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An Analysis on Device Sociality: Deriving Human Social Relationships from Device Interactions

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Abstract

Collaboration of smart devices often requires troublesome configuration and management, involving human interventions. In order to reduce these burdens, smart devices should be able to configure and manage themselves in device collaboration by self-understanding high-level information such as social relationship between the owners. This paper introduces collaboration framework for devices, called device social network, which is built based on device sociality. Device sociality describes social relationship of devices, which can be identified by analyzing interactions between devices and social information of their owners. Hence, device social network mimics a human social network and it is constructed by imitating the socialization process of human beings. We conducted an experiment to compare device social network to human social network. The results show that the relationships of devices well-reflect that of their owners. As a result, we foresee that device social network can play a role of collaboration framework, in which devices are able to discover appropriate partners not only in function but also security-wise.

Keywords: *device social network, device collaboration, device sociality, device management, Internet of Things, social network*

1 Introduction

While researchers discuss new innovations and technologies for the consumer device industry, IEEE experts highlights the trends from CES 2012 that will dictate the product development cycles of companies all around the world [1]. They categorized the trends as (1) ubiquitous, nonstop connectivity, (2) cloud-based applications, (3) streaming web-based video, (4) intelligent transportation, (5) automated metadata and (6) convergence of home networking technologies.

A typical device that reflects most of these trends is a smart device. Thanks to the consumer electronics industry's continuous innovation, the computing power and capabilities of traditional desktops have been condensed and mobilized in the form of smartphones and tablets.

In recent years, people particularly use smart devices such as smartphones or smart tablets as means of new communication methodologies. In the near future, people will get most of information through smart devices. Furthermore, they may use smart devices as their avatar executing their commands on behalf of them.

With the increasing proliferation of smart devices in home and mobile environments, configuration and management of multiple devices have become uncontrollably complicate, being serious problems in device collaboration.

However, the confronted problem can be solved if smart devices can configure necessary collaborations themselves on behalf of their users. Smart devices can authorize service requests of peers based on their social relationship, mimicking human collaboration.

A recent success of human social network (HSN) service leads the development of social network service to become a platform for various types of services. The social network service is great tools for communication, information sharing, and collaboration among individuals. The main idea of this paper is that the concept and architecture of human social network can be applied to devices. By constructing a social network platform for devices, they, too, are able to configure collaboration themselves in performing tasks.

To facilitate the process of device collaboration, we introduce a concept called device sociality, which describes social relationship between two devices. We propose a collaboration platform called device social network in which smart devices communicates one another for collaboration. In device social network, multi-functional smart devices can not only advertise their services and resources, but also authorize service and collaboration requests based on their 'friendship.'

The proposed idea of device sociality can also be combined with the idea of IoT, WoT, or M2M to provide new paradigm in device collaboration. International organization for standardization such as ISO/IEC JTC 1 SWG5 begins to discuss 'machine socialization' based on IoT technical background from March 2013. At the meeting of this working group, the concept of the device social network is introduced as evolving and interoperable information and communication technologies [2].

In this paper, we introduce device sociality and how device sociality can be implemented using device interaction data, mimicking socialization process of human. We also demonstrate an experiment to show that devices are able to identify their own relationships with other devices by analyzing device sociality.

The results of experiment show the potential of autonomous management and collaboration of devices.

The remainder of this paper is organized as follows. Section 2 briefly describes related works of this paper. In Section 3, we introduce concept and architecture of device social network and socialization process of human social network and device social network. Section 4 presents experiment on device sociality where we demonstrate its potential as device collaboration framework. Finally, we summarize our work in Section 5 and future work in Section 6.

2 Related Work

Recent researches of M2M (Machine-to-Machine) communication, IoT (Internet of Things), and WoT (Web of Things) discuss technologies about management and collaboration of devices [3, 4, 5]. The studies focus on technologies of discovering and connecting devices in device management and collaboration. Although some researches such as [5] consider semantic properties of devices in discovery process, many of them have not discussed any process to connect and manage devices automatically using social relationship between the devices. Some researchers, on the other hand, propose to use existing social network services as platforms for device collaboration [6]. They claim that recent popularity of human social network services can play a role of connecting interface of devices.

M. Roth et al. [7] propose a method to suggest friends using an implicit social graph. The implicit social graph is formed by analyzing user interactions in user contacts, whereas an explicit social graph is formed by users explicitly adding other individuals as their 'friends.' This method constructs implicit social graph and uses it as a clue of finding appropriate email recipients. Although they consider implicit social relationship between users, they do not utilize device-level information such as device interaction history.

L. Atzori et al. [8] introduced an interesting paradigm of 'social network of intelligent objects', namely the Social Internet of Things (SIoT), based on the notion of social relationships among objects. Through the SIoT paradigm, the capability of humans and devices to discover, select, and use objects with their services in the IoT is augmented. This method is similar to our concept, device sociality. In our research, we focus more on social process of devices, how the social relationship between devices forms and evolves. Furthermore, in our framework, we treat non-smart things (i.e. sensors) as resources of smart devices. In other words, only smart devices may build social relationships.

3 Device Social Network

Device social network is a mimic of human social network, consisting of network-capable smart devices and device sociality. In device social network, devices may publish their profile and status, and establish valuable and trustworthy relationships to satisfy tasks of the user. The ultimate goal of device social network is to automate the process of making decisions on authentication and authorization in sharing their functions and resources by allowing them to communicate one another with minimized human intervention.

3.1 Architecture

Fig. 1 shows a conceptual diagram of device social network. Basically, device social network mimics the human social network.

Fig. 1 Conceptual diagram of device social network

Similar to human social network, newly connected smart devices establish a social relationship with one another and then the relationship evolves as any activities occur between the two devices.

In device social network, when a device discovers a new device, the socialization agent running on each device initiate the socialization process by exchanging device identification and profile information. Then, when a new task is triggered by the user or the inner-logics of application in one of the devices, devices that received service/resource requests carefully analyze social relationships to determine whether to participate in executing the task.

3.2 Socialization Process

Socialization is a term used by sociologists, social psychologists, anthropologists, political scientists and educationalists to refer to the lifelong process of inheriting and disseminating norms, customs, and ideologies, providing an individual with the skill and habits necessary for participating within his or her own society [9].

In literatures, several models for socialization process of human beings are introduced [10, 11].

J. Levine and R. Moreland [10] identified five stages of socialization which are transition, investigation, socialization, maintenance, resocialization, and remembrance.

Investigation: a stage where a cautious search for information takes place. Individuals compare groups in order to determine which one will fulfill their needs while the group estimates the value of the potential member. The end of this stage is marked by entry to the group, whereby the group asks the individual to join and she accept the offer.

Socialization: at socialization stage, the individual has moved from a prospective member to a new member, and she must accept the group's culture. The individual accepts the group's norms, values, perspectives, while the group adapts to fit the new member's needs. The acceptance transition point is then reached and the individual becomes a full member.

Maintenance: during this stage, the individual and the group negotiate what contributions are expected from members (role negotiation).

Resocialization: if the divergence point is reached, the former full member takes on the role of a marginal member and must be resocialized.

Remembrance: in this stage, former members reminisce about their memories of the group, and make sense of their recent departure.

K. Miller [11] identified three stages of socialization process: pre-arrival, encounter, and metamorphosis.

Pre-arrival stage: explicitly recognizes that each individual arrives with a set of organizational values, attitudes, and expectations.

Encounter stage: upon entry into the organization, new members enter the encounter stage. Here the individuals confront the possible dichotomy between their expectations about their jobs, their supervisors, and the organization in general and reality.

Metamorphosis stage: finally the new member must work out any problems discovered during the encounter stage. Metamorphosis is complete as is the socialization process.

In analogy with socialization process of human beings, the stages of device socialization can be mapped as following stages: registration, socialization, allocation, and collaboration, as shown in Fig. 2.

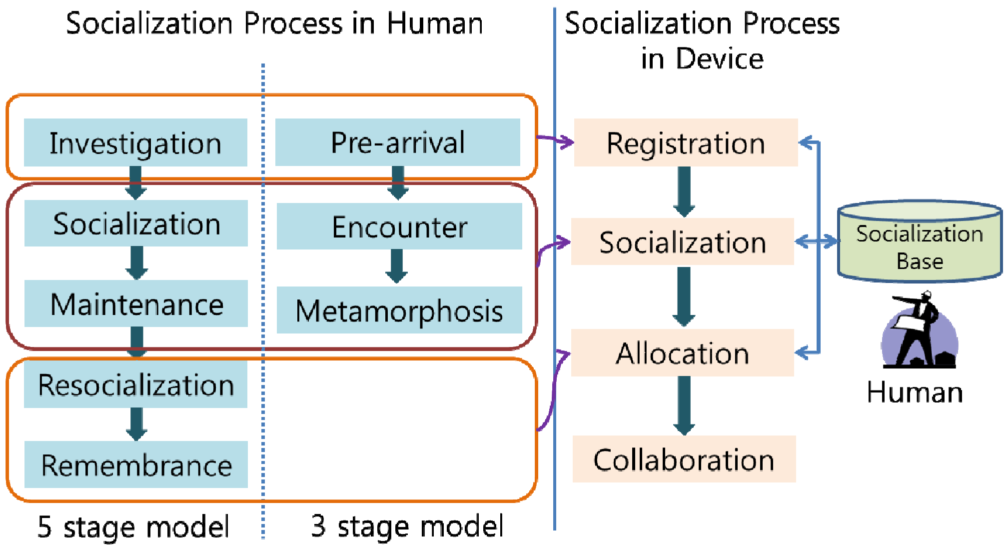

Fig. 2 Mapping of socialization stages between human and device

In addition, there are a number of things, so called 'agents of socialization', that can affect an individual's socialization process [12]. The amount of impact that each of the agents has on an individual will depend on the situation, the individual's experiences, and the stage of life the individual is in. In case of human relationships, the examples of the typical agents of socialization are family, schools, peers, mass media, etc.

In case of device socialization process, the agents of socialization would be owners, location, resources, tasks, etc. Therefore, we should also consider these entities for describing social relationships among devices.

3.3 Socialization Process in DSN

The socialization process usually starts when two entities recognize each another in both cases of human and device socialization. As a method to contact with one another, devices may send or broadcast a beacon message through either NFC (Near Field Communication), Bluetooth, Wi-Fi direct, or Wi-Fi to catch the appearance of devices. After receiving the message, the devices can connect with one another either automatically by themselves or manually by their owner. This action is carried out by the social agent running on each smart device. The social agent, shown in Fig. 3, listens to the event of beacons through conventional technologies, in which the event invokes the registration stage of the device socialization process.

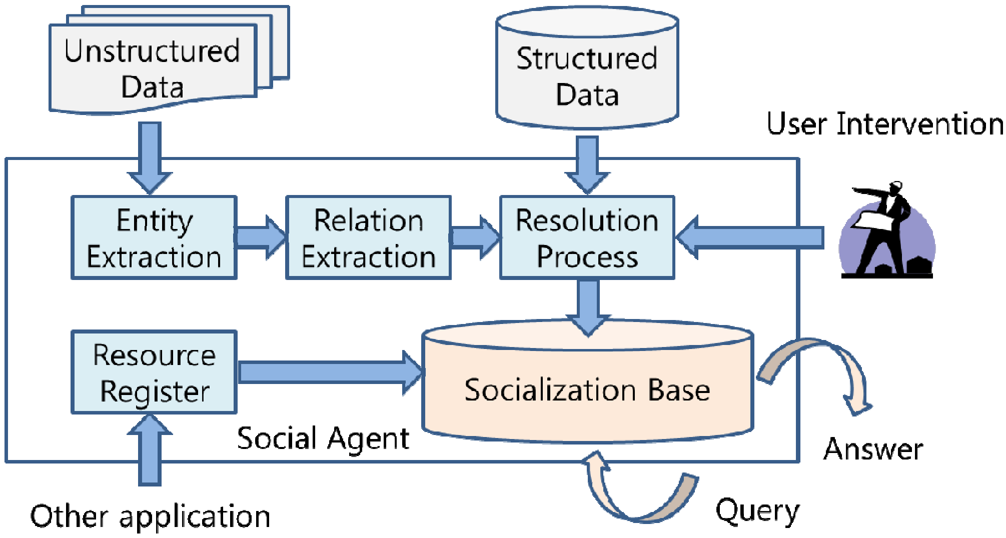

Fig. 3 Social agent in socialization process

To participate in the registration stage, the smart device should have a unique identification and profile describing who it is. We use the MAC (media access control) address as the unique identification and an XML-formatted text file as the device profile. The device profile consists of attributes, functions, services, interfaces, etc. The initial version of schema for the device profile has been standardized in TTA (Telecommunications Technology Association) of Korea [13].

The unstructured data of the device profile are collected by entity extraction module of the social agent. These data are then formatted and stored in the socialization base via the resolution process. In this process, the user can intervene to modify the profile.

To clarify the social relationship between device owners, the social agent can collect their social relationship data from the open social network (OSN) services such as Facebook, Twitter, LinkedIn, Google+, etc. In this process, a user intervention may be needed to access OSNs. The information from the OSNs may help determine authentication and authorization scope for collaborating operations. For instance, certain operations and resources must be permitted to certain devices only whose owner has ‘friend’ relationship with.

Any 3rd party applications that want to participate in the DSN-based collaboration can register their resources with a specification and interfaces. Then, the other applications can query the available service specifications and access the services. This resource information is also stored in the database of socialization base independently. When a new task is requested by a user or any application, required resource information is retrieved from the socialization base, which is used to trigger authorization process.

In mathematical sociology, interpersonal ties are defined as information-carrying connections between people [14]. Interpersonal ties, generally, come in three varieties; strong, weak, and absent. The strength of an interpersonal tie is a linear combination of the amount of time, the emotional intensity, the intimacy, and the reciprocal services which characterize each tie [15].

In social network theory, social relationships are viewed in terms of nodes and ties. Nodes are the individual actors within the networks, and ties are relationships between the actors. There can be many kinds of ties between the nodes. In its simplest form, a social network is a map of all of the relevant ties between the nodes being studied. In our initial work, the strength of the edges in DSN is calculated using the interactions between nodes.

4 Experiment

We have conducted an experiment to investigate the relational implication between human social network and device social network. The purpose of this experiment is to confirm whether relationships among devices reflect actual relationships among people.

4.1 Data Collection

Communication data between devices are collected from ten team members for 24 hours a day and 7 days a week. The recorded data consists of timestamp, sender, receivers, used device, tools, and content type. The types of tools are e-mail, SMS, instant messages, phone calls, and SNS posts. Content types are ranged from a simple text to complex documents. A total of 397 interactions has occurred among the devices during the experiment.

4.2 Data Interactions among Devices

Fig. 4 shows data exchanges among 25 devices of the 10 members in a laboratory, disposing the nodes based on the number of interactions among the devices. In this graph, each color represents a user, who has 2 to 4 network-capable, multifunctional smart devices, i.e. smartphone, tablets, laptops and desktop. The thickness of the edges indicates the number of communication exchanges between the smart devices. Several interesting facts can be discovered in the graph. First, most of the participants use multiple devices in communication. Second, interactions occur more frequently between the same types of devices than between the different types of devices. From these observations, we can infer that there exist certain tasks, which are preferred or must be done using a specific type of device. Devices can detect these interactions by analyzing device social network, eventually become able to make decisions autonomously while executing tasks.

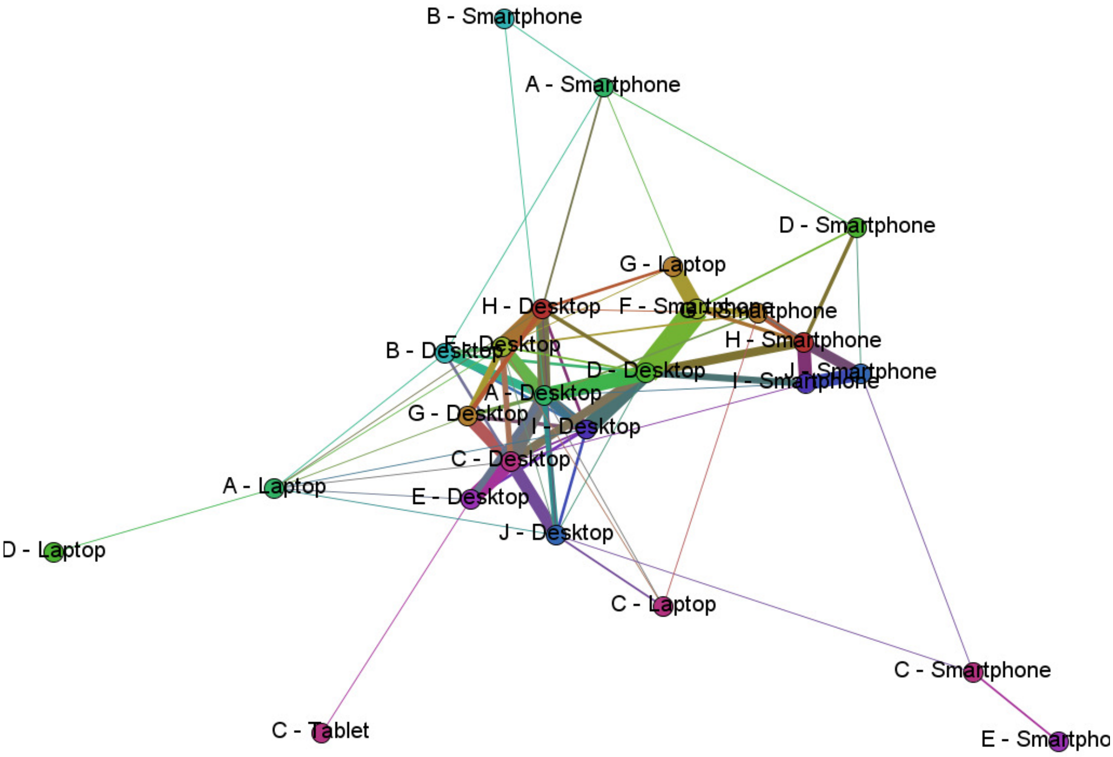

Fig. 4 Data interactions among the devices

In addition, in the device social network, one can easily discover clusters of common interest and their center node. In Fig. 4, for instance, the innermost node of the graph is '*A-Desktop*', which indicates that it has the highest number of interactions with other devices. In fact, desktop is the main device of *A* and *A* is the head manager of laboratory. Furthermore, clusters of common interest can also be detected in the device social network using a modularity algorithm by Blondel et al. [16]. The detected clusters are listed in Table 1.

Table 1: The detected clusters in the device social network (Resolution: 0.5)

Cluster #	*Member*	*Device*	*Members of the cluster*
C0	G	Desktop	A, C, D, E, G, J
	C	Desktop	
	J	Desktop	
	E	Desktop	
	A	Laptop	
	D	Laptop	
	C	Laptop	
	C	Tablet	
C1	I	Desktop	D, I
	D	Desktop	
C2	B	Desktop	A, B
	A	Desktop	
	A	Smartphone	
	B	Smartphone	
C3	F	Desktop	F, H
	H	Desktop	
C4	H	Smartphone	D, H, I, J
	D	Smartphone	
	J	Smartphone	
	I	Smartphone	
C5	G	Smartphone	F, G
	F	Smartphone	
	G	Laptop	
C6	C	Smartphone	C, E
	E	Smartphone	

Then, we compared the detected clusters with the actual groups of common interest. For all 7 detected clusters, we could match them with actual groups in the laboratory, even though a few of them show slight differences in members. It is majorly due to the nature of clustering method that a node can only belong to one cluster, when actual devices are often belong to more than one group activity. The matching result is shown in Table 2.

Table 2: Matching detected device-based clusters with actual groups of common interest

Group Name	*Members*	*Clusters#(Members)*	*Difference*
Project i	A,C,D,E,G,J	C0(A,C,D,E,G,J)	Matched
Project ii	D,I	C1(D,I)	Matched
Project iii	A,B	C2(A,B)	Matched
Project iv	F,G,H	C3(F,H) + C5(F,G)	Matched
Project v	C,E,J	C6(C,E)	1 (-J)
Club	H,I,J	C4(D,H,I,J)	1 (+D)
# of found groups: 6/6		*Sum of difference*: 2	

4.3 Data Interactions among Members

We also analyzed device sociality graph in human-based form, in which device nodes of the graph are grouped if they have the same owner. In the rearranged graph, we can also easily identify the hub nodes with the degree of nodes and the weight of edges. As shown in Fig. 5, *A*, the head of the laboratory is placed at the innermost center.

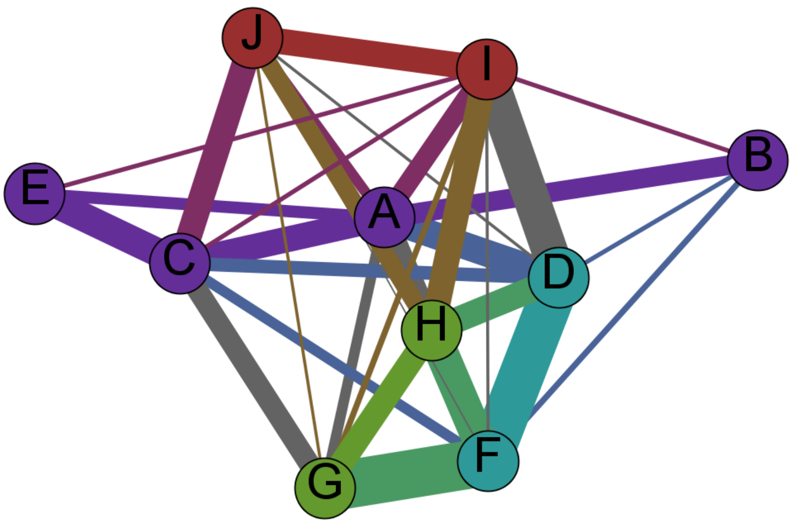

Fig. 5 Data Interactions among Members

In order to detect clusters of common interest, we also ran the modularity algorithm (with resolution 0.5) on this graph, too. In Fig. 5, nodes of the same cluster is assigned with a unique color. Since a node can only belong to one cluster, the problem of people belonging to multiple activity groups gets worse.

Hence, the matching coverage of human-based clustering is significantly lower than that of the device-based clustering. The match result of human-based clustering is shown in Table 3.

Table 3: Matching detected human-based clusters with actual groups of common interest

Group Name	*Members*	*Clusters#(Members)*	*Difference*
Project i	A,C,D,E,G,J	H0(A,B,C,E)	4 (+B, -D,G,J)
Project ii	D,I	H1(D,F)	2 (+F, -I)
Project iii	A,B		2 (-A,B)
Project iv	F,G,H	H2(G,H)	1 (-F)
Project v	C,E,J		3 (-C,E,J)
Club	H,I,J	H3(I,J)	1 (-H)
# of found groups: 4/6		*Sum of difference*: 13	

4.4 User Survey on Human Relationship

We have also surveyed the members for their relationships with the others. The survey consists for two types of relationship: business relationship and personal relationship, each score ranges from 1 to 5. The relationship score of two people ranges from 4 to 20 as it is sum of one's scores toward to another and that of vice direction. Fig. 6 describe the result of the surveys.

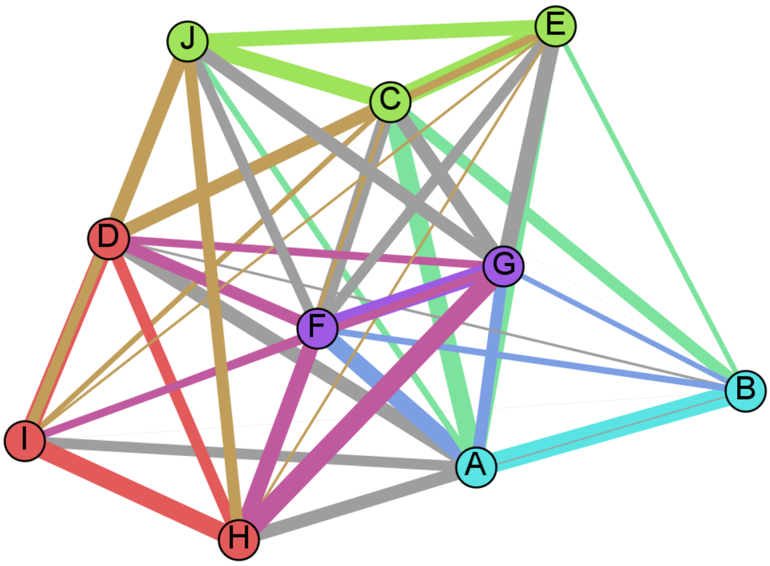

Fig. 6 Relationships among the members (Survey)

An interesting fact discovered from the survey graph is that the edges are quite similar in thickness. In other words, the members seemed to avoid giving low score such as 1 or 2 regardless their actual relationship. Although the overall shape is similar to the human-based device social network, we also applied modularity algorithm (resolution = 0.5) for comparison. The result is shown in Table 4.

Table 4: Matching detected clusters in relationship survey with actual groups of common interest

Group Name	*Members*	*Clusters#(Members)*	*Difference*
Project i	A,C,D,E,G,J	S1(C,E,J)	3 (-A,D,G)
Project ii	D,I	S2(D,H,I)	1 (+H)
Project iii	A,B	S0(A,B)	
Project iv	F,G,H	S3(F,G)	1 (-H)
Project v	C,E,J		3 (-C,E,J)
Club	H,I,J		3 (-H,I,J)
# of found groups: 4/6		*Sum of difference*: 11	

4.5 Discussion

Despite fact that the relationship scores are directly surveyed from the members, the number of matching groups is about 33% lower than that in device social network. Perhaps, the main reason is that people tend to lose objectivity in measuring actual relationship with others. Moreover, as we already discussed, another weakness is that the members belonging in multiple groups decrease the accuracy of discovering exact groups.

In this experiment, we verified the potential of device social network by finding groups of common interest. It can help automate process of configuring and managing device collaboration through identifying and analyzing the groups. Once the groups are found, the common goal/interest can also be perceived by analyzing what kinds of applications and data are exchanged among the members. Device can learn extracted patterns and recommend the user necessary services and possible collaboration.

5 Conclusion

Although smart devices provide a variety of features for user convenience, the users often face burdens of controlling multiple devices and their resources. The burdens of configuring and managing devices increase as the number of possessed devices increases. In order to reduce these burdens, we propose a device social network as a collaboration framework for more convenient device collaboration.

The device social network mimics the human social network and it is constructed by following the socialization process of human beings.

As verification of its feasibility, we conduct an experiment to construct a prototype and investigate the relational implication between a human social network and a device social network. The results of experiment show that relationships among devices reflect relationships of their owners. In addition, device social network is often more accurate than user survey in understanding actual relationships among the users, because digital footprints are far more objective. Lastly, since device social network directly executes and manages services and resources, it can manage authorization at more specific level. This is a significant advantage over management using human social network, because most users have different boundaries in sharing their resources to different groups.

Currently we are continuously improving device social network infrastructure in parallel with elaborating the device sociality. We strongly believe that this paradigm introduces a novel methodology, which bring us much closer to the autonomous device collaboration.

6 Future Work

In this paper, the experiment extract device sociality mainly from communication and data exchange between devices. However, to take full advantage of device sociality and achieve autonomous device collaboration, device sociality must take service exchanges into account. Hence, we are currently developing a middleware that can monitor and keep tracks of more various types of interactions.

In addition, for more accurate prediction, we are working on elaborating device sociality, considering different aspects such as spatial (i.e. location of the device) and temporal (i.e. interaction occurrence time) aspects. We are currently analyzing how these information affects decision making in service authorization.

Lastly, we are also modelling device interactions, because different types of interactions would have different impacts on device sociality. We are applying a number of analytic and machine learning techniques to model the interactions in device sociality.

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