Social Life Amidst the Internet of Things: Using P2P and Social Connectivity

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Abstract

We considered P2P and social network as platforms to link up internet of things in order to integrate them into a seamless social life. Our P2P is a recently updated architecture. A set of rules are devised to instruct IOT to join P2P for eased communication and to join a social network for cooperative interactions that can lead to formation of an online organization.

Keywords: Internet of things, P2P, social network,

1. Introduction

Internet of things (IoT) are algorithmically controlled mechanisms involving networked devices [6][7][13]. Proliferation of IoT introduces them as commonplace agents for interaction in our daily lives. Peer to peer (P2P) is a network engineering paradigm that provides a transient computer network that allows a group of nodes to connect directly with each other to provide certain services; e.g., access to a file, voice, video, a device, etc. This paradigm is applicable to IoT devices that must share resources and objectives in our daily lives. By forming an ad hoc P2P network, IoT nodes can readily share resources; e.g., access to data bases, memory and processing, and a variety of input/output devices. Instead of traditional centralized communication, P2P is also the preferred medium of distributed communication in middleware platforms for IoT [6].

Social networks have afforded social affinity among people. Execution of *social acts* among a group of individuals leads to a plethora of social landscapes with nuanced expressions necessary for social life. A social act is an act that is intended to affect an individual's mental state about relative social standing over some individuals. For a given objective or a claim, social networks (e.g., twitter) identify alliances and allegiances. In order to incorporate IoT in human social lives and to allow IoT their own social capacities for them to possess properties of social agency, we must accommodate IoT with capabilities to form social networks. Eventually, IoT devices need to comprehend and perform human like social acts. In the interim, we aim to empower IoT devices to interact for cooperative, mutual action toward shared objectives.

The combination of social network framework and P2P communication principles produce online environments that feel immersive and natural. This is, as if IoT nodes live seamlessly online with us on social media such as Facebook with some ongoing initiatives as described in [5]. Section 2 outlines some related work. A novel structured P2P architecture is expressed in section 3. Section 4 argues for emergence of nodes in P2P and social network. Conclusions in section 5 culminate our paper.

2. Related Works

We are following a trend that incorporate social networks with P2P [15]. In one perspective, social networks are used to accommodate flexible ebb and flow for existing P2P [9]. This is an application of social networks in service of P2P robustness. In another less explored perspective, P2P is used to allow formation of social networks [12]. Separate from interplay of reciprocal benefits between P2P and social networks, they can be combined in novel applications such as in connecting wifi-enabled vehicle to the IoT systems [10]. A P2P based platform is proposed to support secure online social networks shown in Figure 1, which provide the functionality of common online social networks in a totally distributed and secure manner [5].

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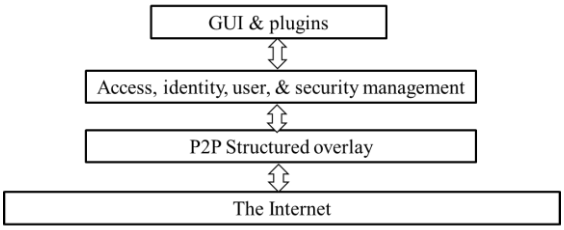

Figure1: Architecture of LifeSocial.KOM (adapted from [5])

Numerous suggestions posit that things in physical proximity form social links creating social networks. Minimally, things provide profiles that include goods and services relevant to other things [3][4][6][9][18]. Hence, we will refer to them as Social networks for IoT (SIoTN) [3][4][14][18]. For effective interaction with human peers and other animals, things need to be equipped with biological sensors (i.e., biosensors) so that their corresponding agents would ascertain conditions of their bio-organism cohabitants. Agents controlling things can use biosensors as proximity sensors and behave in socially meaningful ways. Once agents inhabiting things perceive bio-presence, they may perceive and initiate as well as expect reciprocal sociality.

Settings where humans and things form collaborative teams are fascinating [8]. Typical tasks might be guarding or giving a tour of a large place. There have been attempts to form autonomous robotic ad hoc coalitions; e.g., [18]. Collaborative human-robot exploration strategies also exist where tasks are interchanged between humans and robots [8]. Responsibility, *authority*, *autonomy*, and *power* are other key social constructs to consider.

3. A P2P Community for IoT

Generally, P2P networks use distributed hash tables (DHTs) to achieve efficient data insertion, lookup etc. However, maintaining DHTs is a complex task and require a huge amount of effort to handle the problem of churn. Therefore, the major challenge facing such architectures is how to reduce this amount of effort while still providing an efficient data query service. There exist several important works, which have considered designing hybrid systems [16]; their objective is to incorporate the advantages of both structured and unstructured architectures. However, these works have their own pros and cons. In this work, we have considered designing a hierarchical architecture in which at each level of the hierarchy, existing networks are all structured. We have used Linear Diophantine Equation (LDE) as the mathematical basis to realize the architecture. Note that all existing structured approaches use DHTs and SHA to realize their architectures. Use of Linear Diophantine Equation in designing P2P architecture is a rather novel idea [11] and not in widespread use. We have explored many different possible advantages that can be attained from using LDEs; some of these advantages include efficient handling of data look-up, node (peer) join/leave, anonymity, load balancing among peers, to name a few; besides achieving fault-tolerance is simple. Complexity involved in maintaining different data structures is much less than that involved in the maintenance of DHTs. On several points, LDE-based overlay architecture can outperform DHT-based ones. In this paper, we considered interest-based P2P systems [15][16], where peers in a group are exclusively interested in the same type of resource. Generalization of the work is ongoing. We are primarily focused on presentation of the architecture. In the next section, we discuss the proposed architecture and the mathematical foundation used in the design phase. Subsequently, we highlight the main features of the architecture.

3.1 Our Novel P2P Architecture

We present a structured architecture for interest-based P2P system and the required mathematical basis supporting the architecture. P2P nodes who share an interest will be interested in pooling their resources. Interchangeably, we will use *objective* for interest for when a P2P node is an actor who is attempting to achieve an objective. The following notations along with their interpretations will be used while we define the architecture. We define a resource as a tuple <R_i, V>, where R_i denotes the type of a resource and V is the value of the resource. A resource can take on many values. For example, let R_i denote the resource type 'songs' and V' denote a particular singer. Thus <R_i, V'> represents songs (some or all) sung by a particular singer V'. In the proposed model for interest-based P2P systems, we assume that no two peers with the same resource type R_i can have the same tuple; that is, two peers with the same resource type R_i must have tuples <R_i, V'> and <R_i, V''> such that $V' \neq V''$. Similarly, an objective is a tuple <O_i, A>, where O_i denotes an objective i and A is an action that is appropriate for achieving the objective. An objective may take on many actions. For example, an objective can be to warn occupants of a building about an emergency evacuation situation. This can be achieved via an action of producing an audio alarm or a video display of a text message. We define the following.

Let S be the set of all peers in a peer-to-peer system. Then $S = \{P^{R_i}\}$, $0 \le i \le r-1$. Here P^{R_i} denotes the subset consisting of all peers with the same resource type R_i and no two peers in P^{R_i} have the same value for R_i and the number of distinct resource types present in the system is r. Also, for each subset P^{R_i}, P_i is the first peer among the peers in P^{R_i} to join the system. We now propose the architecture shown in Figure 2 suitable for interest-based peer-to-peer system. We assume that no peer can have more than one resource type. Generalization of the architecture is not considered in this paper.

We shall use solutions of a given Linear Diophantine Equation (LDE) to realize the architecture. The solutions are used to determine the following.

(a) Logical addresses of peers in a subnet P^{R_i} (i.e. group G_i). Use of these addresses will be shown to justify that all peers in G_i are directly connected to each other (logically) forming an overlay network of diameter 1. In graph theoretic term, each G_i is a complete graph.

(b) Identifying peers that are neighbors to each other on the transit ring network.

(c) Codes of distinct resource types.

In the next section, we give an overview of LDEs, which will offer the mathematical foundation of the proposed architecture.

3.2 Linear Diophantine Equation (LDE) and Its Solutions

Let us consider the LDE as stated below.

$$an \equiv b \pmod{c} \qquad (1)$$

where a, b, and c are integers.

Let $d \mid b$, where $d = \gcd(a,c)$. It means that equation 1 has d mutually incongruent solutions.

The above equation can also be stated as

$$an + (-c)k = b \qquad (2)$$

where k is an integer.

Each solution of Equation 1 (& hence of (2) as well) has the form $n = n_0 + ct/d$ $k = k_0 + at/d$ where n_0 and k_0 constitute one specific solution and t is any integer.

Among the different values of n described by $n = n_0 + ct/d$, we note that the d values n_o, $n = n_0 + c/d$, $n = n_0 + 2c/d$, --- , $n = n_0 + (d-1)c/d$ are all mutually incongruent modulo c, because the absolute difference between any two of them is less than c. The values of a, b, and c can be so chosen as to make d very large. There are infinite other solutions, which are congruent to each of the d solutions. For example, all solutions of the form $(n_o + mc)$ where m is an integer are mutually congruent. Similarly, all solutions of the form $[(n_0 + c/d) + mc\}$ are mutually congruent. Examples are found in [10].

3.3 Implementation of the Architecture

Assume that in an interest-based P2P system there are r distinct resource types ($r \le d$). That is, a maximum of d resource types can be present. Note that this is not a restriction, because d can be set to an extremely large value a priori by choosing an appropriate LDE. Consider the set of all peers in the system given as $S = \{P^{R_i}\}$, $0 \le i \le r-1$.

As mentioned earlier, for each subset P^{R_i} (i.e. group G_i) peer P_i is the first peer with resource type R_i to join the system. Now we use the mutually incongruent solutions of a given LDE to define the architecture as follows.

The ring network (shown in Figure 1) at level 1 will consist of all such P_i's, for $0 \le i \le r-1$, and $r \le d$, such that

i) Each P_i will be assigned the logical address $(n_0 + i.c/d)$. Note that $(n_0 + i.c/d)$ is the i^{th} mutually incongruent solution where $0 \le i \le d-1$.

ii) Two peers in the ring network are neighbors if their assigned addresses differ by c/d, with the exception that the first peer P_0 and the last peer P_{l-1} will be considered as neighbors even though their addresses differ by (r-1).c/d. Such an exception is required for forming the ring. This 'exception' makes the joining of new peers having new resource types very simple. This has not been considered in this paper.

iii) Resource type R_i possessed by peers in G_i is assigned the code $(n_0 + i.c/d)$ which is also the logical address of the group-head P_i of group G_i.

iv) Diameter of the ring network can be at most d/2.

At level-2 all peers having the same resource type R_i will form the group G_i (i.e. the subset P^{R_i}). Only the group-head P_i is connected to the transit ring network. Observe that any communication between any two groups G_i and G_j takes place via the respective group-heads P_i and P_j. Peers in G_i will be assigned with the addresses

$$[(n_0 + i.c/d)+ m.c], \text{ for } m = 0, 1, 2, \ldots \quad (3)$$

Note that m = 0 corresponds to the address of group-head P_i of G_i. It is observed from Equation 3 that all addresses in G_i are, in fact, mutually congruent solutions for a given i. Also 'congruence relation' is reflexive, symmetric, and transitive. Therefore, it can be concluded that all peers in a group G_i are directly connected (logically) to each other forming a network of diameter 1 only.

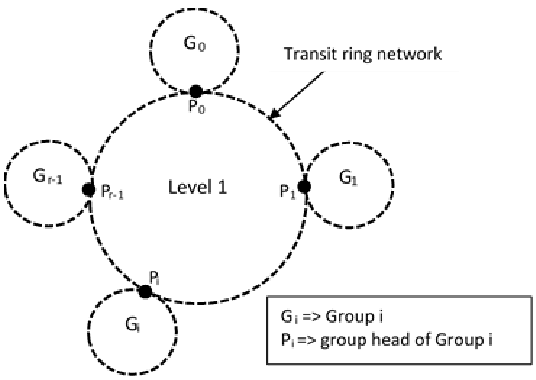

Figure 2: A two-level structured architecture with distinct resource types

3.4 Salient Features of the Proposed Overlay Architecture

We summarize the salient features of the proposed architecture with the following five points.

1. It is a hierarchical overlay network architecture consisting of two levels; at each level the network is a structured one.
2. Use of LDE allows a group-head address to be identical to the resource type owned by the group. We have shown the benefit of this idea from the viewpoint of achieving reasonably very low search latency (we have not considered in this paper).
3. Number of peers on the ring is equal to the number of distinct resource types, unlike in existing distributed hash table-based works some of which use a ring network at the heart of their proposed architecture. [15] [16].
4. The transit ring network has the diameter of at most d/2.
5. Each overlay network at level-2 is completely connected. That is, in graph theoretic term it is a complete graph consisting of the peers in a group. So its diameter is just 1. Because of this smallest possible diameter (in terms of number of hops) the architecture offers minimum search latency inside a group (we have not considered it in this paper).

4. Rules for using P2P and Social Network

We conceive of a rule that specifies conditions for an IoT node to initiate and form a new ad hoc P2P. Entering a P2P incurs communication cost, which is justified by providing a readily more accessible communication link among peers for frequently sharing resources and objectives. Figure 3 depicts this situation by an arrow labeled A. The rule is succinctly stated next.

Definition (Rule A): A node may enter a P2P network to either share a resource or an objective iff the projected gains from frequent communication with peers is larger than the initial cost of forming a P2P. As a logical overlay, such a P2P is a virtual private network intended for peers who mutually determine needs to share specific resources or objectives. Steps for forming this ad hoc P2P are outside our current scope and assumed to be intuitive.

Once an ad hoc P2P network is established, a node in the P2P may further benefit from forming a social link with another node stated in Rule B, shown in Figure 3.

Definition (Rule B): A node i in a P2P may form a social link with another node j with whom it shares an objective O when there are corresponding actions A_i and A_j that mutually contribute to their shared objective O. It is conceivable that pairs of nodes form social links via explicit agreements (i.e., service level agreements or contracts) to collaborate on shared objectives prior to having taken actions compatible for an objective that initially makes their ties tacit converted to overt links by acknowledgement. Continued interactions among nodes may become codified in an *online organization* stated next. For brevity, we have presented online organizations elsewhere in [1] and [2].

Definition (Rule C): A node i that is a member of a P2P and has active and frequent social ties with other nodes in the context of an objective O, may form an online organization with them to address their objective O.

Forming a P2P prior to a social network (i.e., rule A followed by rule B) is just as likely as starting with a social network first and then a P2P stated in the next pair of rules (rule D followed by rule E).

Definition (Rule D): A node that shares an objective O with others and believes that their vector of corresponding group's actions will benefit their objective O, will form social links with the members of the group hoping that their interactions will contribute toward achieving their objective O. Subsequently, such a group may wish to further join a P2P to facilitate their communication that is stated in Rule E.

Definition (Rule E): A group of socially linked nodes will establish an ad hoc P2P in order to expedite their communication.

Once ad hoc networks are established, nodes will be motivated to sustain them by remaining in them stated in the next three rules. Otherwise, nodes may abandon their peers and eventually the networks will be defunct.

Definition (Rule F): A node in a P2P will remain in the P2P network as long as it shares the resource or objective with its peer at the inception of the P2P. Otherwise, it may abandon the P2P.

Definition (Rule G): A node in the social network will remain in the network, as long as there is progress in its shared objective with others at the inception of the social network.
Definition (Rule H): A node that is a member of an online organization will remain a member as long as it perceives they are collaboration propels them toward their shared objective. Otherwise, it may exit the online organization.

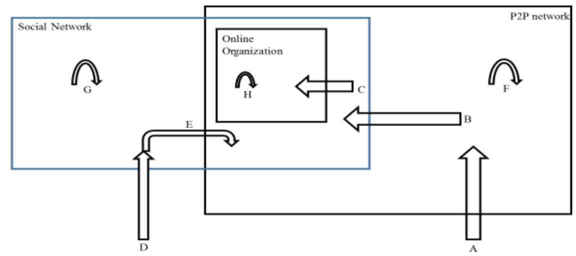

Figure 3: rules for forming and sustaining ad hoc P2P and social network

5. Emergence of P2P, Social Network, and Online Organizations

Following rules in the section 4, an IoT node will follow conditions for initiating as well as participating in the corresponding P2P, social network, and online organization. Such networks ebb and flow in size along with interactions among nodes that share resources and objectives. In order to cluster IoT interactions for efficiency we posit that there are many benefits from ad hoc logical grouping. Far more elaborations are needed to present the full spectrum of benefits from closer interaction among IoT nodes, which will remain as our ongoing research.

We make the observation that P2P and social networks are enabling technologies for IoT node organization as their sharing of resources and objectives demand them. Whereas P2P will lower their communication overhead, social networks will provide them with constructs for cooperative interaction.

Surely, ubiquity as well as diversity of burgeoning IoT in all facets of life will yield IoT populations that must replicate social interactions as in the biological populations. Ad hoc networking frameworks of P2P and social networks as well as online organizations are inevitable constructs on the horizon.

6. Conclusions

We used Linear Diophantine Equations (LDEs) for a novel P2P architecture that affords advantages over other P2P. We suggested using our P2P system for communication among internet of things in order to share resources as well as when IoT work collectively on a shared objective. This is augmented with IoT forming a social network. We delineated rubrics for joining P2P and social network. Online organizations are depicted to dwell on the social network and closely knit IoT are considered to form such an organization. The socially networked IoTs can be considered to be the background fabric on which the organization dwells. We have been developing conceptual frameworks for these electronic organizations [1][2].

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