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# Research on social relations cognitive model of mobile nodes in Internet of Things

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ABSTRACT

Interaction and communication between humans with smart mobile devices are a new trend of development in Internet of Things (IoT). With the powerful sensing capability of smart device and human mobility, various services could be provided by building a trusted chain between service requesters and suppliers. The cognition of social relations between mobile nodes is the basis of final mobile-aware services. It involves many decision factors, such as time, space and activity patterns. Using social network theory, a new cognitive model for social relations of mobile nodes in IoT is proposed. Firstly, nodes' social relations are reasoned and quantified from multiple perspectives based on the summary of social characteristics of mobile nodes and the definition of different decision factors. Then the location factor, interconnection factor, service evaluation factor and feedback aggregation factor are defined to solve the shortcomings in existing quantitative models. Finally, the weight distribution is set up by information entropy and rough set theory for these decision factors; it can overcome the shortage of traditional methods, in which the weight is set up by subjective ways and hence their dynamic adaptability is poor. We compare our cognitive model to existing models using MIT dataset by defining a variety of test indicators, such as network overall density (*NOD*), the degree center potential (*DCP*), the network distribution index (*EI*), etc. Simulation results show that, the cognitive model has better internal structure and significant validity in network analysis, and thus can provide mobile-aware service effectively in dynamic environment.



## 1. Introduction

IoT brings great changes to our traditional thinking mode (Atzori et al., 2010) and forms a closed loop including context sensing, information processing and feedback control to the physical world, together with building the information bridge between things and things, things and people, and people and people, and finally generates a new kind of intelligent network. Compared with the Wireless Sensor Network (WSN), the sensing area of IoT is more extensive, and focuses more on people's daily lives and working environment. Therefore, it is not possible to deploy large number of sensor nodes like WSN to achieve the coverage of target area.

Interaction and communication between humans with smart mobile devices are a new trend of development in Internet of Things (IoT) (Gao et al., 2012). Many mobile devices become more and more powerful, such as iPhones and iPads. Different types of micro-sensor devices can be embedded and obtain information interested by users. This awareness information can bring us great convenience in daily life by its rational and effective use. For example, Alice wants to obtain the context information of the target region sometime (such as environmental information, traffic conditions), and provider Bob is currently in this area. So, our research goal is to establish interaction between them, and let Bob provide various services for Alice. In addition, some characteristics of human will inevitably bring new challenges to IoT in the following aspects:

- Humans are not only the consumers of information, but also the participants. However, new awareness nodes, human's mobility, sociality and complexity in space and time will bring new technical challenges to the awareness and transmission of data. Moreover, human has some social natures (Gonzalez et al., 2009); their movement and activity pattern are not aimless and chaotic when they are engaged in social activities.
- In the past studies (Campbell et al., 2008; Pan et al., 2005; Long and Huang 2006; Lane et al., 2010; Boyd and Ellison 2007), it is supposed that humans could interact with each other as long as their communication coverage range is reachable, without considering the trust problem. However, in the actual situation, a trust relationship exists between them, making people only respond to service requests from familiar nodes, but refuse strangers.

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- The emergence of smart mobile devices will greatly expand the scope of human communication. It has broken the constraints of communication in traditional networks. The communication range will be increased dramatically, and even any two nodes can interact with each other.

Therefore, the concept of mobile-aware computing based on the social relations cognitive model in IoT (An et al., 2011a) was proposed. It includes the following steps: firstly, using a variety of smart devices carried by mobile nodes,[1] the virtual social network is formed. These devices can realize the mapping of the virtual society to the physical world with social network theory. Then, we can establish the trusted transmission chain for service requests by means of the trust relationship and social attributes of mobile-aware nodes, discover and choose appropriate candidate nodes which can provide the mobile-aware services in the target area.

As aforementioned, the completion of mobile-aware service needs initiators and providers. We know that the services mainly rely on the social attributes of nodes, whose essence is the evolution of the social relations between mobile nodes. By successfully quantifying the social relations of mobile nodes from physical and social dimensions, the communities can be constructed so as to further establish the trusted chain. The overall goal of service is to improve the real-time performance and reliability of the mobile awareness, and overcome the limitations in traditional network framework. Ultimately, it will be used to solve the problem of awareness hole in sparse network and improve the quality of mobile-aware service in IoT.

All the above points are rarely involved in past studies, so research needs to be conducted by new approaches. To sum up, the main contributions in this paper include:

- This paper introduces a new concept, which is used to guide the completion of mobile-aware service, and summarizes the different social characteristics of mobile nodes in mobile-awareness of IoT, such as sociality, complexity, and so on.
- This paper proposes the social relations cognitive model and defines the various Decision Factors (DF).
- This paper considers the dynamic changes of the social relations between mobile nodes, and then uses the information entropy and rough sets method to study the weight distribution of social relations. The final experimental results prove the validity of the model.

The remainder of the paper is organized as follows: Section 2 reviews and summarizes the existing related work in mobile awareness. Section 3 introduces the system framework of social relations cognitive model, and has an in-depth study of social relations of mobile nodes. Section 4 is a detailed discussion of the modeling process. In Section 5, the feasibility and effectiveness of the cognitive model are analyzed by some experiments. Finally, Section 6 summarizes this article and proposes some future research plans.

## 2. Background

The concept of IoT is formally proposed by the International Telecommunication Union (ITU) (Atzori et al., 2010), and it is a conclusion and extension of the Pervasive Computing, Cyber Physical System (CPS), and Machine to Machine (M2M) in the macro sense. Presently, studies related to mobile awareness in IoT include the following aspects.

### 2.1. Mobile awareness

Mobile awareness achieves real-time sensing of the physical world through the deployment of various sensors in the real world, and with the help of decision analysis like machine learning and data mining, it would be used in different areas, for example, social networks, telemedicine, and intelligent transportation. Campbell et al. (2008) performed some research about the data awareness of sparse sensor networks deployed in a wide range. He introduced the concept of "human-centered" with the background of urban sensing. According to this concept, researchers used mobile phones as the carrier and proposed opportunity sensing and shared sensing, according to the randomness of people. The Pocket Switch Network (PSN) (Pan et al., 2005) jointly developed by the University of Cambridge and Intel research institutes is the opportunity network composed of people carrying mobile devices. All kinds of information could be forwarded through human encounter. Long and Huang (2006) designed and implemented a mobile sensor platform based on the mobile WSN nodes; CONSORTS-S provides the customized context awareness services for the mobile user through communications with the wireless sensor nodes. Lane et al. (2010) studied the current situation and challenges faced by the applications and systems of mobile awareness based on mobile phones, and designed a structure of the mobile phone-based sensing system. Boyd and Ellison (2007) used Facebook as an example, explored the sensing of social networking, information sharing and privacy issues, and pointed out the importance of social networking nature and privacy settings.

### 2.2. Cognitive modeling of mobile node

Cognitive modeling of mobile nodes mainly relies on a variety of sensing devices and positioning technology to survey and analyze the personal location information and behavioral patterns of users, and then it digs out the behaviors, intents, experience and lifestyles of users from this knowledge. Ogata et al. (2001) measured the strength of social relations by observing the frequency of e-mail interaction between nodes. Qiao et al. (2011) proposed a trust calculation method based on the context information of users in the social network. Nicholas et al. (2011) used the mobile phone to automatically collect the GPS information of the mobile nodes and compared the similarity of the nodes to construct the social networks. Li et al. (2008) proposed a measuring approach based on the Hierarchical Position Trajectory Model (HGSM). This method measures the social relations between nodes through analyzing and computing the similarity of the activities trajectories of mobile nodes from the horizontal and vertical dimensions. In this framework, both the sequence and hierarchy dimension of mobile nodes are taken into account. Among these dimensions, the horizontal dimension represents the sequence property of people's movement trajectory, and the vertical dimension represents the hierarchy property of geographical spaces. In addition, the role of mobile phone in human's interaction is taken into account. Zhang et al. (2011) proposed a Socioscope model to analyze the social network and behavior of nodes, on the basis of analyzing the call information between the nodes. Zhang and Dantu (2010) used the Affinity Model (AM) to calculate and predict the dynamic changes of social relations by collecting the phone call records of the nodes in a given time period. The author first assumed that the number of call arrivals is a Poisson process, then used three attributes including incoming, outgoing and reciprocity index to calculate the social relations of

[1] In this paper, mobile node refers to human with various smart devices.