P2P: The Concept and Its Future Potential

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Abstract

This article reviews the concept and nature of the peer-to-peer (P2P) model. To uncover the essence of P2P, it looks at the notion of genuine P2P, examines the kind of world P2P aims for, and explains the brokerless model as a new business model. Finally, it discusses the latest trends in P2P and the outlook for the future.

1. What is P2P?

P2P (peer-to-peer) is a new concept in information technology that aims to bring about a free, fair, and equal autonomous networked society with only the minimum necessary control or management [1]. The essence of P2P is direct and seamless communication (information exchange) between individual users or user groups, without the intervention of intermediaries or brokers, so it is also known as a "brokerless model" [2]. The brokerless concept at the heart of P2P is put to use in a variety of communication situations. Moreover, the technology for implementing the P2P concept plays a key role in bringing about the world of ubiquitous computing.

2. Brokerless model

The original motivation for proposing the brokerless model in 1998 was the desire to form an autonomous networked society that would be free, fair, and equal and subject to only the bare minimum of oversight [3]. The brokerless model is a concept that aims at a pure and simple world with the following characteristics.

(1) Brokerless

In the brokerless model, the role traditionally played by a broker (e.g., administrators, managers, and management module with central authority) is voluntarily taken on by each user. Various network services are configured and operated flexibly, scalably, dynamically, and inexpensively, without being premised on the existence of a particular broker. It is a new communication model that enables communication (information transmission, delivery, discovery, grouping, sharing, and policy negotiation) directly between users or groups of users.

(2) Self-organizing

Even if user terminals that are voluntarily taking part in the operation of spaces (places) such as P2P networks, P2P services, and the peer group leave, the other user terminals autonomously reorganize themselves to keep the places. This means that the creator of a place can leave too. The remaining peers can reorganize themselves so that the peer group can continue to exist and operate. When the number of member peers falls to zero, the peer group automatically disappears. A peer group can be created without the need for a mediator and without affecting any other peers.

(3) Autonomous (respecting individuality)

Participating in or leaving a user group (place) is left up to each user's discretion. In other words, the autonomy, freedom, and privacy of users are given maximum respect. Users are not forced in or out of a user group. Just as people taking part in volunteer activities do so of their own free will, each of the user terminals takes on and shares its role as a broker autonomously and voluntarily.

One technology devised to implement this brokerless model is the semantic information-oriented network, SIONet [4]. When it was proposed, P2P did not

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exist either as a term or as a concept[*1]. The brokerless model can be regarded as a new business model that preceded P2P.

3. SIONet architecture

SIONet was one of the world's first P2P technologies. It is applicable to a wide variety of P2P services. Developed in 1998, SIONet is a next-generation communication tool that enables users to discover like-minded individuals based on such diverse attributes as personal interests, sense of values, situation, and environment. Using SIONet, these individuals can form peer groups called "event places", provide and share information and services in each group, and forge seamless links and create collaboration across groups.

In SIONet, a host is called an entity (equivalent to a peer). An entity has no fixed identifier, such as an IP address. Instead, dynamic and flexible identifiers (semantic information) are attached to each entity, like "interested in baseball" or "provides medical information". Moreover, events[*2] are sent to entities based on these identifiers. That is, unlike ordinary communication where the question is "to whom" to send an event, in SIONet it is "to what kinds of recipients" to send an event. In other words, event destinations in SIONet are decided based on semantic information, with events being sent only to entities that match an event's semantic information.

Many ideas for implementing this new communication paradigm in SIONet have been proposed, based on the key concepts of flexibility and locality. These include a chain reaction scheme (for passing on events from one entity to others based on metadata), a self-organizing scheme (a brokerless means of forming communities as entity groups (event places) through self-formation, self-propagation, and natural sharing scheme), an application plug-in and sharing scheme (for incorporating and sharing applications in event places), a semi-pure scheme for brokerless authentication, property and entrance mechanisms for achieving an ID-less communication scheme, and a scheme for seamless linkage and collaboration across groups. Common to all these approaches are SIONet's advan-

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*1 As protocols for interaction between peers, there are client/server protocols, peer-to-peer protocol (used by Napster), bucket brigade protocol (proposed by Gnutella), and chain reaction protocol (proposed by SIONet). Here, the peer-to-peer protocol is the classic form of interaction among peers, used also in e-mail and telephone services, for example. Although some papers define this peer-to-peer protocol as "P2P", they are mistaken. The peer-to-peer protocol was defined rather a long time ago as a peer-to-peer interactive method. It is quite different from the P2P (brokerless model) discussed here. For example, while the peer-to-peer protocol is one possible technology for implementing the P2P (brokerless model), it is also possible to use other methods, such as chain reaction proposed by SIONet. A peer, which always provides any information or services, is a server, but not a broker. And a broker is a coordinator, but not a peer.

*2 Events here mean SIONet packets consisting of semantic information and data parts.

P2P chronology

1996-97:
ICQ (instant messaging service) appeared. Groove Networks, developer of Groove, was established. In Japan, research began on SIONet for implementing the brokerless communication paradigm. The term "P2P" did not yet exist at this time[*1], but the concepts on which P2P is based began to emerge.

1998-99:
As P2P file sharing using Napster, Freenet, and other networks enjoyed explosive growth (Napster had some 64 million users at its peak), the term P2P and its concept became widely known.

2000-01:
With the appearance of Gnutella and the proliferation of its clones, P2P gained even more attention. There were also moves to establish more universal P2P technologies, as Sun Microsystems announced its JXTA plans and NTT announced the SIONet architecture. The P2P Conference and other gatherings were held, while standardization efforts began to appear in the P2P Working Group and elsewhere.

Since 2002:
The use of P2P technology in business came to be seen as inevitable, as also seen in the renaming of the P2P Conference as the Emerging Technology Conference, which now deals with a broad range of technologies centered around P2P. While P2P products for business are aimed mainly at large enterprises, many vendors have announced such products. The brokerless notion at the heart of P2P can be seen in grid computing, sensor networks, ubiquitous computing, ad hoc networks, and other areas. In addition, numerous P2P technologies have been the subject of press releases and patent applications in this period, as element technologies for community activation, and as a next-generation communication platform.

tages of privacy, freedom, flexibility, scalability, fault-tolerance, and low cost [3], [4].

4. Future potential for P2P services

P2P gained rapid fame with the advent of Gnutella in March 2000. Lately, the brokerless concept and implementation technology have found wide application beyond file sharing, to areas such as grid computing, ubiquitous computing, sensor networks, and digital appliance networks (**Tables 1** and **2**). Meanwhile, information technology is being introduced into a variety of communities, including volunteer organizations, non-profit organizations (NPOs), local governments, and universities. The aim is to revitalize these groups with a bottom-up approach that emphasizes individuality. One of the keys to attaining this goal is to promote smooth communication in the community and timely information sharing. Indeed, applying information technology (IT) is an important factor in activating communities, and such efforts are part of a growing trend. Here, a community means a virtual group formed and mutually operated by like-minded people. The scopes of its activities are not necessarily limited physically or geographically.

Applying IT to communities should not be an entirely top-down process. A bottom-up approach needs to be taken while the community's situation and circumstances are adequately taken into account. The nature of IT introduction into communities has a strong affinity with the P2P concept of brokerless, autonomous, self-organizing communities. With the great potential for P2P services in community IT introduction being recognized, efforts are now being made to bring such ideas to fruition. Similarly, there are plans to employ P2P technology in the 2005 World Exposition in Aichi, Japan, given the applicability of the brokerless concept to the event's themes of the environment and citizen participation.

5. P2P Forum

The IEICE (Institute of Electronics, Information and Communication Engineers) technical committee on community activation manages a P2P Working Group [5] in which industry, government, academia, and communities themselves cooperate in promoting awareness and the spread of P2P. The objective is to undertake a global effort toward community activation in the real world, shining a light on what communities and community activities will be like in the future, when seamless links are created across the grassroots and voluntary activities of NPOs and volunteer groups, as well as academic activities in universities and corporate activities in companies, and when organic ties are forged across social sciences, the humanities, engineering, and other fields. This undertaking will attempt to establish community-building techniques, field-testing them and promoting their use.

The first P2P Forum [6], held in June 2003, brought together leading figures in the P2P field for panel discussions on "P2P in Community IT". The themes included (1) what is to be hoped for in bringing information technology to local communities, (2) the role, aims, and effectiveness of using P2P in this process, and (3) actual examples of P2P application to local communities.

The second P2P Forum [7], held in October 2003 addressed the theme of merging next-generation technology with the activities of local communities. The participants sought to determine the network needs of local communities from the standpoint of those actually involved on the ground floor. There is a strong desire to see these efforts at promoting P2P awareness be accompanied by actual field trials and practical introduction [8].

6. Future of P2P

Finally, let us look ahead to what is in store for P2P in the future. From the standpoint of content delivery, all kinds of information distribution media, including TV and radio broadcasts, newspapers, and even local advertising fliers, act as brokers between individuals or groups. Before the appearance of the brokerless model, the dominant communication model was one of distributing information to individuals and groups through a broker. As a result, there were major limitations on distribution scope, cost, and flexibility.

From the standpoint of cost and flexibility, for example, it would not be feasible to broadcast live feeds of public seminars from universities or little league baseball games on commercial TV channels. Nor is it guaranteed that requests for urgent notification will be granted in real time. Local advertising fliers are limited in their reach. On the other hand, brokers can select information for distribution and ensure the quality and accuracy of content. A typical example of this is a content database compiled by a public broadcasting station or library, with its large budget.

Ideally, the broker and brokerless models need to be chosen depending on the application field. In other

Table 1.   Examples of P2P services.

- File sharing
- Message exchange
- Distributed computing
- Grid computing
- Content delivery
- Collaboration/groupware
- Distributed search service
- Ubiquitous computing
- Sensor networks
- Digital appliance networks
- E-commerce
- Knowledge management
- *Ad hoc* networks

Table 2.   Actual P2P services employing SIONet.

- Distributed computing (ShareStage)
- Hakuhodo wine diary
- Healthcare system
- Demand vehicle
- Gaming system
- *Ad hoc* network
- Streaming media delivery (personal broadcast station)
- Digital rights management (DRM) system
- Brokerless agent system (COMNet)

words, the brokerless model is not intended to replace the broker model, but to offer another alternative alongside it. At the same time, since the brokerless model was not available as an option until recently, the broker model has been used in application fields where the brokerless model would have been much better. This has created problems that are starting to become apparent to many people now that the brokerless model (P2P) has come onto the scene.

The World Wide Web (WWW) was the technological revolution that opened the door from the broker-centered information delivery model with its lack of flexibility to an individual-centered model (brokerless model) that does not depend on the existence of a broker. On the Web, anyone can start his or her own home page and publish content from it. By defining relationships (hot links) between pages, the content distribution network becomes self-forming, self-propagating, and subject to the laws of natural selection as pages and sites come and go.

The essence of P2P can be seen in the Web. This essence is the ability of users to communicate with each other without assuming the existence of a broker. Whether all users behave on equal terms is not as important as is generally believed. From the standpoint of the brokerless model, the Web is not the polar opposite of P2P, but rather should be seen as the first P2P success story.

Then SIONet was proposed as a model for community self-formation, self-propagation, and natural selection using mechanisms for discovering, grouping, and sharing. As a result, individual-centered communication moved ahead to a new stage. The appearance of P2P technology, of which SIONet is an example, represented an advance from the one-way communication of the Web or e-mail to communication based on participation in communities. In this way the SIONet concept is a highly innovative one, achieving a new communication model applicable to a vast array of scenarios, from tiny niches in daily life to huge businesses. Inherent in this concept is great potential for transforming the way we communicate and the way we live. Its possibilities are limitless. Already there are efforts under way to tap this potential through new forms of communication.

In proceeding, we need to be aware of the relationship with social sciences and the humanities and to pursue basic questions about the nature of communication, asking whether our lives will really be enriched by this technology and how cyber-communities can be made people-friendly. After all, the leading role here is played by human beings, not by technology. Consider the example of the pocket pager. It was designed originally to notify people of telephone calls, but it became popular among young people as a primitive short messaging tool. This is a good example of how users often create forms of communication that were not imagined when a technology was developed. As another example, in the early 1980s, most networking experts and commentators were highly skeptical that the Internet, with its bottom-up approach and best-effort service, would succeed on a large scale. Then when the Web appeared in the late 1980s, many experts likewise voiced doubts about its prospects, citing reasons like the following.

a. Low quality and reliability of content
   The content offered on Web sites would be created and published by individuals. It would not go through a selection process. The supervision, editing, proof-reading, and verification of accuracy that go into producing an encyclopedia would not be applied to content on the Web.

b. Paucity of available information
   When the Web first appeared, it was only natur-

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P2P research milestones

1997: Stream interface devised and prototyped as technology implementing the brokerless delivery model.
1998: Brokerless model advocated as new business model. PREFERENCE architecture proposed.
1998: Semantic information-oriented network architecture devised and prototyped as technology implementing the brokerless discovery model. P2P application software for SIONet test-developed.
2000: "Intelligent places" architecture proposed for community collaboration. This is an advance from simple event places for exchanging events to places having intelligence about matters such as incentive, trust, and policy.
2000: Research started on COMNet as the next-generation SIONet, for implementing the intelligent places architecture.

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al that little information was available on it, but even now the Web still has far less material available than is available from traditional broker-produced content sources. This was of course a chicken-and-egg problem, since without much interesting content there would be few users, and without many users there would not be much content. Only after the amount of content available reached a certain threshold did the Web start to take off, but experts thought this was unlikely to happen given the bottom-up business model in which individual Web users were responsible for coming up with content. Without the existence of brokers offering strategic leadership, critical mass was expected to be difficult to achieve.

c. Lack of incentive (motivation)

Only a small number of people were likely to create content voluntarily without expecting payment. There was scant incentive to produce Web content.

d. Obsolete framework

Lacking such concepts as quality of service, the Web was little more than a plaything. Many people believed falsely that the greater the complexity, the better the technology. In reality the opposite is true.

History has, of course, proven such skeptics to be quite wrong. And now the Web itself seems to be at an historical turning point with the arrival of the P2P era. P2P, based on the spirit of individual, autonomous, bottom-up, and self-organization without the presumption of a broker, is imbued with the mechanism of self-propagation and natural selection not found in the broker-led and top-down approach. Human communication is by nature a spontaneous act of sentient beings. P2P provides a communication model well matched to the behavior and activities of human beings, who desire to disseminate information.

In addition to the mechanism for self-organization and natural selection, in which individuals own their own content and communicate with whomever they need to, when they need to, this model includes an incentive mechanism. The incentive is based on the sense of sharing that derives variously from a commonality of feelings or sense of values; the enjoyment of respect, honor, and praise; a sense of rightness, duty, or mission; a sense of purpose; the joy, satisfaction, and feeling of accomplishment that comes from contributing; give-and-take; fear of penalty; and so on. From this incentive mechanism comes a motivation to participate actively in a community. There is also a mechanism for rating the trust of information. Among the pioneering research projects being undertaken is COMNet, with its concept of "intelligent places" as an advanced form of ordinary event places for exchanging events [3], [9].

It is still too early to know what will turn out to be P2P's killer application (something that P2P alone can do). It is also true that P2P has raised various problems in today's society. The important thing will be to work together to nurture the true P2P society.

Since the appearance of Gnutella, there has been a great rush of companies and universities into the P2P arena. This in itself is good news, but many schemes that are not really P2P are being trumpeted as such. It seems undeniable that "P2P" is being used as a convenient label. This may also be an inevitable result of the rapid way in which P2P has burst onto the scene. As noted earlier, peer-to-peer interaction by itself simply makes use of the conventional peer-to-peer protocol and is not a sufficient condition for being a P2P system.

None of this is cause for pessimism or panic. Moving forward one step at a time is all that is necessary. Even the Internet, which today anyone can use freely, was not so long ago an academic network limited to use by researchers. It was some years before the Internet became a fixture of everyday life. P2P is the same. Up until six years ago, no one even knew of a world in which P2P was possible.

What we need to do now is to discover, one by one,

ideas for making P2P part of our daily lives, then work incrementally toward turning those ideas into reality. If P2P is to spread beyond what it is today, an educational effort will be essential, so that the public can understand that P2P has much greater potential than simply being a means of sharing files (File sharing is no more than one of the areas to which P2P is applicable. Moreover, P2P exists independently of copyright protection issues; there is no direct relationship between the two.). The public today does not have a clear understanding of the essence of P2P. I hope that this article will be of some help in rectifying this situation.

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