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PEER-TO-PEER KNOWLEDGE NETWORKS AND E-LEARNING CLUSTERS OF APPLICATIONS: A CONCEPTUAL AND TECHNOLOGICAL APPROACH OF POTENTIAL BUSINESS VALUE

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Abstract

During the 1990s the Client Server architectures efficiently supported and enhanced e-business applications. Based on this communication model, a number of new fields emerged including: e-learning, Knowledge Management, e-banking, Customer Relationship Management etc. Recent developments have further expanded the capabilities of networking. In this context, Peer-to-Peer (P2P) technology has emerged to secure the one-to-one networking and improve the quality of network services. This paper focuses on knowledge networks establishment for e-learning purposes through P2P technology. A critical analysis of normative literature on knowledge networks is presented followed by a discussion for P2P applications. In doing so, the authors investigate P2P applications in several sectors to reveal the areas of potential convergence. The paper proposes a two-dimensional taxonomy in which types of P2P applications and knowledge networks are combined. e-learning supporting models are identified based on this taxonomy. Thus, the propose taxonomy can be used a decision making tool.

Keywords: Peer-to-peer knowledge networking, e-learning, taxonomy of applications

Introduction

Learning as well as knowledge management is a contextual phenomenon. From this perspective the specific context where knowledge is created, disseminated and used is of significant importance in the course of evaluating possible exploitation for learning purposes. In a generic e-learning environment there is a requirement for a systematic analysis of technologies that support (a) the collaboration of users, (b) knowledge exploitation and (c) learning performance converge in describing ways for high motivating e-learning systems. As a result, the of area knowledge networks in which several actors are participating in knowledge flows or dynamic exchanges should be further studied and analysed (Ezingeard, Chandler and Leigh 2000; Carver 2001). The development of a backbone that integrates the participants in such network can be directly related to e-learning. The isolation of learners and their limited willingness to participate on knowledge sharing practices (Eklund and Woo 1998) need a holistic approach. The development of a knowledge sharing culture requires a psychological shift in self-perception. An e-learner has to feel as a part of a network where collective experiences, attitudes and beliefs are promoting the context for knowledge exploitation and qualitative learning.

Knowledge networks are not a something new. However, the interconnection of knowledge providers, and knowledge users by defining specific flows requires an extensive analysis. Technology provides the mean for the realization but conceptualizations and abstractions provide the underlying logic of implementations. This general statement sets the context of the research objectives

of this paper. Peer-to-peer technology in the last five years has supported the promotion of extensive file sharing initiatives on the web.

The basic notion of cooperative computing and resource sharing has been around for quite some time, although P2P applications have opened up possibilities of very flexible web-based information sharing (Kant, Iyer and Tewari 2001). E-learning is not just information sharing. Learning content requires enormous effort on selecting and integrating several knowledge resources while several others intangible ingredients provide value to the learning product (Lytras, Pouloudi and Poulymenakou 2002c).

The overall objective of this paper is to provide a context for discussion concerning the role of Peer-to-Peer technologies for e-learning purposes. Peer-to Peer networking is providing a wide range of possible exploitation model for learning purposes. In the next sections we will try to elaborate further the employment of P2P technologies for e-learning purposes.

Knowledge Networks and E-Learning

The definition of the term network refers to entities that communicate and exchange information according to specified rules for the transmission. In the case of knowledge networks the main difference is the need to clarify a knowledge sharing culture since the infrastructure doesn't work its self. A knowledge network can be defined as a cooperation of individuals who produce, share or use a common repository of knowledge (Baets 1988). According to Creech and Willard (2001) several types of knowledge networks can be identified. As a result, they proposed a preliminary spectrum of collaboration models, using three basic variables for categorization. In Figure 1 the preliminary spectrum is depicted.

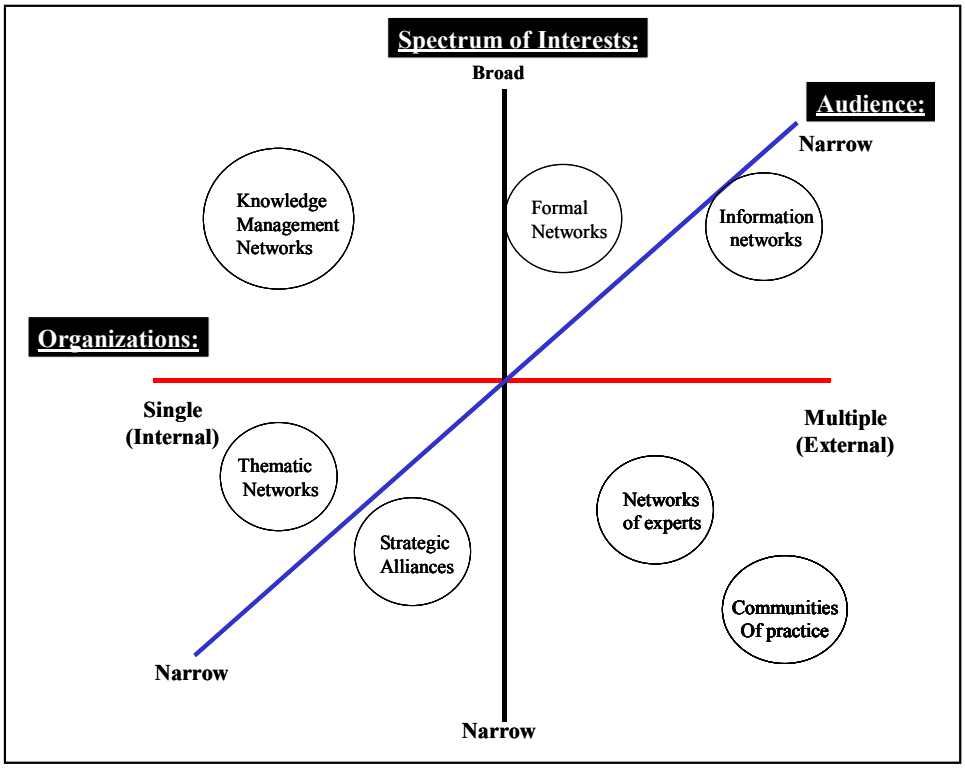

Figure 1. Collaboration Models (Source: Creech and Willard (2001))

According to Creech & Willard (2001) seven types of collaboration models are summarized including Internal knowledge management networks, strategic Alliances, Communities of practice, Networks of Experts, Information networks and Formal networks. Knowledge networks have specific characteristics such as they are purpose driven working networks, which requires institutional commitment beyond the participation of individuals and experts. In addition, knowledge networks are built on

expertise, not just interest and are also cross sectoral and cross regional. Their aim is to develop and strengthen capacity in all members by utilizing their communications capacity. Clark (1998) provides a second classification of networks. Clark (1998) distinguishes informal networks, information networks as well as open and development networks. The basic characteristics of formal networks can be identified as follows. They create and disseminate knowledge for use beyond the membership of the network. Their structure and operation are designed to maximize the rate of knowledge creation. The network must be beneficial for all participants, and the participation is by invitation. Finally there is a well-developed communications strategy, which helps network to cause a reduction of boundaries between sectors such as universities and industry.

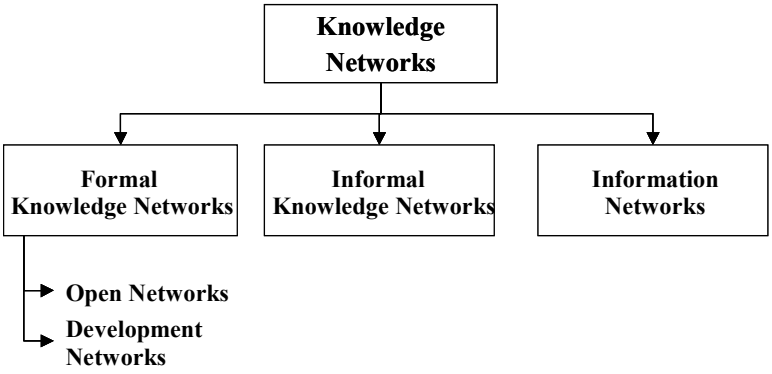

Figure 2. A Classification of Networks (Source: Clark (1998))

Allee (2000) provided an interesting overview of issues concerning the growing need for facilitation and support of communities of practice and knowledge networks (see Figure 3). By using two general dimensions namely Relationships and Connectivity she provided a stack-like taxonomy of groups and networks. From working groups to business networks the whole spectrum is completed by Project teams, Internal Communities of Practice, Extended Communities of Practice and Knowledge networks. Peer-to-Poor technology can support the whole spectrum of groups and networks. Connectivity as a critical factor does not necessarily implies less knowledge performance or utilization. The knowledge capacity of knowledge networks or business networks forces the establishment of effective management mechanisms. The knowledge and the collaboration outcomes as critical resources of a group or a network require an extensive design of routes that link the knowledge sources and the knowledge users. Each arched district in Figure 3 provides a different context for the application of e-learning. From single working groups to business networks e-learning can facilitate the increased demand for effective learning.

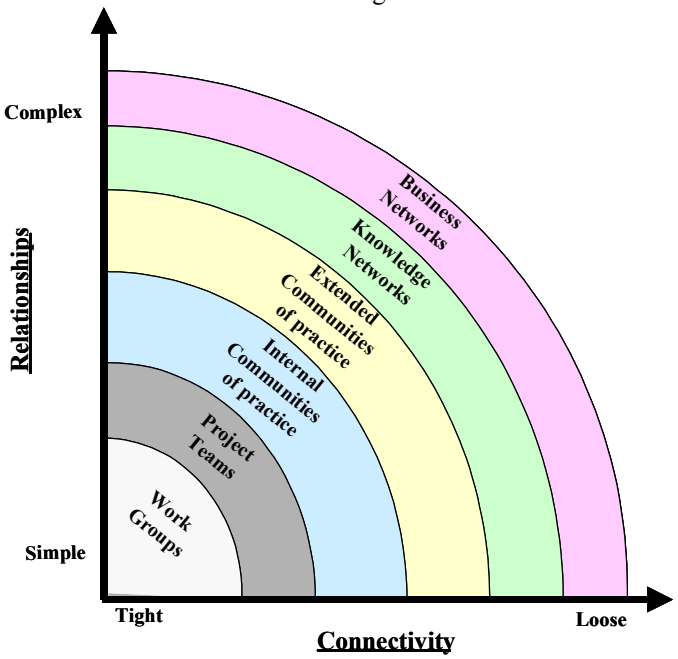

Figure 3. Taxonomy of Groups and Networks (Source: Allee (2000))

The convergence of P2P technology in the direction of supporting the main characteristics of each e-learning context requires a systematic analysis for the specification of five critical variables: Nodes, Processing, Data, Display, Indexes/Catalogues. A more detailed consideration of this key issue will be discussed later. Inherently to knowledge network there is the concept of the knowledge flow. Nissen approach (2002) debates on two basic knowledge-flow models (Nonaka's and Dixon's) and proposes a model of knowledge flows dynamics. Carver (2001) refers to several knowledge flows types:

Table 1. Types of Knowledge Flow

Flow Type	Description
Longitudinal flow	Involves the transfer of knowledge up and down management reporting lines or along 'linear' processes. Can also be referred to as 'Hierarchical flow
Circular flow	Involves knowledge sharing in cyclical planning processes.
Centre to periphery flow	Involves the flow of knowledge and practice from the 'core' of the business out to its remote offices or less central business units and back.
Lateral flow	Involves the 'sideways' transfer and creation of knowledge between staff or units performing like or complementary roles.
Viral flow	Involves the rapid transfer of self-replicating ideas (memes), generally through social networks within organizations.
Networked flow	Involves the transfer of knowledge through the traversal and interconnection of individual networks within the organization.

On a peer-to-peer network the notion of knowledge flow is critical. The fact that several nodes are linked together through direct or indirect connections is not the key issue for the performance of the whole infrastructure. By defining what flows on the P2P backbone is very critical and for the realization of a knowledge network for e-learning purposes. The emphasis on knowledge relates directly to specific boundaries. Knowledge networks focus on information, concepts, processes, procedures and methods important in solving problems across various kinds of local boundaries e.g. communities of practice, organizations, institutions, nations, languages and cultures (Monarch and Levine 2000). Mentzas *et al.* (2001) distinguish between four levels of knowledge networking: individual, team, organizational and interorganizational. Haldin-Herrgard (2000) emphasise that diffusion of tacit knowledge is a difficult task. Parameters such as perception and language and time, value and distance affect the willingness of individuals, teams and organizations to exploit knowledge. The authors, consider a P2P network as the medium for the realization of knowledge flows. The expansion of boundaries due to the extended character of peer-to-peer networks seems to fit better in the context of e-learning where the learning performance is directly related to knowledge utilization (Lytras *et al.* 2002a; Lytras, Pouloudi and Poulymenakou 2002b). In next session the authors investigate some critical concepts of P2P technologies and their implications towards the specification of potential clusters for e-learning applications.

Peer-to-Peer Concepts and Implications

In a client/server model, a server receives requests to serve several clients and decides the resources allocation. For many years this architecture secured high performance while computational power and available resources of clients were limited. Nowadays the majority of clients are characterized by increased capacity of processing and enough resources. In this case the client server model is utilized only in the case where all clients' resources are used for supporting tasks. Peer to peer technology sounds very promising especially concerning the establishment of a backbone for the exploitation of knowledge. Gartner Group (2001) provided a classification of P2P applications and emphasized on five application dimensions: Data, Index, Directory, Processing and Display.

These dimensions are of critical importance in case of knowledge networks. Transmitted data within knowledge networks maybe structured or unstructured and supposed to have several locus such individuals, teams or organizations. Indexes provide the logical links to data elements and from this perspective they indicate resources, facilitating knowledge exploitation. Directories differentiate from indexes since they provide direct linkages to users. A classification of P2P models is provided by Gartner Group (2001) in which five peer-to-peer models are distinguished: Atomistic, User centred, Data Centred Web MK2, and compute centred – distributed processing. Each of these models can be critically reviewed to evaluate its appropriateness for the support of specific modes of knowledge exploitation but this will be a later task.

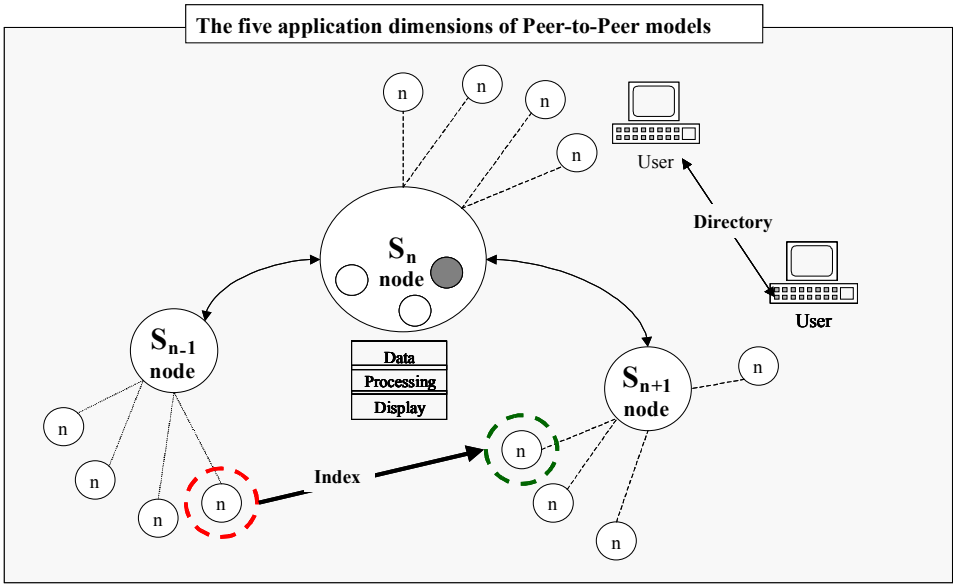

Figure 4. The Five Application Dimensions of P2P Computing

Peer-to-Peer architecture can be found in older services and protocols. UUCPnet, SMTP and IDRP (Inter-Domain Routing Protocol) protocols present specific features that characterize peer-to-peer networks, such as the absence of central authority in the system as well as the capability of each node to provide and accept services. Several applications were developed on the above protocols (FreeNet, BearShare, Gnucleus, Morpheus, Shareaza, Swapper, XoloX, LimeWire, Phex). Peer-to-peer networks are based on the rule that better utilization of resources (processing capacity, bandwidth, main storage) is achieved when instead of a central server, all the nodes of a network are used peer-to-peer. In simple words in such architecture every network node is client and server concurrently. This characteristic is so-called as servant. The term resource refers to a greater context of services that can be allocated in a peer-to-peer network. In the common case resources are supposed to be data files which through a file-sharing service (e.g. Gnutella - Napster) are transmitted on the peer-to-peer network. As a resource it can be considered also the storage capacity in the node of the network (e.g. idrive) as well as the processing capacity of a node (e.g. SETI@home, Cancer Research Project, Genome@home,).

Table 2. The Five Models of P2P (Source: Gartner Group (2001))

Peer-to-Peer Model	Characteristics
Atomistic ("true" P2P)	It involves direct client-to-client connectivity without any mediation by servers There is no method for establishing communication links based on data availability or user identity
User Centered	Utilizes a directory (distributed or on a single server) that facilitates user connections
Data Centered	Allows users to search and access data and content held on other users' systems
Web Mk 2	They integrate the three previous P2P types into task-specific environment Multiple directory services will link users together on an ad-hoc basis allowing access to different forms of data, whether on servers (Web, FTP, application servers) or on client systems
Computer Centered – Distributed Processing	An application' s processing is split between multiple clients. A server is used to coordinate the split processing. The nodes are distributed over the Internet and used on an opportunistic basis.

In most cases the development of architectures and protocols based on P2P architecture required extensive research effort aiming at maximizing the utilization of resources. A good example is JXTA protocol of Sun. File sharing services have been a great success through peer-to-peer networks as well as services concerning distributed processing. Especially in the case of exploiting processing power, storage and bandwidth the capabilities and the functionality of peer-to-peer networks can be compared to systems based on grid computing. P2P networks became well known due to their use for illegal tasks such as illegal file sharing

without paying IPRs. Additionally according to security gaps on P2P applications several worms (e.g. VBS.GWV.A and W32.Gnuman) were transmitted through their channels. This situation empowers the belief that P2P networks are possible threats for the security of users, companies or organizations. P2P networks can be classified in several categories according to the degree of centralization that provide. There are fully centralized P2P networks half-centralized and hybrid architectures based on both client server and P2P approach.

Hybrid P2P Networks

Hybrid is a P2P network that uses a mixed architecture, which integrates features from both the theory of P2P networks, as well as from the client/server architecture. In this case there is usually a supernode, which is responsible for the overall management of the network. A major task of super node is to maintain indexes that specify resources on each node. When a node requests a resource the supernode informs the applicant node by returning the address of the node where the resource resides and not the resource per se. Subsequently the applicant node connects to the specified node and uses the resource. The most known application that uses the hybrid P2P – client/server model is Napster, while several instant messaging programs are based on the same philosophy. In hybrid P2P networks is very convenient to summarize available resources on each node. The most significant obstacle in this model is the "single point of failure". If the supernode drops then the whole P2P network collapses (this is the case of Napster where supernode due to legal pressures stopped its operation). Hybrid networks can be effectively employed for learning purposes. An excellent example is the case of an immediately updated networked encyclopaedia.

Fully Decentralized P2P Networks

The demand for autonomy in the context of P2P applications and the requirement to overcome the "single point of failure" decentralized protocols were developed and used. Gnutella is one of the most known. In the initial edition Gnutella was fully decentralized. The major advantage of this architecture is the fault tolerance towards node malfunction. Overall network will continue to operate even though a great number of nodes collapse. Several problems have been encountered when there is a big number of nodes on the P2P architecture. For example, the indexing of resources on the network is becoming quite problematic while significant overload slows down the performance. Considering the potential of fully decentralized networks for learning purposes we can concentrate on several applications. Networks of experts and communities of practice could be configured through P2P networks. In the near future we expect a great number of such networks to be established contributing to the scientific productivity and the knowledge exploitation.

Partial Decentralized P2P Networks

Partial decentralized networks were developed in order to overcome the problems encountered on fully decentralized networks especially concerning the problematic operation when the number of nodes exceeds a specific number. In partial decentralized architecture we distinguish between supernodes and nodes according to the available resources of each node. There are few supernodes proportionally to the total number of nodes. Each node connects at least to one supernode and uses several services such as the search of remote nodes. A critical variable for the categorization of nodes depends on their availability. Obviously a permanently connect node would be selected as a supernode instead of an occasionally connected one. The second version of Gnutella is based on a partial decentralized architecture. In the context of universities a partial decentralized network could support their integration. In a network of research centres and universities (supernodes) researchers (nodes) could search on adjacent nodes (researchers on the same institute). In case of absence of requested information the supernode could provide links to other supernodes of the whole P2P network.

Towards the Development of a Taxonomy for E-Learning Peer-to-Peer Applications

The integration of knowledge networks and peer-to-peer architecture is promising. The capacity of peer-to-peer networks to utilize the content sharing and the establishment of communities foster our research interest to enlighten the possibility of a convergence in the context of e-learning. An interesting project concerning application of P2P architectures for e-learning purposes is EDUTELLA (Nejdl, Wolf, Qu, Decker, Sintek, Naeve, Nillson, Palmer and Risch 2002) which stands for a project aiming to facilitate the exchange of educational resources (using schemas like IEEE LOM, IMS and ADL SCORM). In Figure 5, an initial taxonomy of possible e-learning applications based on P2P technologies is depicted. A two dimensional matrix is used in order to summarize the key areas of potential exploitation. The type of intended knowledge network and the type of peer-to-peer

architecture are combined in order to specify six areas of contribution. In each cell we provide key e-learning application types. Our objective is to expand further the above conceptualization in order to reveal how the technology can support the theoretical foundations of each cell. The underlying logic of our contribution is that P2P networks as the backbone of e-learning applications instead of traditional client server applications promote further the learning effectiveness and the knowledge utilization.

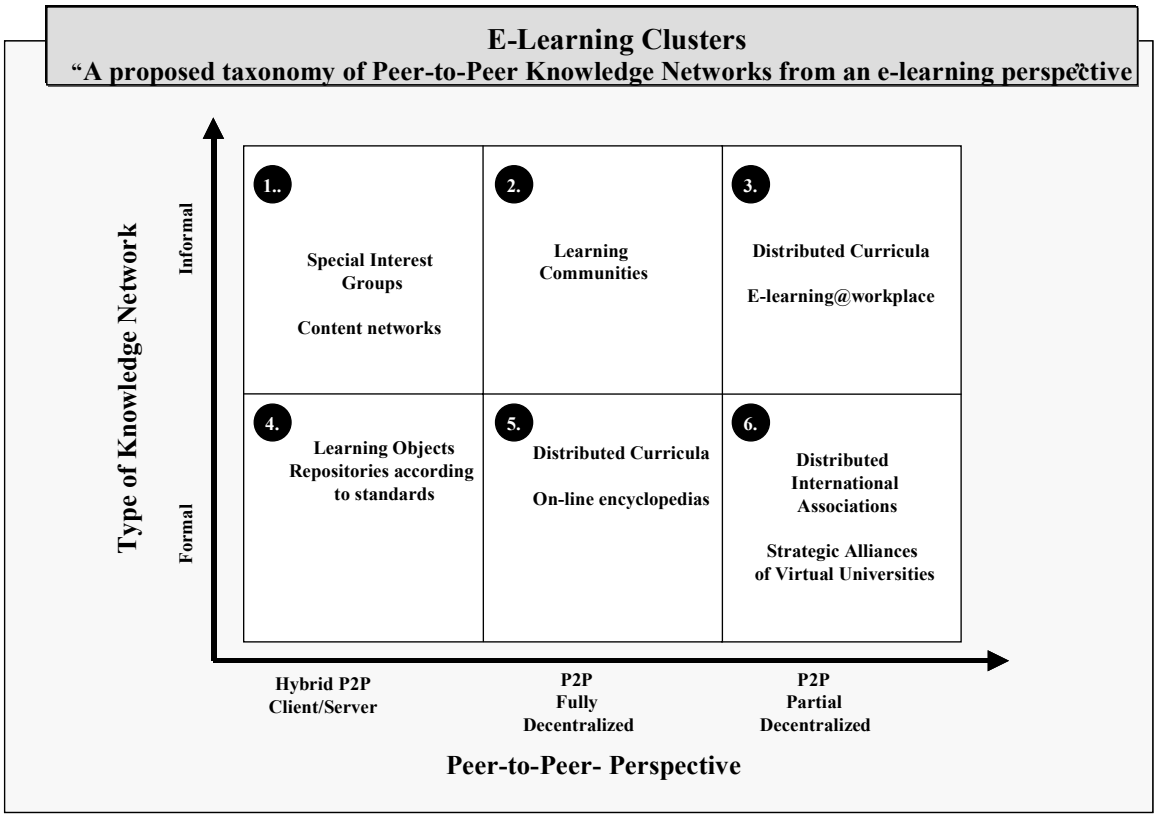

Figure 5. E-learning Clusters for P2P Exploitation

Nine clusters of applications are mapped on the taxonomy:

- ***Special interest Groups (SIGs)***: Informal knowledge networks where a central supernode facilitates the building of a knowledge sharing culture. The presence of a supernode serves the major need to map every resource on the SIG.

- ***Content Networks***: Informal knowledge networks where a central supernode fosters content exchanging. In this case there is a great business opportunity. The integration of several content distributors and the development of metadata standards for P2P networks is the prerequisite for significant cash flows. In this context another critical issue is the development of incentives for sharing in peer-to-peer networks (Golle, Leyton-Brown and Mironov 2001).

- ***Learning communities***: Informal networks of people involved in learning context. Tacit and explicit knowledge dimensions of such communities require an integrated consideration of techniques for knowledge acquisition and exploitation (Byrd, Cossick and Zmud 1992). A learning community is a huge knowledge repository but also and a context where new ideas and insights are generated. In this type of networks a critical application layer would be the development of plug-ins that could mine from the whole backbone relevant learning objects. The dynamic synthesis of learning content through the repositories of learning communities is a challenging research issue. Several disciplines could contribute on such goal: Psychology of e-learning,

- ***Distributed curricula:*** Distributed curricula refer to the establishment of P2P networks where a formal mechanism designates procedures and processes for the enrolment on undergraduate, graduate or postgraduate studies. Several super nodes mainly on Universities, Businesses and Research Centres would expand further the supposed borders of educational systems. This

perspective reflects the new era in collaborations of academic institutions. The development of master programs where the whole curriculum is provided by a ring of universities looks quite interesting and embeds a multicultural philosophy.

- ***E-learning@workplace*** applications stand for the ability of P2P networks to bring together workers and other participants in any working setting. Such systems could facilitate processes such as skills building, problem solving (by linking experts) and experience codification. The availability of a peer-to-peer network as an underlying infrastructure of every business setting expands further the flexibility for decision-making and sensors the requirements for personal and organizational development.

- ***Learning Objects Repositories*** according to specific standards is another area of possible contribution of P2P networks. Several schemas provide standards for the enrichment of learning objects. Their formalization and a central supernode could index available resources on the Web. Nowadays several dispersed systems based on traditional client/server model provide limited services relevant to Learning Objects indexing and retrieval.

- ***On-line encyclopaedias:*** A P2P network can support flexible mechanisms of mining content. The traditional librarian-approach of accumulating enormous digitized contents in huge repositories and the development of inflexible indexes of available resources can be reengineered through P2P networks. The integration of many peers can assist the overall objective to establish flexible ways of content selection and packaging to greater meaningful units such as encyclopaedias. Another facet of the same logic could be the development of manuals of experts where cooperatively their wisdom could be summarized in dynamic containers.

- ***Distributed International Associations:*** A formal International Association (e.g. AACE) could gain significant advantages through the development of a P2P network. Researchers, Academics, Consultants, Students, Policy Makers, Managers and other roles could exploit a P2P infrastructure relevant to a subject e.g. e-Learning. The strengthen of a knowledge sharing culture in the context of an association is rather an easier task.

- ***Strategic Alliances of Virtual Universities***. Several virtual universities nowadays offer courses or full programs on the Internet. In the case of Strategic Alliances the scenario is more market oriented: Executives training requires a holistic orientation on curriculum development. Universities with different specialization could provide programs that capitalize on the synergies of integration.

This work is concentrated on the detailed analysis of required architectures for the realization of the clusters. Another classification of P2P networks already mentioned, is the one who distinguishes five peer-to-peer models. Atomistic, User centered, Data centered, WebMK2 and Compute Centered can be employed for the integration of formal and informal knowledge networks. Knowledge management in general can be focus on artifacts (knowledge objects) or on processes that manage artifacts and promote their value to users. E-learning and knowledge management convergence proposes that e-learning can be analyzed as a process and as a product implying that several value adding processes are employed in order to diffuse the value ingredients of learning objects. According to this approach we have developed an initial taxonomy of e-learning clusters that are not complementary to the others mentioned before but provide more challenges for possible employment of P2P networks. In this second taxonomy the two dimensions used are ***E-learning perception*** and ***Peer-to-Peer Model***.

In Figure 6 the revised taxonomy is presented. Ten clusters with several applications are summarized. Each of them requires a more elaborate analysis. For the subsequent analysis it is required a more concrete definition of what means a cluster but this goes beyond the scope of this publication.

This set of P2P applications in the context of e-learning requires a detailed specification. In a future publication we are going to provide a more technological-oriented approach in order to describe the basic logic of each cluster.

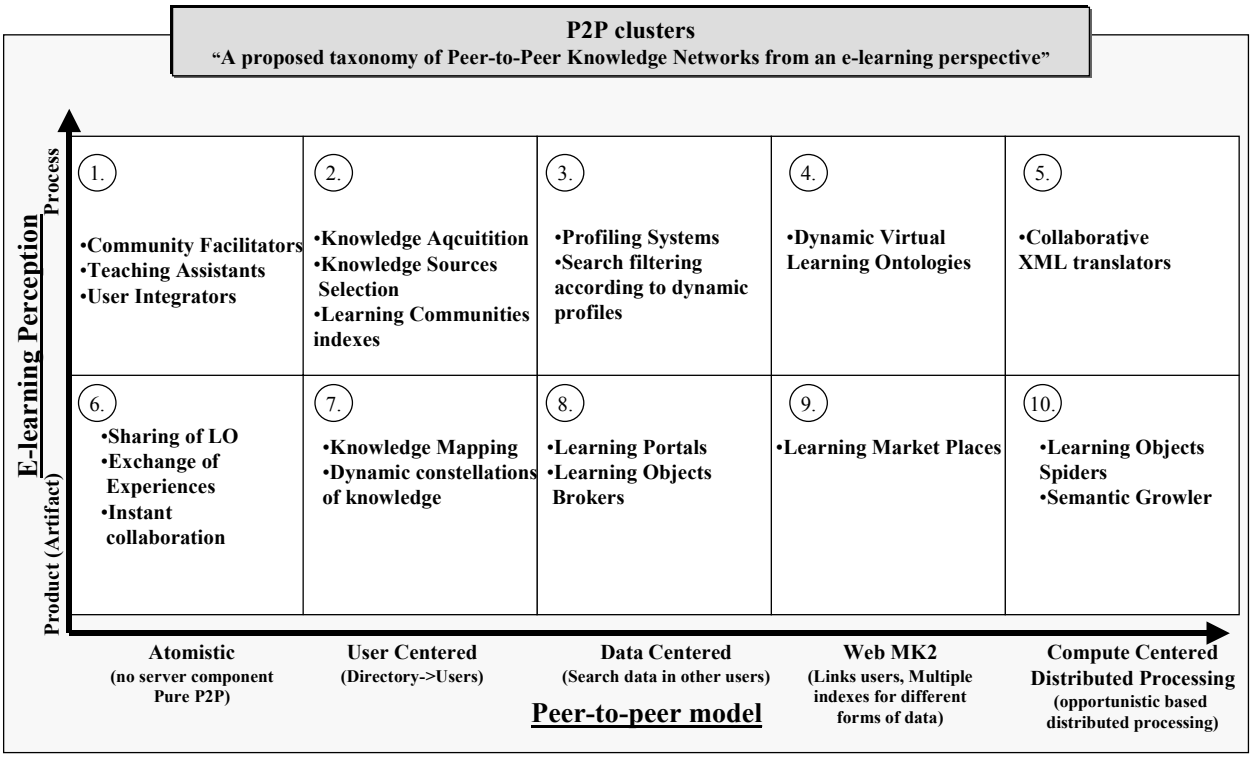

Figure 6. E-Learning Clusters for P2P Exploitation (II)

Conclusions and Future Research

P2P technologies provide an interesting research context. Especially in the case of e-learning where the learning phenomenon requires a multifold support. Tacit and explicit knowledge exploitation can be based on specific clusters of applications. A revision of the above taxonomy is under development. This is accompanied by a layer-based abstraction where according to the general OSI model specific applications for e-learning purposes are depicted for each layer. For example consider the presentation layer of the OSI model where it would be necessary the development of a browser-based tool able to mine through the P2P infrastructure of several learning objects. In the next months we are going to test JXTA protocol of Sun in several clusters in order to analyze deeper the several issues that affect learning performance. Our belied is that in this area there is enormous potential business value and several products can be developed aiming at capitalizing it. We are welcome any comments that could strengthen our research effort.

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