Review and Comparative Analysis of Distributed Knowledge Management Systems

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Abstract. Distributed technologies attract researchers interest as they propose many technological, but as well organizational and end-user benefits. With development of Web 2.0 and Cloud computing, distributed networks are considered as new source of business opportunities. The present research will identify advantages and limitations of distributed knowledge management systems (DKMS). Thus technologies and models of distrubuted KMS will be assessed as an alternative approach to centralized KMS. A review of several theoretical DKMS model will be made in order to outline the common characteristics and alternative approaches to DKMS architecture. At the end will be summarised conclusions for development of new theoretical model of user-centered DKMS.

Keywords: Distributed knowledge management systems, Centralized knowledge management systems, peer-to-peer knowledge management systems

1 Introduction

In response of the increased complexity and globalization, companies have quickly transformed its hierarchical structures to flexible business networks, heavily depending on interorganizational and intraorganizational communication [1]. Fast acquiring, processing and sharing knowledge is admitted as substantial factor for success, explaining why knowledge management (KM) gain much popularity among practitioners and researchers. The new business models accelerate evolution of new forms of cooperation with knowledge workers within and outside organization[2]. While centralized KMS put the focus on organization but remain underused in many cases, distributed knowledge management (DKM) propose an alternative people-centered approach to support knowledge work.

The present research aims to summarize and to assess the main advantages and limitations of distributed architectures and peer-to-peer (P2P) technologies to KM. Firstly distributed systems and P2P networks will be assessed in the context of KM, reviewing the basic applications of P2P systems and its advantages and limitations. The second part will present the principle KMS architectures. Afterwards, a short review and comparative analyses will sumarize the models of distributed KMS, proposed in literature. Finally some conclusions and future work roadmap will be identified.

Distributed Information Systems (DIS) represent collections of networked

information resources in some kind of interaction with communities of users [3]. For example Internet, WWW, corporate intranets and databases are DIS. The distributed systems approach regain popularity with the emergence of Web 2.0, mobile applications, cloud computing, development of internet of things and embedded systems.

P2P systems are distributed systems composed of independent nodes that run software with equivalent functionality without centralized control or hierarchical organization [4]. The general interest to P2P architectures is due on their ability to function, scale and self-organize, in the presence of a highly transient population of nodes, networks, and computer failures and without the need of central server [5]. According the literature [4,5,6,7], the P2P are well suited for KM because of their scalability, acceleration of communication processes and reduced collaboration costs, lack of centralized control, freedom to express, privacy of the user data (bigbrother phenomena), increased access to resources, opportunity to maintain own knowledge structure and to conserve original knowledge context while exchanging knowledge. There exists as well a number of limitations of P2P technologies [8], concerning connectivity, security, privacy, especially the risk of unauthorized access to confidential and private information, the installation of unwanted applications, fault tolerance, availability. The P2P architectures have been employed for a variety of application categories [5] as: communication and collaboration (chat, instant messaging, VoIP), distributed computation, Internet service support (as multicast systems, Internet indirection infrastructure and security applications), content distribution (sharing digital media). Finally the most common applications of P2P remain the file-sharing and communication wich are the main issues in KMS.

2 Review of KMS

KMS are widely defined as IT-based systems developed to support/enhance the process of knowledge creation, transfer, and application [9]. KMS are complex socio-technological systems and require a special attention because of the difficulty of their applications in practice and low success rate.

There is no single approach for building a KMS that could fit to all industries. In general, three different approaches can be observed in KMS design, which are bottom-up, top-down and middle-updown [10].The bottom-up approach put more emphasis on people needs, while the top-down approach is based on the classic hierarchical model of decision making. Finally the middle-up-down approach reflects the need of intermediary position between top management and end-users needs and requirements. The both general KMS types are centralized and distributed KMS.

2.1 Centralized KMS

Centralized KMS (CKMS) have been longly prioritized because of their focus to collect, organize and provide access to pool of documented knowledge within organization [11]. Most CKMS aim at creating large, homogeneous knowledge repositories, in which corporate knowledge is made explicit, unified, represented and organized according to a unique conceptual schema.

The common outcome of Centralized KMS is the creation of an Enterprise Knowledge Portal (EKP), a (web-based) interface which provides an access point to corporate knowledge. The underlying representation of EKP is typically unique and enables communication and knowledge sharing across the entire organization, based on unified conceptualization of corporate knowledge [12].

Centralization brings some advantages in terms of scope, control and organisation, and enable organizations to consolidate their knowledge base [11]. However, CKMS application requires advanced machines, optimized systems, and sophisticated search technologies, which could be expensive [13]. Further, CKMS are slow to adapt to new developments, they hardly respond on personal needs of individuals, require additional efforts and time to insert knowledge and in general are not conformed to business processes. As a consequence, often CKMS lack user acceptance and don't live up to the initial expectations [14]. Limitations of centralized KMSs can be summarised as follows [13]: the cost of implementation is high, too much effort must be put in its construction and integration, the knowledge codification remove its context, only marginally satisfy integration requirements, inefficient at capturing tacit knowledge and retain only the encoded knowledge certified by the "organisation".

Apparently, the limitations of centralized approaches are not technological, but mainly organizational. They create a mismatch between social and technological architectures [12], which limit knowledge acquisition and dissemination possibilities [15]. The centralized approach and its underlying objectivist epistemology, is one of the reasons why so many KMS are deserted by users [12].

2.2 Distributed KMS

Distributed KM (DKM) is defined as management of autonomous groups that create local knowledge and exchange it across groups [12]. Distributed KMS are commonly described as socio- technical KMS aiming to actively engage users in knowledge acquisition and dissemination process (push and pull approach). DKMS enables both the utilization of tacit and explicit knowledge and merge knowledge from different organizations in a transparent to the user process [15]. DKMS is based on the principle that the multiplicity (and heterogeneity) of perspectives within complex organizations should not be viewed as an obstacle to knowledge exploitation, but rather as an opportunity that can foster innovation and creativity [16]. DKMS are often based on P2P collaboration and rely on bottom-up knowledge management.

DKMS respond on 2 basic principles – autonomy and coordination [17]. Autonomy designate the possibility each organizational unit to have the opportunity to conceptualize its local knowledge through maps, ontologies, contexts etc. This could be also achieved with tags and folksonomies. The second principle – coordination, reflects the mechanism of projecting what other units know into its own interpretation schema. Thus DKM suggest autonomous management of locally produced knowledge and coordination among different units without centrally defined view.

Advantages of the P2P DKMS are [11]: autonomy (using local knowledge representation scheme), direct communication (no filters), flexibility (configuration of temporary networks), improved acceptance and access to

knowledge. The P2P approach help to resolve some of the main limitations of CKMS and namely[11]: reduce costs of design, implementation, and maintenance of centralized server; simplify system complexity, reduce the barriers for participation, integrate the shared knowledge work space with personal knowledge work spaces.

2.3 Comparative analyses of CKMS and DKMS

Table 1 summarizes the main features of CKMS and DKMS architecture [18]:

Table 1. Comparative analyses of Centralised and Dictributed KMS adapted from Lehner (2008) and Maier (2005).

	Centralised KMS	Distributed KMS
Focus	Technology-oriented	Human-oriented
Type of Knowledge	Objective, stable, widely approved and principle knowledge	Ad-hoc, subjective, unsertain, focused, personalized knowledge
Organizational Structure	Hierarchy and departments	Project teams, Communities, Ad-hoc groups/inside/ outside organization
Database	Centralised database with organizational ontology	Decentralized database, with group or individual ontology/taxonomy
Content	Lessons learned, knowledge products, secured knowledge, ideas, experiences, individual contents	Individual content, ideas, results of group experience, lessons learned
Goal	Protecting and reuse organizational knowledge	Managing knowledge according the personal needs
Organizational Culture	both types of culture (restrictive or loose)	open, trustful culture
Type of knowledge	Common knowledge interpretation scheme	Specialized knowledge areas

3 Review of Distributed KMS models

Distributed KMS can be based on various technologies and architectures. A short review and comparative analyses of DKMS models will allow better identification of architecture type and principles behind systems. The proposed analyses will be limited to comparison of theoretical models, as there lack empirical data for detailed DKMS assessment. Among the most popular P2P platforms in practice are Groove, JXTA and Magi [19].

KEEx (Bonifaceo) [7] is a DKMS based on P2P and Semantic Web (SW). In KEEx, each community of knowledge nodes is represented by a peer. The basic principles of the system are autonomy (each peer provides all services needed by a knowledge node to create and organize its own local knowledge), and semantic coordination (defining social structures and protocols of meaning negotiation, when searching documents from other peers). Distributed local knowledge can emerge and aggregate through a bottom-up process from

individual level to organizational one, passing through the establishment of communities (group of peers that share a similar interest) and zones (networks of peers that relate to a neighbourhood). Each Knowledge Node can play two main roles: knowledge provider and knowledge seeker.

DOM (Belsis) [15] describes an extended distributed architecture based on Distributed Organizational Memory [DOM]. The DOM comprises a variety of information sources supporting all kinds of structures, contents and media types, includiing images repositories. The system is based on agents that enable transparent identification of assets and provide automated authorization for users. The system provide support for tacit knowledge exploitation through its capability to interconnect users with experts. The system maintain as well multimedia modules and inter-organizational cooperation for geographically dispersed organizations through a GIS interface, that provides users with some facilities to seek experts in different locations and establish direct contact with them.

Cuel [17] proposes a DKMS model, based on knowledge nodes (KN), composed by knowledge owner, system of artefacts, shared conceptual schema and coordination of knowledge processes across KN boundaries. The DKMS supports two main roles - autonomous management of knowledge, locally produced in KN (principle of autonomy) and coordination of different KN (principle of coordination). Cuel proposes to use Social network analyses based on nodes behaviour in order to identify borders of existing knowledge networks and to understand how knowledge is exchanged.

SWAP (Ehrig) [4], combines the P2P and Semantic Web technologies and consists of set of peers called "SWAP Nodes". The knowledge of a particular peer is extracted from several knowledge sources, then is integrated and stored in local node repository. A user interface ensures user ability to edit/browse/query the knowledge. Queries that cannot be answered by the available knowledge are sent to the whole system. A specialized component deals with rewriting these queries and selecting the peers which are likely to know the answer.

IKOS (Papailiou) [20] is based on P2P model and semantic technologies using the social semantic desktop framework (making the functionality of the system available as a service) and constitutes a combination of a personal information management system and a group support system. Workspaces give users the opportunity to create virtual locations supporting either their personal work or the collaborative work of groups. IKOS supports personalized services (identification of personal current work context - through User Context Service and personal functionalities – through Task Management component), community services (Community Management component), and ranking services (Ranker component).

Infotop (Maier) [11] is a distributed KMS, developed as personal workspaces. It is designed to help knowledge workers to organize their personal information, to share context and collaborate on the basis of peer-to-peer information workspaces. The Infotop is composed of hybrid P2P architecture - peers (knowledge workers) and super-peers (subject matter specialists). The Infotop architecture consist of several layers (complying with CKMS architectures). The access layer provides Infotop's visualization concept with six dimensions: time, topic, location, process, person and type as well as the OLAP functions. This represents its main interface to collections of contents, both personal and shared across multiple workspaces of networked knowledge workers. Finally

Infotop acts as the main access point both for personal knowledge management and for ad-hoc collaboration in a shared context.

Organik (Bibikas) [21] is a socio-technological KMS architecture designed for SMEs and relies on Enterprise 2.0 model (SLATES) and Semantic Web approach. It aims to provide knowledge workers with a collaborative workspace that comprises a set of integrated Web 2.0 applications (a wiki, a blog, a bookmarking system and a search/recommendation engine), augmented with natural language processing and semantic information integration capabilities that enable the combined use of folksonomies and ad-hoc tagging with thesauri and shared ontologies. The architecture is based on client-server model, consisting of client interface (wiki, blog, bookmarking and search), and server components (supporting client components and extending it with another functions as recommendation, semantic text, collaborative filtering, full text indexing) and data bases.

A short summary for better visualization and comparison of discussed DKMS is presented in table 2.

Table 3. DKMS overview.

System	Model	Functionality of nodes	Components/ Layers	Personal workspace	Organisational perspective
KeeX 2004	P2P&SW	2 roles knowledge provider and knowledge seeker	Bottom-up process Autonomy Semantic coordination	-	Personal Communities Organization
Belsis 2005	P2P & Agents	Agents enable assets identification and automated authorization	DOM, Agent module, Ontology management, Authorization module	-	Inter-organizational integration
Cuel 2003	Distributed platform	Knowledge Nodes	Autonomy, coordination SNA	-	Personal Group
SWAP 2003	P2P&SW	Nodes integrate knowledge in local repository	Support editing and transformation of local knowledge	-	Personal
IKOS 2007	P2P&SW	Functionality is available as a service	Social Semantic desktop, Personal and Community Ranker	X	Personal Group
Infotop 2007	P2P	Peers and Super peers	Integrated knowledge base, Layered structure	X	Personal Group
Organik 2007	Client-server &SW	SLATES and Enterprise 2.0	Client/Server module Database module	X	Personal Group/SME

4 Conclusion and Future Work

The present paper point out that DKMS employ various technologies and architectures to better respond on the knowledge workers needs. Table 2 summarizes the main technologies and architectures behind theoretical models of DKMS, that could be adapted to organizational context.

As KMS are not universal solutions they have to comply to user requirements and organizational context. The centralized KM approach is not necessarily in conflict with distributed KM. Depending on various factors such as organizational structure, environment, knowledge structure, technology infrastructure and culture better will fit CKMS or DKMS [1,23].

The present research is part of larger research project, aiming to propose a new model of User-Centered DKMS, adapted to the needs of networked business structures and emerging independent workers [2], who take part in number of interactions and knowledge flows inside and outside organizations. The new model of user-centered DKMS will be based on P2P, cloud computing paradigm and Enterprise 2.0 approach, taking into account the present DKMS review. P2P technologies propose many advantages to end-users and organizations and has the potential to become a basic approach for building new user-focused DKMS.

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