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Improving efficiency of service discovery using Linked data-based service publication

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Abstract It is considered that Web services have had a tremendous impact on the web as a potential silver bullet for supporting a distributed service-based economy on a global scale. However, despite the outstanding progress, their uptake on a web scale has been significantly less than initially anticipated due to higher usage thresholds. For instance, it is a hard task for service provider to seek appropriate semantic information such as OWL ontologies for service annotation in the service publication stage due to the fact that nowadays we are suffering from serious lack of available and ubiquitous ontologies for global consensus. Also it is not realistic for query users who do not possess much semantic knowledge to specify their requests with associated semantic information in the service discovery stage. In this paper, we propose a methodology to build a global social service network based on Link data principles for reducing the using thresholds. First, we propose Linked social service which is published on the open web by following Linked data principles with social link, and then we suggest a new platform for constructing a global social service network based on Linked social service. Then, an approach is proposed to enable exploitation of global social service network, providing Linked Social Service as a Service. Finally, experimental results show that the Linked social service can reduce the using threshold by enabling exploring service to service based on the global social service network.

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1 Introduction

Web services have been considered to have a tremendous impact on the web, as a potential solution for supporting a distributed service-based economy on a global scale. However, despite outstanding progress, uptake on a Web scale has been significantly less than initially anticipated. On the one hand, the number of services available on the web is far less than the expectation. Today, Seekda.com provides a site that has one of the largest indexes of publicly available Web services, currently accounting for 28,500 Web services with their corresponding documentation. The number of publicly available services contrasts significantly with the billions of Web pages available. Interestingly it is not significantly greater than the 4,000 services estimated to be deployed internally within Verizon. Other academic enquiries into crawling and indexing Web services on the Web have found far smaller numbers of services (Masri & Mahmoud 2008). On the other hand, the handicap of service discovery and automatic service composition results in a lack of applications for using the services in the computer industry. Most services published on the web are never used; only few of services on the web have ever been discovered, composed or invoked (Jiang et al. 2012; Zhang et al. 2011). The merger condition with the handicap in the service environment results in a vicious circle of creation, publication, location, and composition of services in the computer industry. From investigation in several technological perspectives of Web services, the reasons can be mainly described by the following:

First, a lack of available and ubiquitous ontologies for service annotation results in higher using threshold for service provider in service publication stage. To better support service discovery, composition and execution, Semantic web services has been proposed as a key to maximize a higher level of automation by enriching services with semantic annotation and has already shown their benefits (Pilioura & Tsalgatidou 2009). However, up until now, the impact of Semantic web services on the open web has been minimal due to lack of available and ubiquitous ontologies for service annotation in service publication stage. In current ontology engineering field, there is still a large deficiency of uniform and ubiquitous ontologies in many application domains. This is due to the fact that creating ontology usually requires many engineers to cooperate with each other.

Second, a lack of interactions and guidance in service discovery stage results in higher using threshold for service consumer. Nowadays, services published in UDDI or on the web based on current service description approaches such as WSDL (Erl 2007), WebAPI (Richardson & Ruby 2007), OWL-S (Burstein et al. 2004) or WSMO (Fensel et al. 2007), only consider services as functional isolated islands without any links to related services. Therefore, services know only about themselves and not about their peers (that they would like to do business with). In the case of composition they have to compete against their case of service selection (Bellwood et al. 2004). As a consequence, most approaches to service discovery lack the consideration of interactions with the service consumers. The consumers cannot simply discover services by following the links they are interested in, as they do when exploring web pages or finding Facebook friends. Although in most cases, service consumers are not limited to using a single service, but want to locate multiple services that can work together; *TripService*, *HotelService* or *TransportationService*. However, guiding service consumers to discover services dealing in service at hand-to-peer services (which can be combined into more complex functions) such as from *TripService* to *HotelService* and from the *HotelService* to *TransportationService*, is still a challenging issue since current services are isolated.

In order to address the aforementioned issues, we propose a methodology to build a global social service network based on Link data principles. In global social service network, services described in light-weight ontologies are interlinked to related services from different sources across the web and in turn can be linked to from external services functionally using *social link*. To connect isolated service islands for better interaction with service consumer, *Linked social service* proposes to connect service islands into a global social service network with *social link* by following *Linked data principles*, so that the service consumer can explore service to service by following *social link*. To support the semantic service annotation, *Linked social service* is built on a web of data which is an outstanding body of knowledge (light weight ontologies and data expressed in their terms) that can help to significantly reduce the effort for creating semantic annotations for services.

The remainder of this paper is structured as follows: in Section 2 we comment on backgrounds and argues that *Linked data* can give birth of new wave of web service. In Section 3 we propose *Linked social service* to connected distributed services with *social link* using our novel service model. In Section 4, we propose a novel framework to construct global service social network based on *Linked social service*. Then in Section 5 an approach is proposed to enable exploitation of global social service network, providing Linked Social Service as a Service. And then the evaluations for global social service network and service discovery are done in Section 6. And Section 7 gives the intensive analysis on related work. The final section gives the conclusion and future work.

2 Background

In this section, first we give some backgrounds about *Linked data*, and then we argue that *Linked data principles* provides the missing ingredients that will evolve isolated services into global social service network.

2.1 Linked data: Best practices for publishing and interlinking structured data on the web

Linked data technologies, which derive from research on the Semantic Web, refer to data published on the Web in such a way that it is machine-readable, its meaning is explicitly defined, it is linked to other external data sets, and it can in turn be linked to external data sets. While the primary units of the hypertext Web are HTML documents connected by un-typed hyperlinks, *Linked data* relies on documents containing data in RDF format. However, rather than simply connecting these documents, *Linked data* uses RDF to make typed statements that link arbitrary things in the world. The result, which we will refer to as the Web of Data (Heath et al. 2009), may be more accurately be described as a web of things in the world, described by data on the Web (Heath and Bizer 2011). *Linked data* is identified by the application of a set of principles (Bizer et al. 2008) known as the '*Linked data principles*' that provide a basic recipe for publishing and connecting data using the infrastructure of the Web while adhering to its architecture and standards.

1. Use URIs as names for things.
2. Use HTTP URIs so that people can look up those names.
3. When someone looks up a URI, provide useful information using the standards (RDF, SPARQL).
4. Include links to other URIs, so that they can discover more things.

The adoption the best practices of *Linked data* has led to the extension of the Web with a global data space connecting data described by light-weight ontologies from diverse domains using RDF links as shown in Fig. 1. This Web of Data enables new types of applications. There are generic *Linked data* browsers which allow users to start browsing in one data source and then navigate along links into related data sources. There are *Linked data* search engines that crawl the Web of Data by following links between data sources and provide expressive query capabilities over aggregated data, similar to how a local database is queried today. Unlike Web 2.0 Mashups which work against a fixed set of data sources (Hsu 2011), *Linked data* applications operate on top of an unbound, global data space. This enables them to deliver more complete answers as new data sources appear on the Web.

2.2 The need for new wave of services

Web services are nowadays mostly used within controlled environments such as large enterprises rather than on the Web. One could argue that a reason is the fact that the lack of success of UDDI which have several drawbacks, for instance, syntactic discovery returns results with low precision, Web services are treated as independent elements in UDDI, and present registries do not record the services' peer services. Research on SWS has managed to alleviate some of the technical drawbacks of existing Web services technologies by enriching them with semantic annotation (Bell et al. 2007). However, building ontologies is a huge and complicated task requiring most knowledge experts to cooperate with each other resulting in the shortage of consensus and ubiquitous ontologies.

We believe that the advent of the Web of Data together with social principles constitute the final necessary ingredients that will ultimately lead to a widespread adoption of services on the Web. Firstly, the evolution of the Web of Data is highlighting the fact that light weight semantics yield significant benefits that justify the investment in annotating data and deploying the necessary machinery. This initiative is contributing to generating an outstanding body of knowledge (light weight ontologies and data expressed in their terms) that can help to significantly reduce the effort for creating semantic annotations for services. Secondly, the recent evolution around *Linked data* has shown that linking data over the Web can lead to large quantities of very useful data with a low cost. Rather than isolated data islands, connecting distributed structured data into a single data space can lead to reused data, discover data from relevant data and integrate data from large numbers of formerly unknown data sources. This new scenario provides suitable technologies and data, as well as the necessary economic and social interest for the wide application of services technologies on a Web scale. Rather than isolated service islands, connecting distributed services into a single global service space can lead to more effective service discovery and composition.

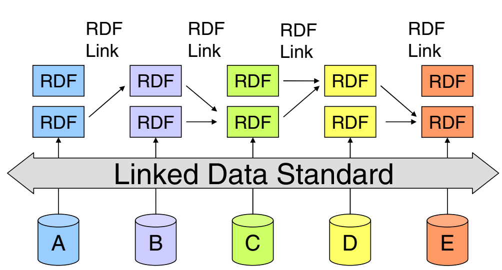


Fig. 1 Linked Data: evolving the web into a global data space

3 Linked social service: Evolving from Linked data

To connect the distributed service islands into the global service space, we first define the *social link*, which links distributed services together. Then we propose *Linked social service* which is built upon web of data using light-weight ontologies, and are linking and being linked to related services by following *Linked data principles*. Finally, we give a novel service model for linked social service annotation.

3.1 Social link: Linking distributed services

To overcome the limitation of service discovery and composition based on isolated service islands, it is extremely important to connect services into the global service space. However, rather than simply connecting services, we use *social link* to make typed statements that link arbitrary services on the open web. In this paper, we define terms of *social link* that represents the functional relationships between the resource service and target services according to service data correlations, which are data mapping between the input/output (I/O) attributes of services. The following are the concepts used by *social link*:

- T_n is a set of target services on the open web, where n is the number of services
- R is a resource service that refers to a known service
- S_n is a set of services that refer to Tn or R.
- e, e′ are data elements. Each element is an addressable subcomponent of data entity.
- D, D′ are data entities that refer to Input (I)/Output (O) of service with arbitrary data type. Each data entity is a set of data elements, such as $D=\{e_1,e_2,\ldots\}$.
- f is a transformation that maps D_n to D'_n.
- $S_n \rightarrow D_n$ is an output relation, which means that S_n produces D_n.

- $D_n \rightarrow D'_n$ is a data correlation, which means that D'_n is a direct subset of D_n.
- $D'_n \rightarrow S_n$ is an input relation, which means that S_n consumes D_n.

Based on these concepts, we give the definition of *social link* as follows.

Definition 1 (Social link) *Social link $L(R,T_n)$ is a quintuple (R_O,R_L,R_I), where*

- $R_O = \{(S_n, D_n) | S_n \rightarrow D_n\}$.
- $R_L = \{(D_n, D'_n) | D_n \rightarrow D'_n\}$.
- $R_I = \{(D'_n, S_n) | D'_n \rightarrow S_n\}$.

To make typed statements that link peer services that can be worked with together, such as for service composition, *Peer social link* is proposed to connect services that can be combined to provide a more complex service. *Peer social link* can be illustrated by the following rules, including sequential, parallel and conditional routing.

1) *Sequential Incoming-SocialLink L(←):* Sequential Incoming-SocialLink L(←) is an R×T relation shown in Fig. 2(a), which can be denoted as follows:

$$\mathrm{L}(\mathrm{R} \leftarrow \mathrm{T}) \text{ if and only if (iff)} \quad \forall e' \in R.D' \; \exists e \in \mathrm{T.D} : f(e) = e'$$

2) *Parallel Incoming-SocialLink L(<⊕):* Parallel Incoming-SocialLink L(<⊕) is an $R \times T_n$ relation (1<n<N) shown in Fig. 2(b). $T_n.D_n$ are merged together for R.D′, which can be denoted as follows (1<k<l<N):

$$\mathrm{L}(\mathrm{R} < \oplus \mathrm{T_n})\text{iff} \quad \forall e' \in \mathrm{R.D'} \quad \exists f(e) \in \bigcup_{1}^{N} \mathrm{Tn.Dn} : f(e) = e' \wedge \mathrm{T}k.\mathrm{D}k \cap \mathrm{T}l.\mathrm{D}l = \phi$$

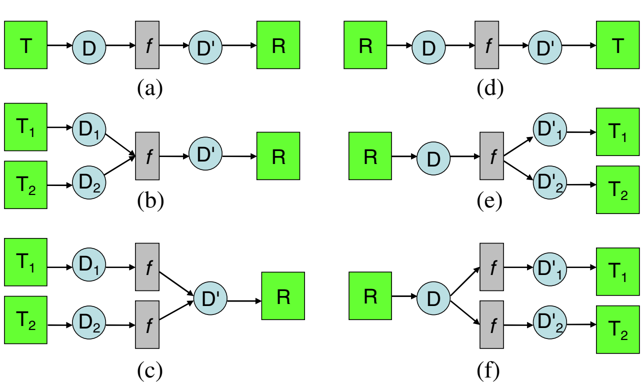


Fig. 2 Peer social link model

3) *Choice Incoming-SocialLink L(<‖):* Choice Incoming-SocialLink L(<‖) is an $R \times T_n$ relation (1<n<N) shown in Fig. 2(c) that holds if:

$$\mathrm{L}(\mathrm{R} < \| \mathrm{T_n}) \text{ iff} \quad \forall e' \in \mathrm{R.D'}. \exists e \in \mathrm{Tn.Dn} : f(e) = e'$$

4) *Sequential Outgoing-SocialLink L(→):* Sequential Outgoing-SocialLink L(→) is an R×T relation shown in Fig. 2(d) that holds if:

$$\mathrm{L}(\mathrm{R} \rightarrow \mathrm{T}) \text{ iff} \quad \forall e' \in \mathrm{T.D'} \; \exists e \in \mathrm{R.D} : f(e) = e'$$

5) *Parallel Outgoing-SocialLink L(⊕>):* Parallel Outgoing-SocialLink L(⊕>) is an $R \times T_n$ relation (1<n<N) shown in Fig. 2(e), which can be denoted as follows:

$$\mathrm{L}(\mathrm{R} \oplus > \mathrm{T_n})\text{iff} \quad \forall e \in \mathrm{R.D} \quad \exists e' \in \bigcup_{1}^{N} T n.\mathrm{D'n} : f(e') = e \wedge \mathrm{T}k.\mathrm{D'}k \cap \mathrm{T}l.\mathrm{D'}l = \phi$$

6) *Choice Outgoing-SocialLink L(‖>):* Choice Outgoing-SocialLink L(‖>) is an $R \times T_n$ relation (1<n<N) shown in Fig. 2(f) that holds if:

$$\mathrm{L}(\mathrm{R} \| > \mathrm{T_n}) \text{ iff} \quad \forall e' \in \mathrm{Tn.D'n} : \exists e \in R.D : f(e) = e'$$

Further, to make typed statements that link services that perform a specific common function, *Cluster social link* is proposed to connect services offering similar functionalities. *Cluster social link L(=):* is an R×T relation that holds if:

$$\mathrm{L}(\mathrm{R} = \mathrm{T})\text{iff} \quad \forall \mathrm{R.D} \; \exists \mathrm{T.D} : \mathrm{R.D} = \mathrm{T.D} \wedge \forall \mathrm{R.D'} \; \exists \mathrm{T.D'} : \mathrm{R.D'} = \mathrm{T.D'}$$

3.2 Linked social service: Connecting service islands into the global service space

To evolve from the “Homepage-Era Service” to the “Social-Era Service” that is described in a light-weight ontologies using RDF, and to link to related services and be linked from related services functionally on the web into the global service space, we propose a new wave of service called *Linked social service*, denoted by nodes on the top layer in Fig. 3.

Linked social services are built upon the Web of Data, and link to related services and are linked to related services using *social link*s into the global service space by following *Linked data principles*. In Fig. 3, the top layer is the global service space, in which services are linked together by *social link*s and are built upon the Web of Data shown on the bottom layer. In a nutshell, the *Linked social service* is a set of functionalities published as *Linked data* on the web following *Linked data principles* with *social link*, so that it is functionally interlinked

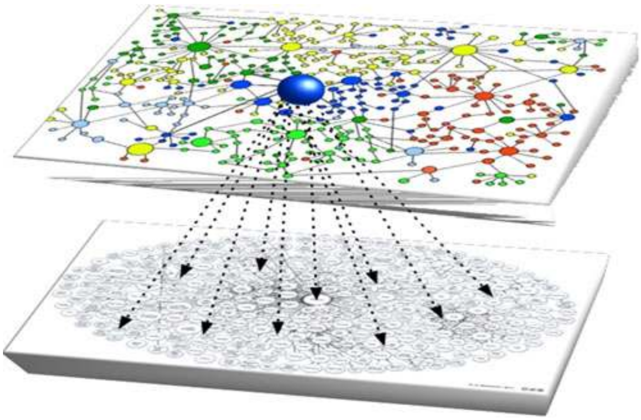


Fig. 3 Linked social service: built upon a Web of Data and linked together to related services by Social link

to neighbor services from different sources across the web to be linked to other external services, and can in turn be functionally linked to and from external services.

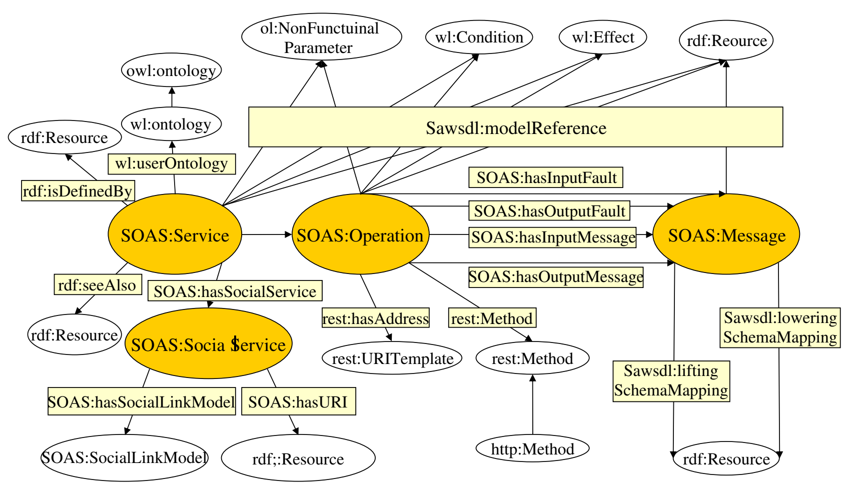
3.3 The Service of a Service (SOAS) Model

In order to publish services on the web of data to construct a global social service network, it is necessary to provide a common vocabulary based on the existing Web standards to be able to describe services in a way that allows machines to automatically locate and filter services according to their functionality, or the data they handle, and to appropriately support their automated invocation. Here we propose SOAS model to describe *Linked social service* in a way that it is machine-readable, its meaning is explicitly defined, linking to other external related services, and can in turn being linked to from external services functionally using *social link*. In a nutshell, the SOAS Model is a simple RDF(S) integration ontology based on the principle of minimal ontological commitment; it captures the maximum common denominator between existing conceptual models for services. Firstly in order to find an adequate trade-off between the expressivity and semantics, the SOAS Model does not aim to be yet another service model to bring further heterogeneity to the SWS landscape; it is instead an integration model at the intersection of existing formalisms, able to capture the core semantics of both Web services and Web APIs in a common model, homogeneously supporting publication and discovery; besides, in order to captures the sociability of services in a way that can be better to support service discovery, composition and invocation, the SOAS Model records service's social relationships, able to knows not only about service itself, but also about the peers we refer to here as social services that they would like to work with in case of composition or they would have to compete against in case of service selection. The SOAS Model, denoted by the SOAS namespace in Fig. 4, defines Services which have a number of *Operations*. *Operations* in turn have *Input*, *Output and* fault *MessageContent* descriptions. *MessageContent* may be composed of mandatory or optional *MessageParts*. The intent of the message part mechanism is to support finer-grained input/output discovery, as available in SAWSDL, OWL-S and WSMO, especially including support for optional parts (Pedrinaci et al. 2010). Moreover, Fig. 4 shows *SOAS: Service* has *SOAS: Social-Service* which has social relationship with the resource service *SOAS: Service* by *social link* in such way that services can link to services and be linked from other services as target services into service social network for effective service discovery.

4 Global service space: Global social service network

Linked social service was proposed to overcome the current service model by using light-weight ontologies and interlinking the isolated service islands into *global social service network* for more effective service discovery and composition. In this section, we will suggest a new framework for constructing *global social service network* following *Linked data principles*.

Fig. 4 SOAS model



Definition 2 (Global Social Service Network) *The global social service network is a directed graph G=< V, E> on the web, where*

- V represents a set of nodes, with each node being a Linked social service
- E represents a set of directed edges, with each edge responding to a social link defined above.

The global social service network connects cross-domain distributed services together with *social link*s. Just as RDF links in the Web of Data connect distributed data into a single global data space, *Linked social service* enables *social link*s to be formed between services in different service sources from multiple domains, and therefore connects these services into a single global service space on the web, thereby enhancing the service's sociability and collaboration for service discovery and composition.

4.1 Motivating scenario

Assume that three service providers from different domains want to publish their services on the web.

Service provider A from the medical domain provides:

- **W1**: Given symptom information, *DiagnoseService* returns a possible diagnosis
- **W2**: Given a possible diagnosis, *getRelatedClinicInformationService* returns address type and clinic information, which is a complex data type including clinicCity and clinicState
- **W3**: Given a possible diagnosis, *findMedicalCommunityService* returns community information.

Service provider B from the geography domain provides:

- **W4**: Given address type and clinic information, *getAddressInformationService* returns postal (or zip) code and clinicAddress
- **W6**: Given two addresses, such as for clinic and hotel, *findDirectionService* returns map images and driving directions
- **W9**: Given map images, *getWeatherService* returns weather information.

Service provider C from the trip domain provides:

- **W5**: Given the postal code, *getTourService* returns the tour address
- **W7**: Given the postal code, *getHotelInformationService* returns the hotel address
- **W8**: Given clinic address, *getRestaurantService* returns the restaurant address.

4.2 Global social service network construction

By *Linked data principles*, services can be published as *Linked social service* and added into global social service network, which allows services to be discovered and composed effectively.

Algorithm 1: Recommend Social Services

```
Input: G<V, E>, threshold λ, service S
Output: A set of social services {S_ss}
Variables: service has SocialLink S.L, input of service S.I,
output of service S.O, service set {S_1}, {S_2}
For each S_i ∈ G·V do
    if(sim(S.I, S_i.I) > λ && sim(S.O, S_i.O) > λ) then
        S_i.L := L(=);
        {S_ss} := {S_ss} ∪ S_i;
    end
    else if(sim(S.I, S_i.O) > λ || S_i.O ⊃ S.I) then
        S_i.L := L(←);
        {S_1} = {S_1} ∪ S_i;
    end if
    else if(S_i.O ⊂ S.I) then
        S_i.L := L(< ⊕ );
        {S_2} = {S_2} ∪ S_i;
    end if
End
    // Recommend Choice Incoming-SocialLink
For each S_i ∈ G.V do
    if( ∃max{S_n} ⊂ {S_1},  ∀S_k ∈ {S_n},
                reachability(S_k.S_i, G) == 1) then
        S_n.L = L(<||);
        {S_1} = {S_1} - {S_n};
        {S_ss} = {S_ss} ∪ {S_n};
    end
End
    // Recommend Sequential Incoming-SocialLink
{Sss} = {Sss} ∪ {S1};
// Recommend Parallel Incoming-SocialLink
while {S_2} != φ do
    if( ∃min{Sn} ⊂ {S2},  ⋃_{k=1}^{N} Sk.O ⊇ S.O ) then
        S_n.L = L(< ⊕ );
        {S_2} = {S_2} - {S_n};
        {S_ss} = {S_ss} ∪ {S_n};
    end
    else break;
    End if
end
```

Definition 3 (Global Social Service Network Construction) *The global social service network construction is a process of publishing services {S} as a Linked social service into the global social service network G=< V, E> by following the Linked data principles such that:*

$$\forall Si \in \{S\}.\ \exists Sj \in \mathrm{G.V} : \mathrm{L(Si, Sj)}$$

To publish a service as a *Linked social service*, it is extremely important to find *SOAS: SocialService* to link together functionally. We have developed a *social link* recommendation algorithm as shown in Algorithm 1 to recommend Social Services. Considering that the *incoming-SocialLink model* is similar to the *outgoing-SocialLink model*, we just show the *incoming-SocialLink model* recommendation in Algorithm 1. First the *Cluster social link* candidates are recommended according to service similarity (lines 2–5); then service sets which have strong functional relationship with resource services are selected for other types of *social link*s(lines 6–31). Using the recommended *social link*s, we introduce a process of constructing the global social service network using the scenario described in subsection 4.1. Assume that service provider A wants to publish W1, W2 and W3 into the open web as a *Linked social service*. First, they publish W1 into the open web as shown in Fig. 5(a). Note that W1 links to some services already published on the open web. Then, they publish W2 and W3, as shown in Fig. 5(b), which not only link or are linked to services that do not belong to them, but also link and are linked to services within their own services, for example, W1, W2 and W3 are linked together. In this scenario, the service providers A, B and C from different domains publish their services into the open web, and the final result is shown in Fig. 5(c). Using this method, service providers can publish their own services on the open web to construct the global social service network by following *Linked data principles*.

5 Linked social service as a service

Until now, we have proposed publishing services as *Linked social services* into the global social service network. In this section, we propose an approach to discover services on the global social service network to provide Linked Social Service as a Service (LSSaaS). Our approach, called Link-as-you-go, allows users to start browsing in one service and then navigate along links into related services by following *social link*s in the global social service network. Just as exploring the web of data following the RDF links, or exploring friends in social network, thereby improving using threshold for service consumers.

5.1 Link-as-you-go: Going deeper into the global social service network following social links

If we consider a scenario in which a man feels sick, he would first want to find out what the problem is with his health, and then find which hospital can deal with his health problem well. He also needs to find information about hotels and restaurants near the hospital, and finally, he needs to find information on how to travel to hotels and restaurants from the hospital.

One service cannot satisfy all aspects of this scenario. To fulfill this request, multiple services need to be discovered and combined. The set of services needed to fulfill his request are as follows. First, he needs *DiagnoseService* (W1) to obtain a possible diagnosis based on input of his symptoms. Next, he needs *getRelatedClinicInformationService* (W2) to obtain information on which hospital can deal with his health problem, and *getAddressInformationService* (W4) to obtain more detailed address information. Next, he needs *getHotelInformationService* (W7) and *getRestaurantService* (W8) to obtain information about hotels and restaurants near the hospital. Finally having obtained the hotel, restaurant and hospital addresses, *findDirectionService* (W6) is required to obtain a map.

Traditional service discovery approaches, such as keyword-similarity-based discovery (Inannis 2005) or I/O ontology concept-based discovery (Klusch et al. 2006; Wang et al. 2006), are difficult to guide service consumers to discover services from one service to peer services that can be combined with. To discover services effectively to fulfill a complex request such as that shown in the previous scenario, we propose an approach that allows users to start browsing in one service and then navigate along links into related services based on the global social service network.

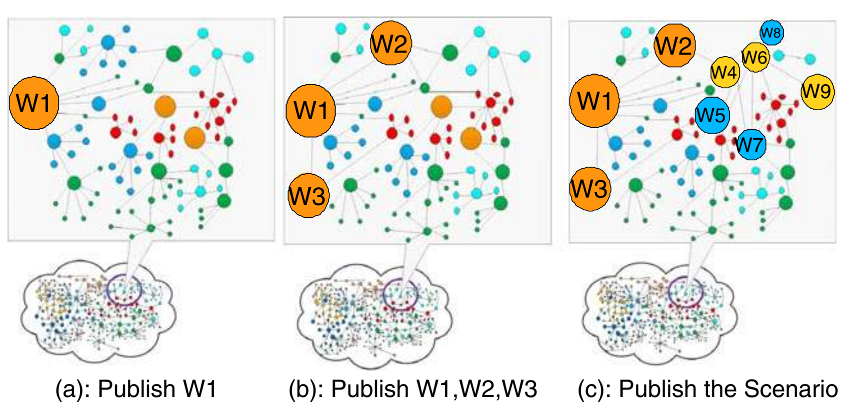


Fig. 5 Constructing global social service network. **a** Publish W1. **b** Publish W1,W2, W3. **c** Publish the scenario

Definition 4 (Link-as-you-go) *Given a service S_o, Link-as-you-go recommends a set of services {S} based on the global social service network following social links, such that:*

$$\forall Si \in \{S\}.L(So, Si).$$

Our new approach is to open the black box for service discovery so that a service consumer can discover services by following the links in which they are interested in the same manner as exploring web pages. Link-as-you-go allows users to start browsing in one service and then navigate along *social link*s into related services to explore service to service, so that users can explore the global social service network more deeply on the open web. *Social link*s of the *Linked social service* can be denoted as follows:

$$SL = \{L_1, L_2, \ldots, L_n\},\ 1 \le n \le N,$$

Where SL denotes a set of *social link*s, and $L_1, L_2, \ldots, L_n$ represent *Linked social services* that have N number of *social link*s. To explore the global social service network by following these links k times, the number of services explored can be denoted as follows:

$$SE = N^k.$$

The following is a solution for the previous scenario: assume now that one is in the position of W4, which is *GetAddressInformationService* as shown in Fig. 6. Here, W4 links to peer services that can be combined, such as W6 and W7. One can explore W4 to W6, as shown in Fig. 7, after which one can explore services from W6 to more services, such as W7 and W8. In this manner, one can easily explore the global social service network more deeply to discover the services needed.

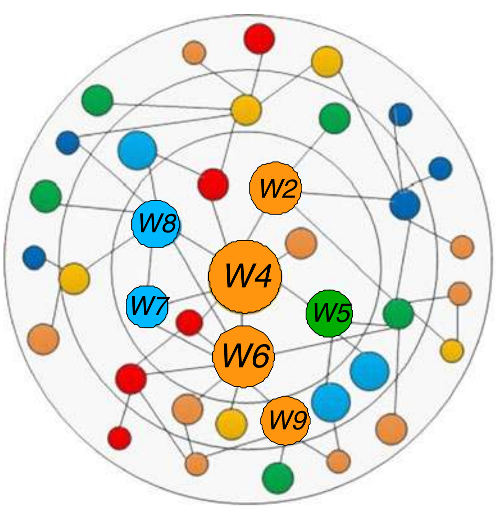


Fig. 6 Linking from W4

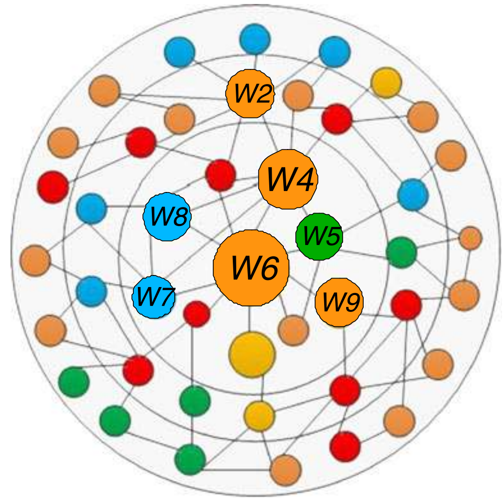


Fig. 7 Linking from W6

6 Implementation and evaluation

In this section, we discuss Service Of A Service (SOAS) which is a prototyping system we developed as a proof of concept in section 6.1. Moreover, we give a preliminary evaluation of the suggested approach by analyzing some results obtained with the prototype developed.

6.1 Implementation

SOAS is a platform to construct global social service network following *Linked data principles* and to enable exploitation of global social service network, providing LSSaaS. SOAS uses the SOAS model as its core conceptual model, which provides a minimal and common conceptual model in lightweight ontologies and uses *social link*s to connect service islands into global social service network. SOAS platform crawls and connects distributed services from web of document and receives the service publication by service providers, who just simply follow Link data principles to link their services to global social service network with *social link* as shown in Fig. 8. To enable exploitation of global social service network, SOAS platform provides service consumers link-as-you-go approach for exploring service to service to go deeper into global social service network.

To show how SOAS supports construction of global social service network and exploitation of global social service network, here we briefly overview the SOAS architecture as shown in Fig. 9 which consists of four main modules:

- First the Translator module receives isolated services based on service description such as OWL-S, WSMO or WSDL, and translates them into RDF description based on SOAS model. DBpedia (Auer et al. 2008) which is a common vocabulary on web of data provides light

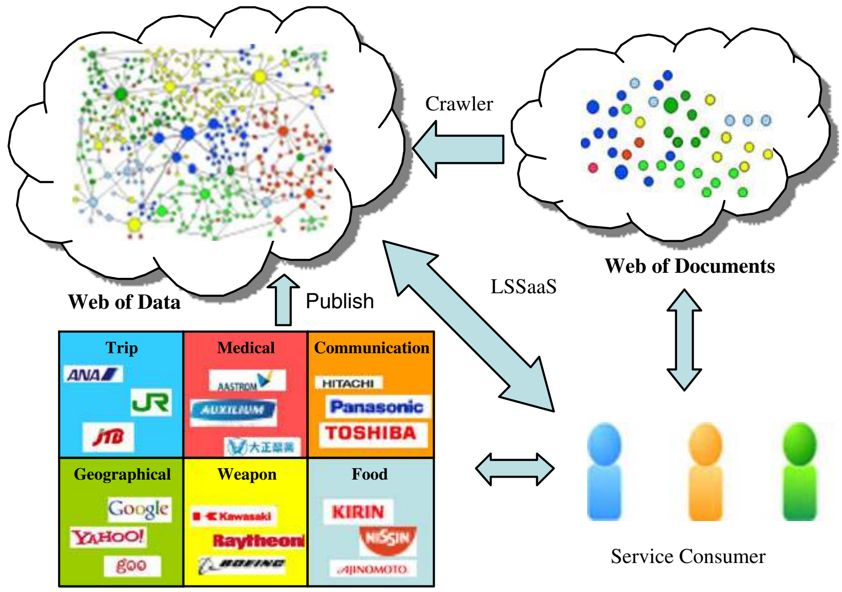


Fig. 8 High-level SOAS architecture

weight ontologies for service semantic annotation. Figure 10 shows an example of service annotation for DiagnoseService based on the SOAS model. In Fig. 10, DiagnoseService is described by using DBpedia for semantic service annotation; besides, in order to captures the essence of services in a way that can be better to support service discovery, composition and invocation, DiagnoseService has SOAS: SocialService such as W2 which has functional relationship, in such way that services can link to services and can be linked from other services as target services into global social service network.

- Secondly the recommender module recommends social services for isolated services using the recommendation algorithm 1 described in section 4.2.
- Thirdly the GSSN module adds services into global social service network with *social links* by following *Linked data principles*. Besides, Sesame (Broekstra et al. 2003) is used as RDF repository for storage, inference and querying of services.
- Finally the *link-as-you-go* module provides service consumers an approach to enable exploitation of *global social service network* just following *social links* by RDF browser.

Nowadays SOAS registers about 2000 services coming from the OWL-S test collection and the SAWSDL test collection, about 3000 services coming from owls-mx_2_0 test collection, around 5000 services indexed by Seekda.com, and about 500 services coming from ProgrammableWeb.com.

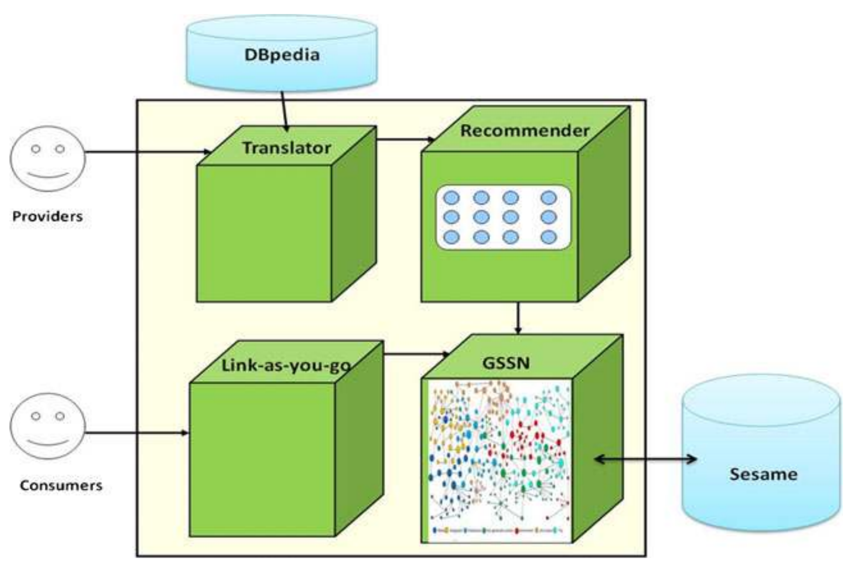


Fig. 9 Lower-level SOAS architecture

```
1 DiagnoseService rdf :type SOAS:Service ;
2 rdfs:isDefinedBy <http://dbpedia.org/resource/#diagnoseinfo>;
4 DiagnoseService SOAS:hasOperation :diagnoseDisease.
5 diagnoseDisease rdf : type SOAS:Operation;
6 rdfs : label "Diagnose disease service";
7 hr :hasMethod "GET";
8 hr :hasAddress "http:// diagnose.de/diagnoseinfoJSON".
9 diagnoseDisease SOAS:hasInputMessage:inputmsg.
10 inputmsg rdf:type SOAS:Message;
11 sawsdl:loweringSchemaMapping
  <http://example.com/DEdiagnose-Info-lowering.xsparql>;
12 sawsdl:modelReference
  <http://example.com/onto#symptom>.
13 diagnoseDisease SOAS:hasOutputMessage :outputmsg.
14 outputmsg rdf:type SOAS:Message;
15 sawsdl:liftingSchemaMapping
  <http://example.com/DEdiagnose-Info-lowering.xsparql>;
16 sawsdl:modelReference
  <http://example.com/diagnoseontology/onto#diseaseInfo>.
17 DiagnoseService SOAS:hasSocialLink :SocialLink1.
18 SocialLink1 rdf : type SOAS:hasSocialLink;
19 rdfs : label "Link to getRelatedClinicService";
20 SOAS:hasSocialLinkType
  <http://SOAS#Choice Outgoing-SocialLink model>.
21 SOAS:socialLink <http://SOAS/example#W2>.
22 DiagnoseService SOAS:hasSocialLink :SocialLink2.
23 SocialLink2 rdf : type SOAS:hasSocialLink;
24 rdfs : label "Link to findMedicalCommunityService";
25 SOAS:hasSocialLinkType
  <http://SOAS#Choice Outgoing-SocialLink model>.
```

Fig. 10 DiagnoseService annotation using DBPedia

The experiments have been conducted on intel(R) Core2 CPU, 2.4 GHz, and 4 GB RAM.

6.2 Evaluation of global social service network

We evaluate the properties of global social service network by:

- Observing the number of services in the five largest components which are largest connected sub-graph to show how well our approach can connect distributed services into a global social service network. Note that two services are in the same component if and only if there a path exists between them.
- Observing the shortest path between two services in global social service network, which is defined as smallest number of *social link*s that must be followed to navigate from one service to the other.

Figure 11 shows the five largest components we obtained. It can be seen that almost all of the services are in the largest cluster, which accounts for 90 % of all services in the global social service network. This indicates that the global social service network is densely connected; this means that starting from an arbitrary service in the global social service network, almost any other service can be reached by following *social link*s. This is one reason why it is interesting to construct a global social service network that allows exploring service to service just by following the links. Figure 12 is another indicator of the density of the global social service network. We compute the components by starting with an arbitrary service. The figure shows the distance of any services in the main cluster from this starting service. Almost all of the objects have a distance of between 5 and 9 from the starting service and are thus within a short distance from the starting service.

6.3 Evaluation of linked social service as service

To show our link-as-you-go approach can effectively improve service discovery, we evaluate the effectiveness of LSSaaS by: observing the total service discovering time which measures how much time a service consumer takes to find services needed in seconds by changing the number of desired services and different participant groups including general user group, IT professional group, and web service professional group; and comparing our approach with state-of-the-art approaches in term of service discovering time. To evaluate the service discovering time, 50 participants including 15 general users, 20 IT professionals, and 15 web service professionals are requested to discover

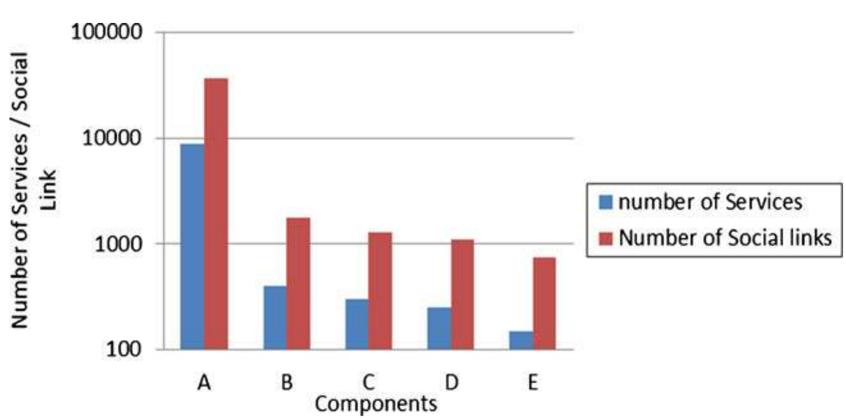


Fig. 11 Number of services in the five largest components

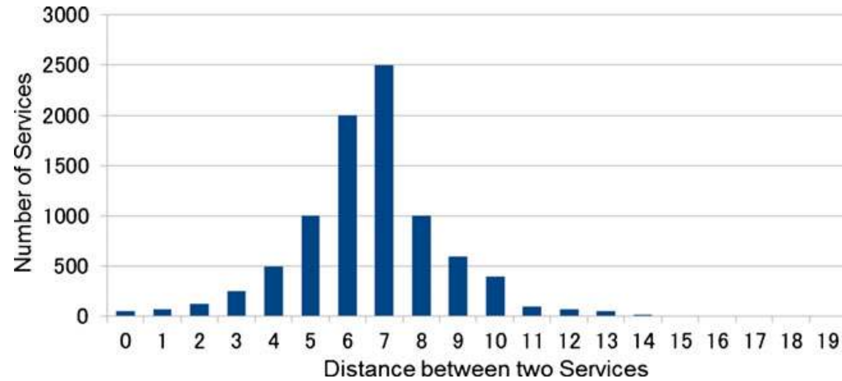


Fig. 12 Number of services with regard to the distance from an origin service

services, including 12 services to accomplish the task described in scenario 4.1, and recorded the time they took.

The first experiment evaluates the effectiveness of our approach by changing the number of desired services from 1 to 12. In most cases, service consumers are not limited to discovering a single service, but want to locate multiple services. As the number of desired services increases, it is expected that the discovering time increases. Table 1 shows that the discovering time increases as the number of desired services increases, but our approach performs far better than other approaches, especially in case of discovering large number of desired services. This occurs because once the participants find one service, then other services can be discovered just following *social link*s as finding friends using Facebook.

The second experiment we evaluate the effectiveness of our approach by observing the total service discovering time for 10 desired services over different participant groups. In most cases, in order to discover services, users are expected to specify their requests with associated service and semantic information, which is not realistic if they do not have much service and semantic knowledge. Table 2 shows that general users can discover services they want more easily in our approach than others. The result indicates that the current using threshold of the existing service discovery approaches is still high and our approach can effectively strength the easiness by linking one service to others just as exploring friends in Facebook.

Table 1 Time of discovering services based on different approaches

Approaches	Number of services discovered				
	2	4	8	10	12
Seekda.com	150s	290s	595s	755s	950s
ProgrammableWeb.com	220s	455s	870s	1120s	1350s
OWLS-MX	100s	202s	420s	550s	659s
SOAS	110s	160s	218s	255s	285s

7 Related work

iServe (Pedrinaci et al. 2010) is the place on the Web where *Linked data* meets services. In a nutshell, iServe is a platform for publishing Semantic Web Services as *Linked data*, no matter their original format. However, services in the approach are still isolated, *Linked service* failed to provide a proper mechanism to interlink distributed services into global service space for service discovery and composition. In our approach, we propose a methodology to interlink distributed services into *global social service network* with *social link* to provide a network model on a global scale for supporting effective service discovery.

Some other approaches were proposed to try to use service social network to enable GPS-like support service discovery and service composition. First, Wei Tan (Tan et al. 2011) proposed a serviceMap to enable recommending relevant services for service consumer and finding an operation chain to connect two operations given based on others' past usage. Second, Jia zhang (Zhang et al. 2011) proposed an approach to help domain scientists find interested services and reuse successful processes to attain their research purposes in the form of workflows. In contrast to existing interface-based services discovery approaches, the authors proposed a novel approach of proactively recommending services in a workflow composition process, based on service usage history. The underpinning is a People-Service-Workflow (PSW) network that models existing scientific

Table 2 Time of discovering 10 services based on different approaches by different groups

Approaches	Groups of participants		
	General users	IT professional	Web service professional
Seekda.com	1100s	721s	650s
ProgrammableWeb.com	1950s	1205s	980s
OWLS-MX	950s	520s	495s
SOAS	310s	295s	205s

artifacts, services and workflows, and their past usage relationships into a social network. Third, Zakaria Maamar (Maamar et al. 2011–1, 2011–2) proposed an approach to use social networks for web services discovery. The authors describe how service engineers can capitalize on Web services' interactions-namely, collaboration, substitution, and competition-to build social networks for service discovery. However, all of these approaches are about using social service networks to enable GPS-like support service discovery and composition, but they struggle with how to construct a cross-domain, web-scale global service space dynamically, as they do when constructing WWW. Our approach proposes a methodology to construct a global social service network using *Linked data principles* to provide effective service discovery, enabling exploring service to service.

8 Conclusions and future work

In this paper, in order to reduce the using thresholds for both service provider and service consumer, we propose a methodology to drive an innovation from isolated service islands to *Linked social service.* Which is described in a light-weight ontologies using RDF, and links to related services and be linked from related services functionally on the web into global social service network, enable exploring from service to service. The experiment results show that our approach can solve the quality of service discovery problem well improving service discovering time by exploring service to service based on the global social service network. In the future work, by connecting isolated service islands or services repositories into service social network, we expect that our approach can make service requirement for service-based economy at global scale clear so that our approach can impel service providers to publish their services on the web as a piece of service social network and motivate service consumer to use services from global social service network.

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