SMARTSAN: A P2P Social Agent Network for Generating Recommendations in a Smart City Environment

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***Abstract*—The rapid advances of the Internet of Things (IoT) has implied that new kind of social networks are becoming pervasive, and the use of the multi-agent technology has been recognized to have a key role in designing distributed software architecture capable of implementing autonomous, adaptive and proactive services for the citizens, with high levels of effectiveness and efficiency.In this scenario, we can imagine the possibility to form groups of agents associated with users and objects that are geographically close, and use these groups to provide the users with recommendations about services of potential interest.In this paper, we propose a novel recommender system for smart city environments, based on a P2P social agent network, designed to faced these highlighted problems. The P2P network topology is continuously adapted to the changes of desires and necessities of the users, using an algorithm that match the different exigences for forming groups of agents geographically close with each other. Moreover, in order to consider also the issue (ii) above, the local groups are integrated in a global social network, that can be used to discover services of interest for a given user also managed by agents that do not belong to the same local group of the user.**

***Index Terms*—Recommendation, Online Communities, Trust, Group.**

I. Introduction

Nowadays, the recent developments of communication technology and intelligent systems generated an increasing tendency to improve human life in its social aspects, including entertainment, commerce, socialization, education, transportation, etc. These advances should make social contexts, in particular the city, to become a better place to work and socialize, implying that communication should be effective and low cost, and the urban organization should be intelligent enough to enable ubiquitous computing environment for delivering smart services to a much wider audience [1]. The rapid advances of the Internet of Things (IoT) [2] has implied that new kind of social networks are becoming pervasive, connecting not only networked devices like PCs and smartphones, but also un-networked things as sensors, actuators, refrigerators, TVs, vehicles, clothes, food, medicines, books, luggage and, obviously, people. In this context, the use of the multi-agent technology has been recognized to have a key role in designing distributed software architecture capable of implementing autonomous, adaptive and proactive services for the citizens, with high levels of effectiveness and efficiency [3]–[5]. In particular, if the agents are provided with social capabilities, making them able of establishing interactions between each others, there is the possibility of making social networks of agents, encoding in them some useful information about the actors of the scenario, and their existing relationships. In this scenario, we can imagine the possibility to form groups of agents associated with users and objects that are geographically close, and use these groups to provide the users with recommendations about services of potential interest. We recognize that two key issues arise in this context, namely (i) the necessity of making highly dynamic the formation of groups, to address the changes of the desires expressed by the users during their movements in the city and (ii) the possibility of considering also the possibility that objects not belonging to the group of a given user can be of interest for that user, in the case no other suitable alternatives are present in the local group. However, although several proposals have been presented in the literature, that use middleware architecture to support the development of applications in the scope of Smart Cities [6]–[10], and also considering that some approaches have been introduced for constructing social networks of agents [11]–[13], any of these proposals, at the best of our knowledge, addresses the issues above. In this paper, we propose a novel recommender system for smart city environments, called **SMART** City **S**ocial **A**gent **N**etwork (SMARTSAN), based on a P2P social agent network, designed to faced these highlighted problems. The P2P network topology is continuously adapted to the changes of desires and necessities of the users, using an algorithm that match the different exigences for forming groups of agents geographically close with each other. Moreover, in order to consider also the issue (ii) above, the local groups are integrated in a global social network, that can be used to discover services of interest for a given user also managed by agents that do not belong to the same local group of the user.

The paper is organized as follows: in Section II we deal with some related work. Section III provides technical details about the Recommender System architecture and the Social Network of Agents, while Section IV describes the algorithm for matching the different agent goals in local groups. Finally, in Section V we draw our conclusions and illustrate some possible future works.

II. Related Work

In [6], the authors developed a multi-agent based Smart Mobile Virtual Community Management System (SMVCMS) capable of providing a decentralized and open management of virtual communities, based on the agent-oriented platform JaCaMo and its Android client based platform JaCa-Android. In such a system, a participant in virtual communities is supported by a Jason agent that encapsulates the logic and the control of the participation in a virtual community (such as publishing posts, notifying members, making recommendations for the user, etc.). The authors exploited SMVCMS in the context of Smart Cities, showing that the system fulfills decentralization of community management, personalized automatic management and discovery of communities, so that any agent can create its own community. In [7], the authors presented a scalable agent architecture with emergent properties in the context of Smart Cities. These agents form on-demand control loops within the urban system, by considering both the protection and the comfort of its inhabitants, at varying degrees of intelligence and abstraction of tasks. A case study is analysed regarding a real-time creation of a control loop for an underground railway intersection system. In [9], a system has been designed to provide an easy and ubiquitous access to the desired information about tourist attractions, and to generate proactive recommendations of attractions by means of a hybrid recommendation system that considers elements such as the user profile and preferences, the location of the tourist and the activities, and the opinions of previous tourists. This system is capable to adapt itself to changes in the activities and incorporate new information transparently at execution time. In [10] a system architecture and design methods are proposed to support the delivery of location-based recommendation services to create personalized tour planning, based on tourists current location and time, as well as personal preferences and needs. The system is capable to efficiently provide various recommendations regarding sightseeing spots, hotels, restaurants, and packaged tour plans. Regarding the formation of social networks of agents, in [11] the authors deal with the dynamics behind group formation and evolution in social networks of agents, analysing in particular the notion of compactness of a social group and arguing that the mutual trustworthiness between the group members should be considered as an important factor in defining such a notion. They propose a quantitative measure of group compactness that takes into account both the similarity and the trustworthiness among users, and introduce an algorithm to optimize such a measure. In [12], after defining a notion of compactness for a group, that integrates similarity and mutual trust, the authors propose to provide each user with a software agent associated with each topic of interest for the user, and that represents a user's avatar in the corresponding dimension. This allows the user to delegate to his/her agent the management of group joining requests regarding a given topic, selecting only those interlocutors which appear the most appropriate for their owners. In such an approach a Users-to-Group matching algorithm allows the agents to dynamically manage the evolution of the social network organization. Finally, in [13], the authors present a framework that exploits homophily to establish an integrated network linking a user to interested services and connecting different users with common interests, upon which both friendship and interests could be efficiently propagated. The proposed friendship-interest propagation (FIP) framework devises a factor-based random walk model to explain friendship connections, and simultaneously it uses a coupled latent factor model to uncover interest interactions.

III. The Multi-Layer Recommender System Architecture

The SMARTSAN recommendender system generates recommendations for each logged user, computing them by means of a set of software agents, and exploiting a number of inert objects with IoT capabilities. We suppose that both users and objects can provide services (e.g. information about city attractions, museums, restaurants, products to buy or trip to organize etc.). The system architecture is composed by components organized in a stack of four layers, as graphically represented in Figure 1. The layers are described below:

IoT. It is at the bottom of the layer stack, and contains all the objects in the Smart City that are registered in the system, and that have IoT capabilities. All these objects can communicate with the device agents of the users (see the P2P communication layers) and also with the server agents of the Social Agent Network to which they transmit information about their position and the deployed services.

P2P Communication. This layer is placed on the top of the IoT, and it is composed by a set of device agents, where each of them, denoted by d_u, is associated with a fixed user of the system and lives in a device exploited by the user (e.g. a smartphone, a tablet). All the device are organized in a P2P Network, and communicate with each others by means of a P2P protocol. Moreover, the device agent of a user u builds and updates a *profile* P_u of u, containing some information about the u's preferences and past behaviours. Such a profile is periodically sent to the DF agent belonging to the Smart City Recommendation Layer.

Social Agent Network. It contains a set of social agents, each of them associated with a different user u or with an IoT object o of the system. This layer maintains a representation a social network, where each node represents a social agent and each arc between two nodes represents a trust relationship between the two respective social agents. Formally, the social network is denoted by $\mathcal{SN} = \langle \mathcal{SA}, \mathcal{G} \rangle$, where $\mathcal{SA}$ is the set of *social agents* and $\mathcal{G}$ is the set of *groups* contained in $\mathcal{SN}$. We also assume that each group g is managed by an administrator agent a_g. The formation of a group is a process based on two main events: a user asks for joining with a group

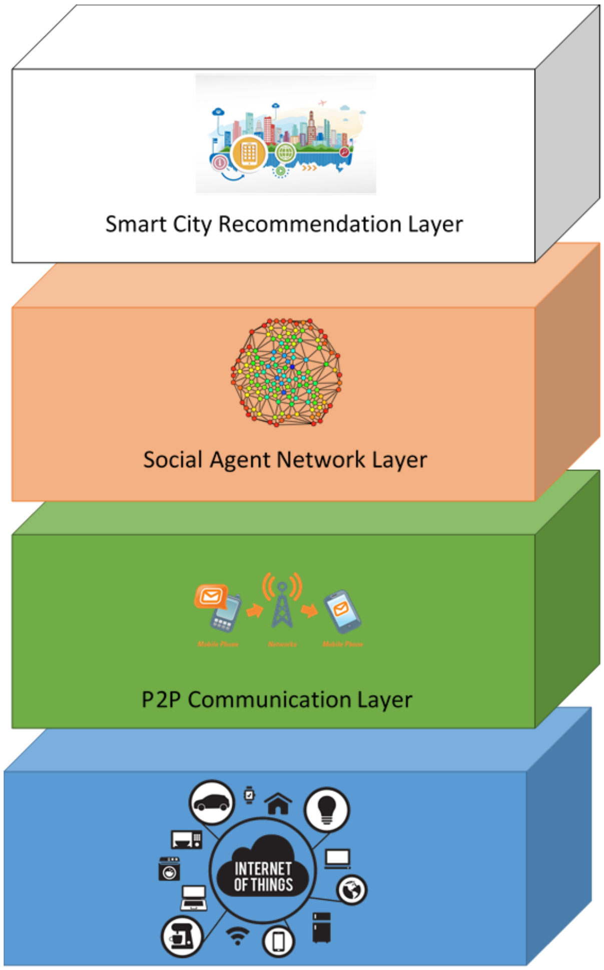

Fig. 1. The SMARTSAN Multi-Layer Architecture

and the administrator of the group accepts or refuses the request. We assume that the group formation follows the algorithm described in Section IV.

Smart City Recommendation. This layer is at the top of the stack, and it contains the following components:

- An Agent Management System (AMS), that manages the registration of each user and each IoT object in the system.
- A Directory Facilitator (DF) that provides a service of yellow pages, storing for each user u his profile P_u.
- A set of recommender agents, where each of them, denoted by r_u, is capable to generate some useful recommendations that are sent to the device agent $d:u$.

A. Trust Measures

The trust measure $t_{u,v}$ between two social agents u and v represents the degree of trustworthiness that u assigns to v: $t_{u,v}$ = 0 (resp. $t_{u,v}$ = 1) means that u assigns the minimum (resp. maximum) trustworthiness to v. The trust measure is

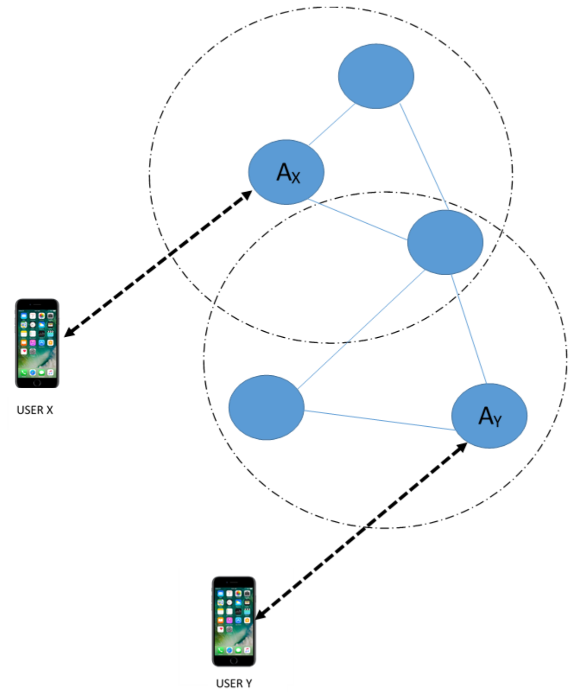

Fig. 2. The Social Agent Network, as integration of local networks

asymmetric, in the sense that we do not automatically expect that v trusts u at the same level.

Generally, in traditional approaches as in [14], a trust measure combines two components $r_{u,v}$ and R_u, where $r_{u,v}$ is called *reliability* of u, and represents the trustworthiness that v has in u based on the past interactions between u and v, while R_u is called *reputation* of u, representing the trustworthiness that the whole social network assigns to u.

As for the reliability, we denote it by the mapping $r_{u,v}$, assuming values ranging in the domain $[0 \cdots 1] \bigcup NULL$, while $r_{u,v}$ = NULL means that v did not have past interactions with u and thus it is not able to evaluate u's trustworthiness.

Regarding the reputation of u, we denote it by R_u in the interval $[0 \cdots 1] \epsilon \mathbb{R}$. The reputation is computed as follows

$$R_u = \sum_{\rho \in FED_u} f_\rho \tag{1}$$

where $|FED_u|$ is the set of the services provided by the agent u and f is the feedback, representing the level of satisfaction of the other agents for those services.

The two trust components reliability and reputation are integrated in a unique value to compute the mapping trust $t_{u,v}$ of u about v, producing a input ranging in $[0 \cdots 1]$ as follows:

$$t_{u,v} = \omega \cdot rel_{u,v} + (1 - \omega) \cdot rep_v \tag{2}$$

where ω is a real number, ranging in $[0...1]$, which is set by u to weight the relevance he/she assigns to the reliability with respect to the reputation.

B. Similarity

The *similarity* measures how much close the profiles of two agents are. The information stored in agent profiles strictly depends on the application domain. Generally, it can be formalized as a tuple of pair, $\leftarrow (f_1, v_1), (f_2, v_2), ..(f_n, v_n) \rightarrow$, where f_1,..,f_n are the *features* composing the profile, i.e. some agent characteristics representing interests, preferences, technological parameters etc., and v_1,..,v_n are the corresponding values, such that each value $v_i \in \mathcal{D}(f_i)$, where $\mathcal{D}(f_i)$ is the *domain* of f_i. The similarity between two agents u and v is a mapping $s_{u,v}$ yielding values ranging in the real interval [0.1], representing the degree of closeness between the profiles P_u and P_v: $s_{u,v}$ = 0 (resp. $s_{u,v}$ = 1) means that P_u completely differs (resp. perfectly coincides). Differently from the trust, the similarity measure is symmetric. Many proposals have been presented in the literature for modelling similarity (e.g., those described in [11], [15]). The approach presented in this paper is dully orthogonal to the particular definition chosen for the similarity measure.

C. Agent recommendation

The user receives, at the current step, some recommendations about the services present in the system. In other words, r_u^s is the recommendation that the agent u receives about a service s provided by an agent k. It is calculated as follows:

$$r_u^s = \psi \cdot s(u,k) + (1-\psi) \cdot \frac{\sum_{v \in \rho, v \neq u} t_{u,v} \cdot rate_v^s}{\sum_{v \in \rho, v \neq u} t_{u,v}} \quad (3)$$

In other words, is composed by two components, the first depnding on the similarity between the agent u and the agents k that provides the service s, and the second depending on the opinions expressed by the whole community of the agents about s, taking into account the trust measures. Each of the two component are weighted, using a weight ψ, appositely chosen depending on the application domain, ranging from $[0, 1]$.

As for the second component, $rate_v^s$ is the opinion of the the agent v about the service s (a number between 0 and 1), weighed by the trust of v. This means that his/her opinion about a service is taken into account if his/her trustworthiness is high. The weighted average allows us to identify an average value in which the starting numerical values have their own importance, specified by its weight. In particular, we can identify the centre of gravity of the rate. In this way, we give more importance to the rate from users that the agent u trusts.

D. Groups

At this point, we introduce the group's concept in the social network. In this context, we define trust $t_{u,v}^*$ in two different ways. We suppose that the trust perceived by an agent u with respect to the component of his/her group is equal to 1 (i.e, $t_{u,v}^*$=1), instead the agent u considers the trust that the agent has in the whole community (see Equation 2). In this way, we define r_g^{*w} that is the recommendation that the user u receives about the service s in presence of the groups:

$$r_u^{*s} = \psi \cdot s(u,k) + (1-\psi) \cdot \frac{\sum_{v \in g_u} rate_v^s + \sum_{v \notin g_u} t_{u,v} \cdot rate_v^s}{\sum_{v \in |R_s|} t_{u,v}^*} \quad (4)$$

where g_u is the group to which the agent u belongs and $|R_s|$ is the set of the agents who have evaluated the service s. It is calculated as the combination of two contribution: the average rating of the agents that belong to the group of the agent u and the score that the other groups give to the product multiplied by the trust that u assign to its agents.

This way, the recommendation of services depends on the topological structure of the social agent network, that can viewed as composed by the groups, that are a sort of local social networks, whose formation follows the algorithm that will be described in the next section

IV. The Group Formation Algorithm

The algorithm for forming the groups periodically repeat a fixed behaviour, allowing the groups' composition to dynamically change with the evolution of the social agent network. Let T be the time between two consecutive executions of the algorithm. On the single agent side this procedure is executed to join with a set of groups focused on the same topic (or set of topics) for taking benefits from joining with more than one group. We also assume that agent can query to a distributed database, named GR (*Group Repository*), on which the list of groups of the social network is stored.

The behaviour performed by the social agents is as follows. Let X_i be the set of the groups which the agent a_i is affiliated to, and N_{MAX} the maximum number of groups which a trader agent can analyze at time t. It is supposed that $N_{MAX} \geq |X_i|$. Furthermore, we suppose that a_i stores into a cache the group profile of each group contacted in the past and the timestamp d of the execution of the procedure for that group. Finally, let ξ_i a timestamp threshold and $\chi_i \in [0, 1]$ be a threshold fixed by the agent a_i. The ratio behind the procedure executed by the social agent is represented by the attempt, of the social agent, to improve the advantage in joining with a group. For this aim, first of all, the values of advantage are recalculated if they are older than the fixed threshold ξ_i. Then, candidate groups are sorted in a decreasing order with respect to their trust value. If some groups in the set L_{good} are not in the set X_i, then agent a_i can potentially improve convenience of the user u_i, if they accept the user itself to join with. The only constraint of the algorithm is the maximum number of groups the agent want/can to join with.

On the group side, the algorithm works as follows. Let K_j be the set of the agents affiliated to the group g_j, where $||K_j|| \leq K_{MAX}$, being K_{MAX} the maximum number of users allowed to be within the group g_j. Suppose that the administrator agent A_j stores into its cache the profile P_i of each agent $a_i \in K_j$ and the timestamp d_i of its acquisition. Moreover, let ω_j a timestamp and $\pi_j \in [0, 1] \in \mathbb{R}$ be a threshold fixed by the agent A_j. The procedure performed by the group agent A_j is triggered whenever a join request by the social agent a_i (along with its profile P_i) is received by A_j. First of all, parameter K_{MAX} represents the maximum number of users that can join with a given group. In fact, if the group has reached this maximum, no more users can be accepted to join with the group. The group agent asks the updated profile of the components of the group itself, therefore the trust t_{g_j,a_i} is computed for all these agents and a new, sorted set $K_{good} \subset \{K_j \bigcup a_i\}$ is built. Then, the group agent will send a *leave* message to all the social agents a_i showing a trust t_{g_j,a_i}. Finally, if $a_i \in K_{good}$, its request is accepted.

V. Conclusion

In this paper, we described a novel recommender system for smart city applications, called **SMART** City **S**ocial **A**gent **N**etwork (SMARTSAN), organized in a multi-layer architecture comprehending both a P2P platform and a social agent network, built on top of an IoT infrastructure. The social agent network allows the presence of groups of social agents, formed on the basis of trust measures, and the overall topology derives by the integration of these groups, that are dynamically adapted in time to the changes of desires and necessities of the users, using an algorithm that match social agent desires and existing groups' exigences. The use of local groups is used to discover services of interest for a given user, integrating the recommendations coming from the agents of the local groups the user belongs which and those of the agents that do not belong to the same local groups of the user. Our ongoing research is currently devoted to apply the approach to real smart city applications, in which the advantages and limitations introduced by our proposal can be quantitatively and effectively evaluated.

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