to provide further insights on intra and inter-domain individual and group behaviour, as well as to offer social information as a service to domain applications and their end-users. The importance of these results is twofold. Applications are stimulated to share their social interaction data because they will receive a feedback on inter-domain social activity of their users, and provide new services. Both intra and inter-domain social activity of users can be used as a basis to design, dimension and dynamically adapt applications and networks, as demonstrated by the deployment of the IIDSIS itself. Further, a completely new family of services based on inter-domain social activity can be envisioned, independent of original domains and likely to interest network providers. Future developments will focus on system adaptation to emerging social structures in the involved domains.

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