CENTRALIZED VERSUS PEER-TO-PEER KNOWLEDGE MANAGEMENT SYSTEMS

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Abstract

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Keywords: knowledge management, knowledge management system, architecture, characteristics, peer-to-peer.

Centralized Versus Peer-to-Peer Knowledge Management Systems

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Suggested track: (J) Knowledge and Information technology

1 Motivation

Knowledge management (KM) has been discussed intensively from a human-oriented and from a technology-oriented perspective. Knowledge management systems are seen as enabling technologies for an effective and efficient KM. However, up to date the term knowledge management system (KMS) is often vaguely defined and used ambiguously. Examples are its use for specific KM tools, for KM platforms or for a combination of tools that are applied with KM in mind. It remains unclear what separates KMS from more traditional information systems that are also discussed as supporting KM initiatives. Examples are Intranet infrastructures, document and content management systems, artificial intelligence technologies, business intelligence tools, visualization tools, Groupware or e-learning systems. So far, investigations about the notion of KMS remain on the abstract level of what a KMS is used for, e.g., “a class of information systems applied to managing organizational knowledge" (Alavi and Leidner 2001:114), and do not answer what functions a KMS has to offer, what differences there are compared to more traditional information systems and what a KMS architecture could look like.

Goals of this paper are to define the term KMS and to obtain a set of characteristics that differentiate KMS from traditional information systems (section 2), to contrast two ideal architectures for KMS and to discuss the state-of-the-art with the help of example systems offered on the market (section 3) as well as to discuss the differences between the architectures and which KMS architecture fits what type of KM initiatives (section 4).

2 Towards a Definition of Knowledge Management Systems

Even though there is considerable disagreement in the literature and business practice about what exactly KM is, there are a number of researchers and practitioners who stress the importance and usefulness of KMS as enabler or vehicle for the implementation of these approaches. KMS should help to overcome the shortcomings of current practices of business engineering with respect to organizational effectiveness. A review of the literature on information and communication technologies (ICT) to support KM reveals a number of different terms in use, such as knowledge warehouse, KM software, suite, (support) system, technology or organizational memory (information) system (e.g., Stein and Zwass 1995:98; McDermott 1999:104; Nedeß and Jacob 2000; Seifried and Eppler 2000; Alavi and Leidner 2001; Mentzas et al. 2001:95f; Maier 2004:79ff). In addition to these terms meaning a comprehensive platform in support of KM, many authors provide more or less extensive lists of individual tools or technologies that can be used to support KM initiatives as a whole or certain processes, life cycle phases or tasks thereof (e.g., Allee 1997:224f; Borghoff and Pareschi 1998:5f; Ruggles 1998:82ff; Meso and Smith 2000:227ff; Binney 2001:37ff; Hoffmann 2001:78f; Jackson 2003:5f).

Apart from these terms with a clear focus on KM or organizational memory, there is another group of software systems that supports these approaches called e-learning suite, learning management platform, portal, suite or system (Maier 2004:81). These platforms not only support presentation, administration and organization of teaching material, but also interaction between and among teachers and students (Astleitner and Schinagl 2000:114). KMS with roots in document management, collaboration or Groupware and learning management systems with roots in computer-based training already share a substantial portion of functionality and seem to converge or at least be integrated with each other. Recently, the terms KM tools or KMS have gained wide acceptance both in the literature and on the market. Consequently, we use the term KMS being well aware that there are a number of similar conceptualizations that complement the functionality and architectures of KMS. In the following, we will summarize the most important characteristics of KMS as can be found in the literature.

Goals: Stein/Zwass define organizational memory information system as “a system that functions to provide a means by which knowledge from the past is brought to bear on present activities, thus resulting in increased levels of effectiveness for the organization“ (Stein and Zwass 1995:95; for organizational effectiveness e.g., Lewin and Minton 1998). This definition stresses the primary goal of KMS as to increase organizational effectiveness by a systematic management of knowledge. Thus, KMS are the technological part of a KM initiative that also comprises person-oriented and organizational instruments targeted at improving productivity of knowledge work (Maier 2004:44ff, 55). KM initiatives can be classified according to *strategy* in human-oriented, personalization initiatives and technology-oriented codification initiatives (Hansen et al. 1999). They can further be distinguished according to *scope* into enterprise-specific initiatives and initiatives that cross organizational boundaries. According to *organizational design*, the initiative can establish a central organizational unit responsible for KM or it can be a decentral initiative run by a number of projects and/or communities. The initiative can focus on a certain type of *content* along the knowledge life cycle, e.g., ideas, experiences, lessons learned, approved knowledge products, procedures, best practices or patents. Finally, the *organizational culture* of the company or organization in which the KM initiative is started, can be characterized as open, trustful, collective where willingness to share knowledge is high or as confidential, distrustful, individual, with high barriers to knowledge sharing (see Maier 2004:404ff for a definition of and empirical results about this typology of KM initiatives). The type of initiative determines the type of information system for its support which can be regarded as a KMS from the perspective of its application environment.

Processes: KMS are developed to support and enhance knowledge-intensive processes, tasks or projects (Detlor 2002:200; Jennex and Olfmann 2003:214) of e.g., knowledge creation, organization, storage, retrieval, transfer, refinement and packaging, (re-)use, revision and feedback, also called the knowledge life cycle, ultimately to support knowledge work (Davenport et al. 1996:54). In this view, KMS provide a seamless pipeline for the flow of explicit knowledge through a refinement process (Zack 1999:49), or a thinking forum containing interpretations, half-formed judgements, ideas and other perishable insights that aims at sparking collaborative thinking (McDermott 1999:112).

Comprehensive platform: Whereas the focus on processes can be seen as a user-centric approach, an IT-centric approach provides a base system to capture and distribute knowledge (Jennex and Olfmann 2003:215). This platform is then used throughout the organization. In this case, the KMS is not an application system targeted at a single KM initiative, but a platform that can either be used as-is to support knowledge processes or that is used as the integrating base system and repository on which KM application systems are built. Comprehensive in this case means that the platform offers extensive functionality for user administration, messaging, conferencing and sharing of (documented) knowledge, i.e. publication, search, retrieval and presentation.

Advanced knowledge services: KMS are described as ICT platforms on which a number of integrated services are built. The processes that have to be supported give a first indication of the types of services that are needed. Examples are rather basic services, e.g., for collaboration, workflow management, document and content management, visualization, search and retrieval (e.g., Seifried and Eppler 2000:31ff) or more advanced services, e.g., profiling, personalization, text analysis, clustering and categorization to increase the relevance of retrieved and pushed information, advanced graphical techniques for navigation, awareness services, shared workspaces, (distributed) learning services as well as integration of and reasoning about various (document) sources on the basis of a shared ontology (e.g., Bair 1998:2; Borghoff and Pareschi 1998:5f; Maier 2004:260ff).

KM instruments: KMS are applied in a large number of application areas, e.g., in product development, process improvement, project management, post-merger integration or human resource management (Tsui 2003:21). More specifically, KMS support KM instruments, e.g., (1) the capture, creation and sharing of best practices, (2) the implementation of experience management systems, (3) the creation of corporate knowledge directories, taxonomies or ontologies, (4) expertise locators, yellow and blue pages as well as skill management systems, also called people-finder systems, (5) collaborative filtering and handling of interests used to connect people, (6) the creation and fostering of communities or knowledge networks, (7) the facilitation of intelligent problem solving (e.g., Alavi and Leidner 2001:114; McDermott 1999:111ff; Tsui 2003:7). KMS in this case offer a targeted combination and integration of knowledge services that together foster one or more KM instrument(s).

Specifics of knowledge: KMS are applied to managing knowledge which is described as “personalized information […] related to facts, procedures, concepts, interpretations, ideas, observations, and judgements” (Alavi and Leidner 2001:109, 114). From the perspective of KMS, knowledge is information that is meaningfully organized, accumulated and embedded in a context of creation and application. KMS primarily leverage codified knowledge, but also aid communication or inference used to interpret situations and to generate activities, behaviour and solutions. Thus, on the one hand KMS might not appear radically different from existing IS, but help to assimilate contextualized information. On the other hand, the role of ICT is to provide access to sources of knowledge and, with the help of shared context, to increase the breadth of knowledge sharing between persons rather than storing knowledge itself (Alavi and Leidner 2001:111).

The internal context of knowledge describes the circumstances of its creation, e.g., the author(s), creation date and circumstances, assumptions or purpose of creation. The external context relates to retrieval and application of knowledge. It categorizes knowledge, relates it to other knowledge, describes access rights, usage restrictions and circumstances as well as feedback from its re-use (Barry and Schamber 1998:222; Eppler 2003:125f). Contextualization is one of the key characteristics of KMS (Apitz et al. 2002) which provide a semantic link between explicit, codified knowledge and the persons that hold or seek knowledge in certain subject areas. Context enhances the simple “container” metaphor of organizational knowledge by a network of artefacts and people, of memory and of processing (Ackerman and Halverson 1998:64). Communities or networks of knowledge workers that “own the knowledge” and decide what and how to share can provide important context for a KMS (McDermott 1999:108, 111ff). Decontextualization and recontextualization turn static knowledge objects into knowledge processes (Ackerman and Halverson 1998:64). Meta-knowledge in a KMS, also sometimes in the form of a set of expert profiles or the content of a skill management system, is sometimes as important as the original knowledge itself (Alavi and Leidner 2001:121).

A definition of the term KMS and a subsequent development of architectures for KMS have to stress the focus on a comprehensive platform rather than individual tools, the advanced services, their combination and integration to foster KM instruments and the specifics of knowledge around which content and context of these systems revolve. Also, a KMS has to be aligned with the specifics of its application environment, the goals, types of KM initiatives as well as the acquisition and deployment processes required for the management of knowledge (see Fig. 1).

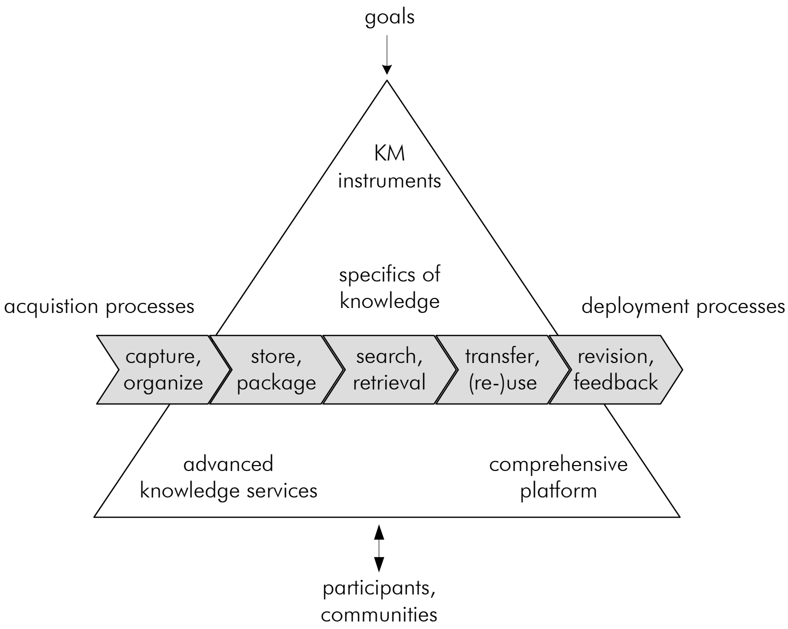

Fig. 1. Characteristics of KMS

Consequently, a KMS is defined as a comprehensive ICT platform for collaboration and knowledge sharing with advanced knowledge services built on top that are contextualized, integrated on the basis of a shared ontology and personalized for participants networked in communities. KMS foster the implementation of KM instruments in support of knowledge processes targeted at increasing organizational effectiveness.

Goals and processes describe the application environment of a KMS and therefore can only be used to judge a KMS that is applied and evaluated together with its organizational environment. In order to determine whether or not a tool or a system offered on the market or installed in an organization qualifies as a KMS from a system-centered view, the following minimal requirements have to be fulfilled:

- *Platform*: The system has to provide an *integrated set of basic functions* for collaboration, document management, classification, visualization, search and retrieval. The system ideally has to support the *entire knowledge life cycle* or at least a complete subset, e.g., capture, store, transfer, search and retrieval. The system has to be a *multi-user system*, scalable and theoretically be usable for a whole organization, i.e., several (overlapping) communities of users. This requirement excludes tools that focus a limited phase in the knowledge life cycle, e.g., text analysis and knowledge mapping tools and excludes tools that help to organize an individual’s knowledge workspace or a single group of knowledge workers.

- *Advanced knowledge services*: The system has to provide more advanced services, at least for *contextualization*, *integration* of various (document) sources, *personalization* and *workspace management*. More specifically, KMS have to offer functions for the handling of meta-data, a shared taxonomy, text analysis, profiling, flexible navigation, shared workspaces, analysis and viewing of multiple (document) formats. This requirement excludes basic Groupware, document or content management systems.
- *KM instruments*: KMS ideally offer default solutions for the implementation of a number of KM instruments, e.g., for skill management, experience management, best practice management, the support of communities or the development of corporate knowledge directories. The minimal requirement is that the KMS offers support for one *document-oriented KM instrument* and one *person-oriented KM instrument*. This requirement distinguishes KMS from systems offering advanced functions for purposes other than KM.
- *Specifics of knowledge*: The system has to provide means to handle various *types of knowledge* including stable, documented knowledge, ad-hoc and/or co-authored "live" experiences, the *internal and external context* of knowledge as well as information about skills and expertise of participants. KMS therefore reflect that knowledge is developed collectively and continuously reconstructed, revised and reused in different contexts. KMS ideally support all *stages of knowledge* from ideas, experiences, lessons learned, best practices to manuals, rules, procedures and patents. This requirement again contrasts KMS from more traditional document management or collaboration software.

Apart from these minimal requirements, actual implementations of ICT systems certainly fulfill the characteristics of an ideal KMS only to a certain degree. Thus, a continuum between traditional IS and advanced KMS might be imagined with the minimal requirements providing some orientation.

3 Architectures for Knowledge Management Systems

Architectures play an important role in MIS as blueprints or reference models for corresponding implementations of information systems. The analysis of the definitions of KMS discussed above, of case studies of organizations using ICT in support of KM and of KM tools and systems offered on the market reveals that there are basically two ideal types of architectures of KMS: centralistic KMS and peer-to-peer KMS.

3.1 Centralistic Architecture

Many KMS solutions implemented in organizations and offered on the market are centralistic client-/server solutions (Maier 2004). Figure 2 shows an ideal layered architecture for KMS that represents an amalgamation of theory-driven (e.g., Apitz et al. 2002, 33; Zack 1999, 50), market-oriented (e.g., Applehans et al. 1999; Bach et al. 1999:69) and several vendor-specific architectures (e.g., Hyperwave, http://www.hyperwave.com; Open Text Livelink, http://www.opentext.com). The ideal architecture is oriented towards the metaphor of a central KM server that integrates all knowledge shared in an organization and offers a variety of services to the knowledge worker or to upward layers.

Data and knowledge sources: KMS include organization-internal sources, e.g., transaction processing systems, data base systems, data warehouses, document and content management systems, messaging systems and personal (or group) information management systems as well as organization-external sources, e.g., databases from data supply companies, or the Internet, especially the WWW and newsgroups.

Infrastructure services: The Intranet infrastructure provides basic functionality for synchronous and asynchronous communication, the sharing of data and documents as well as the management of electronic assets in general and of Web content in particular. In analogy to data warehousing, extract, transformation and loading tools provide access to data and knowledge sources. Inspection services (viewer) are required for heterogeneous data and document formats.

Integration services: A taxonomy or an ontology help to meaningfully organize and link knowledge elements that come from a variety of sources and are used to analyze the semantics of the organizational knowledge base. Integration services are needed to manage meta-data about knowledge elements and the users that work with the KMS. Synchronization services export a portion of the knowledge workspace for work offline and (re-)integrate the results of work on knowledge elements that has been done offline.

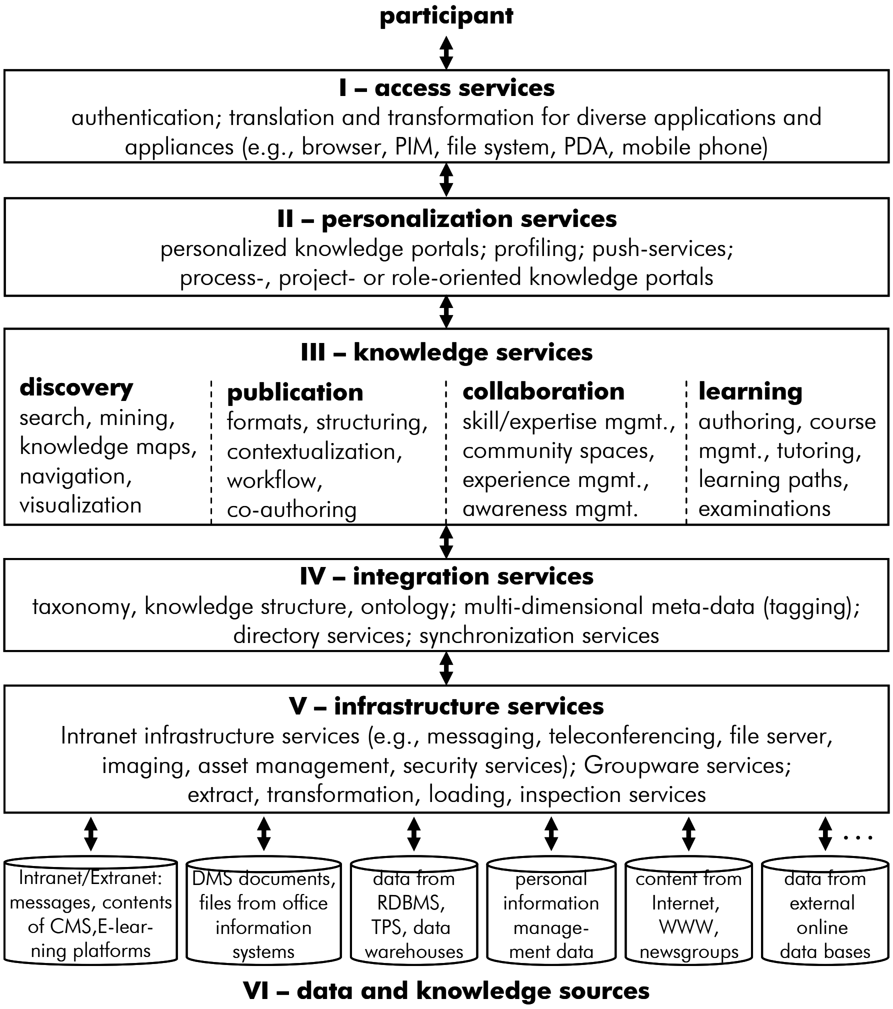

Fig. 2. Architecture of a centralized KMS

Knowledge services: The core knowledge processes - search and retrieval, publication, collaboration and learning - are supported by knowledge services. These are key components of the KMS architecture and provide intelligent functions for:

- *discovery*: means search, retrieval and presentation of knowledge elements and experts with the help of e.g., mining, visualization, mapping and navigation tools,
- *publication*: is the joint authoring, structuring, contextualization and release of knowledge elements supported by workflows,
- *collaboration*: supports the joint creation, sharing and application of knowledge by knowledge providers and seekers with the help of e.g., contextualized communication and coordination tools, location and awareness management tools, community homespaces and experience management tools and
- *learning*: is supported e.g., by authoring tools and tools for managing courses, tutoring, learning paths and examinations.

Personalization services: Main aim of personalization services is to provide a more effective access to the large amounts of knowledge elements. Subject matter specialists or managers of knowledge processes can organize a portion of the KMS contents and services for specific roles or develop role-oriented push services. Also, both, the portal and the services can be personalized with the help of e.g., interest profiles, personal category nets and personalizable portals. Automated profiling can aid personalization of functions, contents and services.

Access services: The participant accesses the organization's KMS with the help of a variety of services that translate and transform the contents and communication to and from the KMS to heterogeneous applications and appliances. The KMS has to be protected against eavesdropping and unauthorized use by tools for authentication and authorization.

3.2 Example: Open Text Livelink 9

Open Text's product family Livelink represents one of the leading KMS platforms with a centralized architecture. Livelink has an installed base of over 6 million users in 4,500 organizations many of which are large organizations.[1] Figure 3 assigns Livelink's modules to the six layers of the centralized KMS architecture. In the following, selected Livelink components are briefly discussed.

[1] According to Open Text Germany's University program "Knowledge management with Livelink"; see also: URL: http://www.opentext.com/. The following discussion is based on our experiences with a Livelink installation at our department and material published by Open Text.

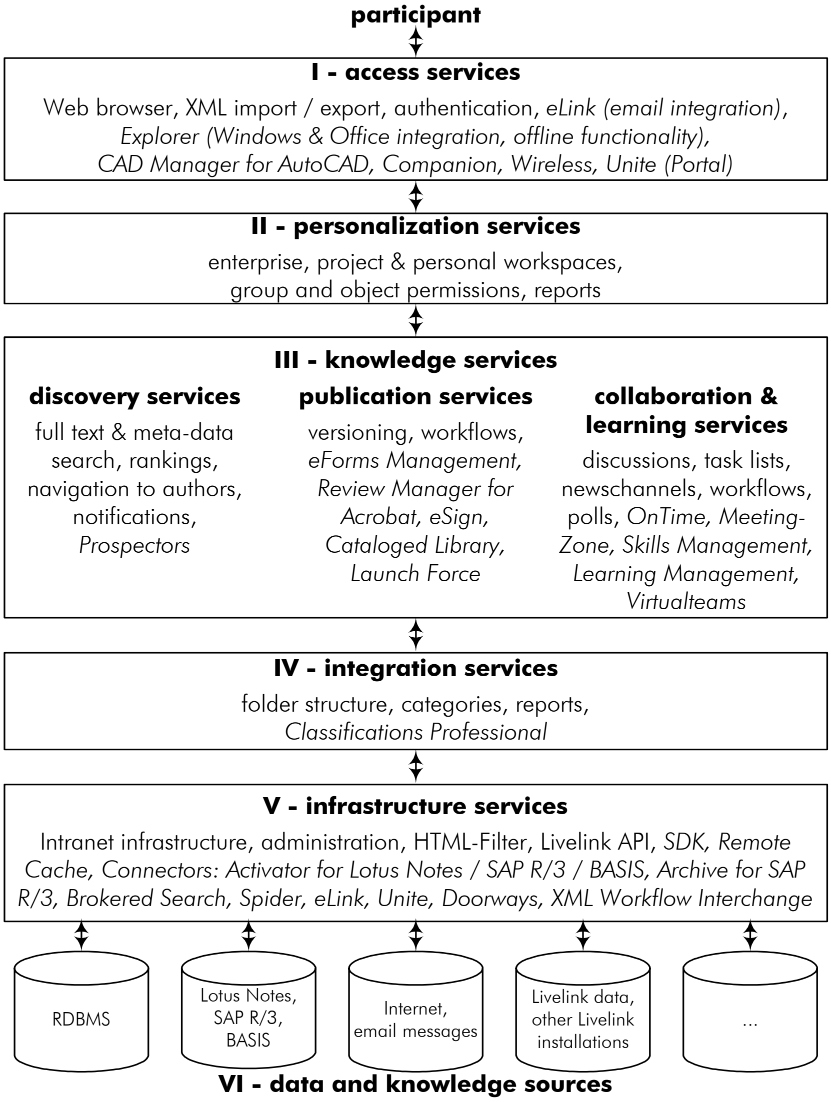

Fig. 3. Livelink's components in the centralized KMS architecture[2]

Data and knowledge sources: The Livelink data is stored in a relational data base system and the file system. Various other data and knowledge sources are made available by services on the infrastructure layer.

Infrastructure services: Services called “activators” extend Livelink’s search domain to sources like Lotus Notes data bases, Web pages (Livelink Spider), search engines and other Livelink installations (Livelink Brokered Search). Livelink is accessed using the Intranet infrastructure installed in an organization. The system’s (open) source code can be altered or extended with the Livelink Software Development Kit (Livelink SDK). The most common types, e.g., formats of office systems, can be converted to HTML.

[2] Italic descriptions refer to separate software modules that extend Livelink’s core functionality. It depends on the actual license agreement whether they are included or not. A variety of additional modules can be obtained from 3rd party vendors and are not considered here.

Thus, documents can be viewed without the native application and indexed by Livelink's search engine.

Integration services: Knowledge is stored in and represented by so-called “objects”, e.g., documents, folders, discussions or task lists that are placed in a folder hierarchy. Meta-data is added automatically, e.g., creation / change date, creator, and manually via customizable categories. All meta-data are stored in a relational data base and can be queried using SQL statements in so-called reports.

Discovery services: Livelink's full-text search engine allows basic and advanced keyword searches. Additionally, the assigned meta-data can be used for limiting the search domain. A typical search result page not only includes a ranked list of various types of objects with short descriptions, e.g., documents, discussion topics, folders or objects from further knowledge sources made accessible through Livelink services on the infrastructure level, but also gives hints to what authors have been most active according to the actual query. Livelink's notification mechanism allows users to place change agents on selected folders to be notified via email if changes occur.

Publication services: Typical document management functions of Livelink are check-in/check-out, a versioning mechanism and workflows. All types of files can be stored in Livelink. Optional modules provide capabilities for electronic signatures (Livelink eSign), functions for the management of electronic forms (Livelink eForms Management), for textual or graphical annotations in Adobe Acrobat’s portable document format files (Livelink Review Manager for Acrobat).

Collaboration and learning services: Some basic functions like discussion forums (black boards), polls, news channels, task lists and workflows aim at supporting collaboration. Optional Livelink modules offer group calendars (Livelink OnTime) and electronic meetings (Livelink MeetingZone). OnTime provides a Web calendar with simple mechanisms to administer group appointments. MeetingZone comprises a set of meeting support tools integrated into Livelink, e.g., whiteboard, chat, shared desktop and objects to be used during the meeting. Livelink supports the design of basic courses and question & answer tests (Livelink Learning Management) and basic skill management functions (Livelink Skills Management).

Personalization services: Livelink offers three types of workspaces that differ mainly with respect to what groups of users are granted privileges to access them. The enterprise workspace is the central workspace for all users. A personal workspace belongs to every user with access restricted to this user. Project workspaces can only be accessed by participants defined by the project's coordinator(s). The operations users and groups may perform on an object are defined by detailed privileges at the granularity of single objects. All knowledge and access services consider these privileges.

Access services: Access to Livelink with a standard Web browser is relatively platform-independent and not limited to a corporate LAN. The system can be accessed via the Internet from every networked computer with a Web browser. To ease the use of the system, e.g., for work with a large number of documents, a client for Microsoft Windows platforms can be obtained optionally (Livelink Explorer). This client provides drag & drop integration into Microsoft's Windows Explorer, basic online/offline synchronization functions and an integration into Microsoft Office e.g., to check-in/check-out documents directly from Microsoft Word. If multiple installations exist, the user can access them over a portal (Livelink Unite).

3.3 Peer-to-Peer Architecture

Recently, the peer-to-peer metaphor has gained increasing attention from both, academics and practitioners (e.g., Barkai 1998; Schoder et al. 2002). There have been several attempts to design information sharing systems or even KMS to profit from the benefits of the peer-to-peer metaphor (Parameswaran et al. 2001; Benger 2003; Susarla et al. 2003; Maier and Sametinger 2004). This promises to resolve some of the shortcomings of centralized KMS, e.g.,

- to reduce the substantial costs of the design, implementation and maintenance of a centralized knowledge server,
- to reduce the barriers of individual knowledge workers to actively participate and share in the benefits of a KMS,
- to overcome the limitations of a KMS that focuses on organization-internal knowledge whereas many knowledge processes cross organizational boundaries,
- to include individual messaging objects (emails, instant messaging objects) into the knowledge workspace and
- to seamlessly integrate the shared knowledge workspace with an individual knowledge worker's personal knowledge workspace.

However, there is no common architecture or an agreed list of functions yet for this type of KMS. Generally, the peer-to-peer label is used for different architectures (e.g., Dustdar et al. 2003:170ff). Firstly, the *assisted peer-to-peer architecture* requires a central server, e.g. to authenticate all users to act as a global search index. Peers send search requests to the server that directs peers to resources which are then transferred directly between the peers. Secondly, the *pure peer-to-peer architecture* does not have any central authentication or coordination mechanism. Every peer provides complete client and server functionality ("servents"). Lastly, the *super peer architecture* is in between assisted and pure architectures. Super peers are peers with a fast and stable network connection. A peer is connected to one single super peer, thus forming clusters of peers in the network. Super peers are also connected to each other, thus forming a separate peer-to-peer network. Requests from peers are always handled by the connected super peer and eventually forwarded to other super peers. As in the assisted architecture, a direct connection between peers is established, once a peer with the desired resource is found.

The more functionality for central coordination is required in a peer-to-peer system, as is the case in a KMS, the more likely it is that some kind of assistance by a server is needed to coordinate the system. Consequently, Figure 4 depicts the architecture of a peer and a server to assist the network. Both architectures basically consist of the same layers as the architecture of centralized KMS. Thus, in the following only the differences to the centralized architecture are discussed.

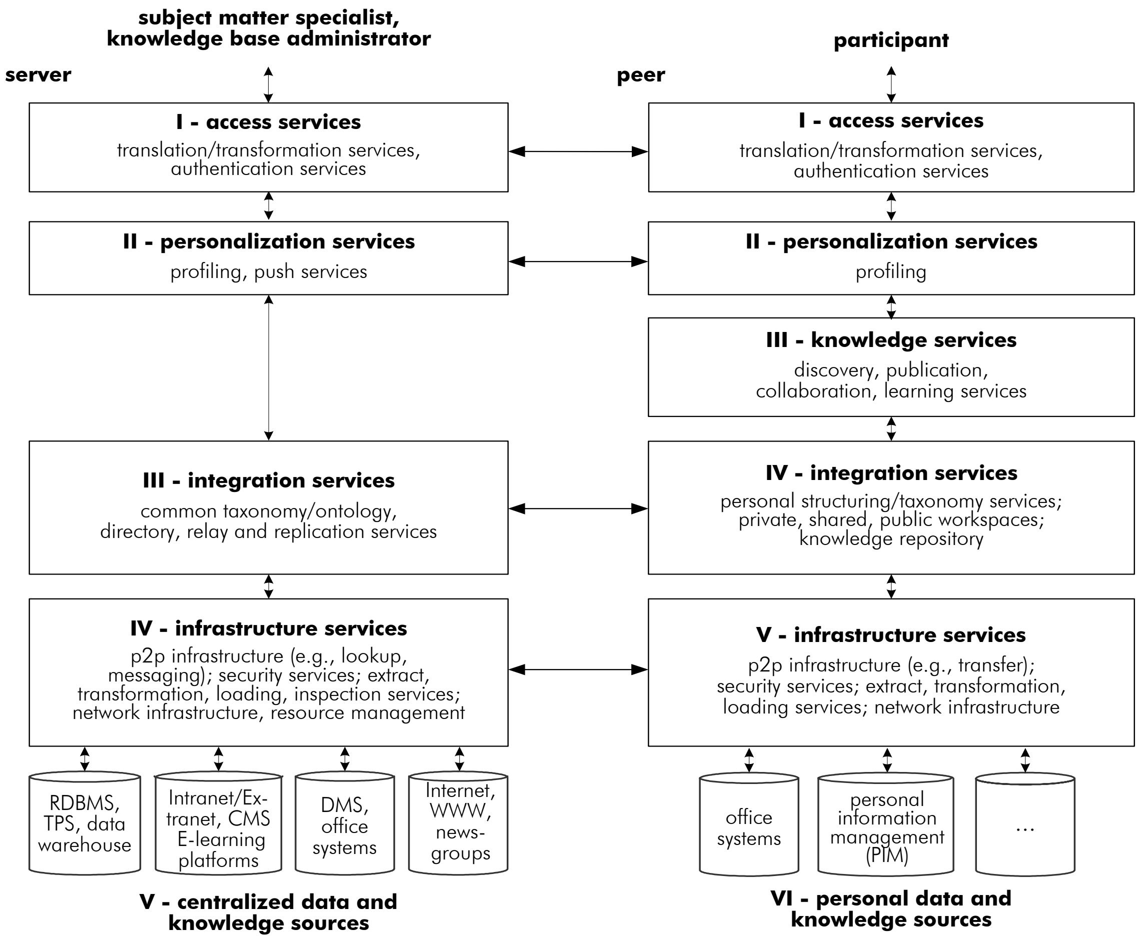

Fig. 4. Architecture of server and peer

Peer

Infrastructure services handle (1) extract, transformation and loading from personal data and knowledge sources and (2) provide the peer-to-peer infrastructure for locating peers, exchanging data with other peers and assuring security of the personal knowledge base.

Integration services handle meta-data of the knowledge objects in the personal knowledge base and establish a personal taxonomy or ontology. The knowledge base comprises private, protected and public areas. Private workspaces contain information that is only accessible for the owner of the private workspace. Public workspaces hold knowledge objects that are published via the Internet and accessible by an undefined group of users. Protected workspaces contain knowledge objects that are accessible to a single or a group of peers that the owner explicitly grants access.

Knowledge services build upon the knowledge base, just as in the centralized case. The main difference is that the knowledge repository now is spread across a number of collaborating peers that have granted access to parts of their knowledge repositories.

Personalization services build on individual user profiles and on centralized personalization services provided by the server.

Access services are similar to the centralized KMS architecture.

Server

Infrastructure services: A server might access a number of additional, shared data and knowledge sources and assist the peers with additional services. The peer-to-peer infrastructure might also provide services for lookup and message handling that improve the efficiency of the distributed KMS.

Integration services offer a shared taxonomy or ontology for the domain handled e.g., by a network of subject matter specialists. This addresses the challenge in a totally distributed KMS that the various knowledge bases cannot be integrated and thus pose a problem for e.g., the interpretation of search results by the knowledge worker. The server might offer replication services to peers that sometimes work offline.

Knowledge services: There are no central services in addition to the peers' services.

Personalization services include profiles and push services that ease accessing the organized collection of (quality approved or even improved) knowledge that the subject matter specialists administer.

Access services are restricted to the administration of the server, the central knowledge structure and the profiles for personalization.

3.4 Example: Groove Networks Groove 2.5

The product Groove from Groove Networks targets collaboration in small groups and is based on the peer-to-peer metaphor. In the following, its functions are discussed briefly using the layers of the peer-to-peer architecture.[3]

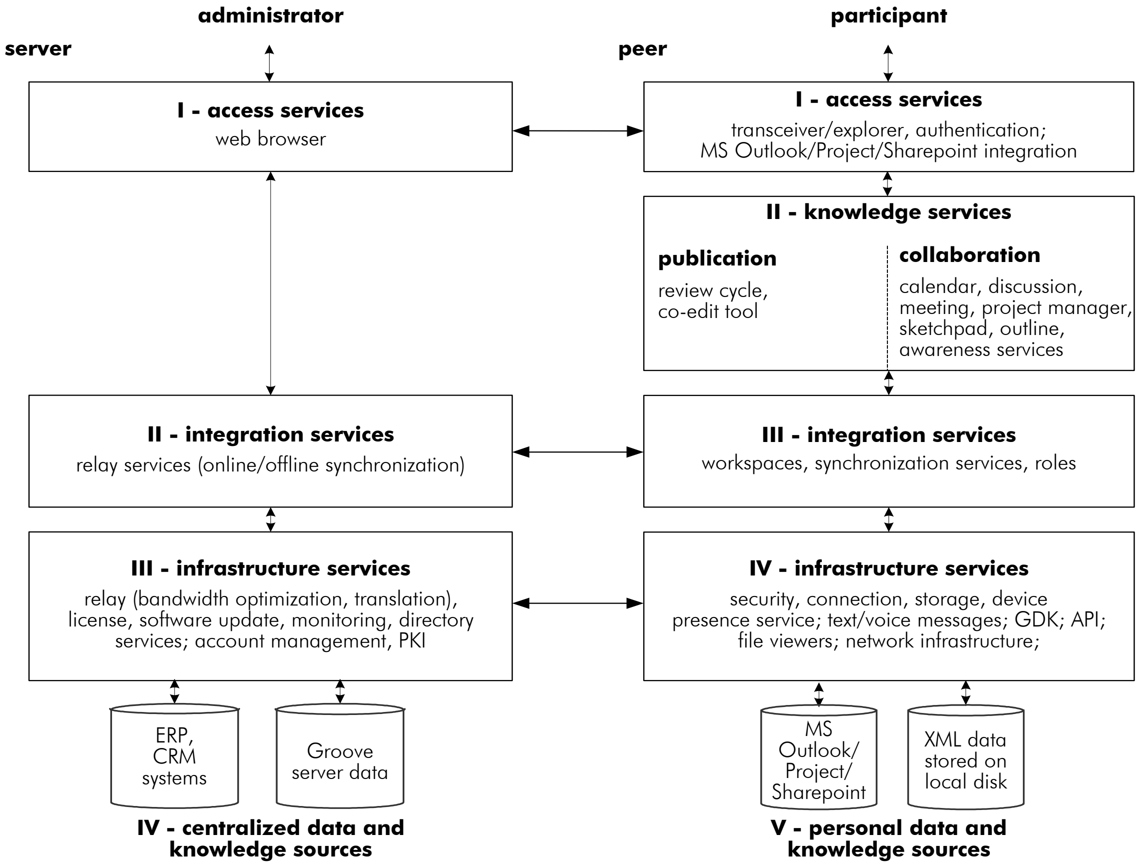

Fig. 5. Groove's components in the architecture of decentralized KMS

Peer

Data and knowledge sources: The data resides in XML stores on the local hard disks of the peers. It is possible to import calendar items, emails and contacts from MS Outlook, to integrate MS Sharepoint workspaces (discussions and documents are synchronized, other elements of a Sharepoint workplace are stored in the forms tool) and to import data from MS Project. File viewers can be downloaded for common file types.

[3] The following discussion is based on our experiences with a Groove installation at our department, on Pitzer 2002 and material published by Groove Networks.

Infrastructure services: The data store is managed by a storage service that ensures persistence of Groove's workspaces. Local data and messages to other peers are encrypted by a security service. A user normally owns one account that includes one or more identities. Every identity has a pair of public/private keys and a fingerprint for encryption and authentication. It is possible to exchange text or voice messages. Peer connection services determine IP addresses of other peers and handle communication using the proprietary simple symmetrical transmission protocol (SSTP). Device presence services handle the detection of other peers and their online/offline status. The Groove Development Kit (GDK) provides an environment for programming software extensions using Microsoft software components (COM) and programming languages like VB.NET, C++ or C#.

Integration services: Knowledge workers collaborate in workspaces that contain a number of tools. Every user can create a workspace, assign tools and invite other users to join. All knowledge elements like basic text, documents, calendar items or images are stored in this workspace and are only visible to the members of this workspace whose privileges depend on their role (guest, participant or manager). There is no central taxonomy or ontology. Changes in workspaces are continuously transmitted to all peers. If a peer goes offline, the differentials are synchronized when he switches back online.

Publication services: Groove offers no advanced publication services except the review cycle tool for joint revision of documents and a function that allows users to simultaneously co-edit MS Word and MS Powerpoint documents. Files can be stored in a basic hierarchical folder structure in the files tool. The picture and the notes tools are for storing and viewing pictures and text. Structured data is stored in forms created with the forms tool.

Collaboration services: Basic collaboration tools offered by Groove are a group calendar, a group contact list, a discussion forum, meeting minutes and a project manager tool (task list). A sketchpad (whiteboard) and an outline tool (structured list) offer basic support for brainstorming sessions. A group of users can jointly browse Internet/Intranet-pages with co-browser functionality using Microsoft Internet Explorer. A "navigate together" option synchronizes the interface of the workspace. Awareness services provide information about current activities of other users, e.g., the workspace and the tools they currently access. Information about users is distributed within Groove or by email.

Discovery and learning services: Groove clearly emphasizes collaboration functions and lacks discovery services like a full-text search engine as well as learning services. Basic discovery functions enable users to navigate within the hierarchic structure of the files tool and subsequently retrieve documents.

Access services: The workspaces are accessed by a Microsoft Windows client called transceiver with a drag and drop interface for files. The Groove explorer offers an alternative user interface with the same functionality. Each user creates an account secured by a password.

Server

A peer-to-peer network bears challenges with respect to central management tasks like license management or coordinating resource utilization, e.g., bandwidth or disk capacity. Groove addresses them with centralized servers.

Data and knowledge resources: Other systems like enterprise resource planning (ERP) software or customer relationship management systems (CRM) can be integrated by software agents called bots. Data needed and produced by Groove's server application resides in a local data store.

Infrastructure services: The server offers relay services to ensure stable and fast communication between peers. If a peer's connection to the network is slow, large files are sent to and distributed by the relay server ("fanout" functionality). Peers behind firewalls can communicate with the relay server using the Hypertext Transfer Protocol (HTTP). The server then transmits the data to the addressed peers using the preferred SSTP.

Moreover, the server offers functions for the management of licenses, distribution of software updates, monitoring of Groove's usage, directory services for exchanging user information, a public key infrastructure (PKI) and basic account management for using one Groove account on multiple computers. Groove allows monitoring of network usage, of workspaces and their tools as well as the activity of single users.

Integration services: Another part of the relay services addresses the synchronization of peers. Messages to peers currently offline are temporarily stored and forwarded when peers go back online. The data resides in a local cache.

Knowledge and personalization services: Due to the fact that the centralized server is designed for coordinating a peer-to-peer network and for the technical integration of legacy systems, it offers no such centralized services.

Access services: The user interface for the administrator is a standard web browser.

4 Discussion

Generally, there has been a shift in perspective of KMS vendors as well as organizations applying those systems from a focus on documents containing knowledge and thus from a pure codification strategy to a combination and integration of functions for handling internal and external context, locating experts, skill management, etc. which bridges the gap to a personalization strategy (Maier 2004:506). Advanced functions supporting collaboration in teams and communities, tools linking knowledge providers and seekers as well as e-learning functionality have been integrated into many centralized KMS. KMS offered on the market differ with respect to the extent and intensity with which they cover the services included in the centralized architecture. Some focus on learning management (e.g., Hyperwave), some on integration (e.g., Lotus Notes / Workspace), on discovery (e.g., Verity) publication (e.g., Livelink), collaboration (e.g., CommunityBuilder) or personalization and access (e.g., SAP Portals).

Table 1 shows to what extent Livelink and Groove fulfill the requirements that were identified in section 2 and for what type of KM initiative these systems are suited.

Table 1. Examples for centralized and peer-to-peer systems compared

characteristics	**Open Text Livelink 9**	**Groove Networks Groove 2.5**
platform	integrated set of functions for all areas required for KMS; multi-user system for 1000+ users; easily scalable	integrated set of functions with strong emphasis on collaboration; limited number of peers, because network traffic and management of privileges might prevent scalability
advanced knowledge services	advanced services for publication and discovery; basic support for collaboration, contextualization, integration and personalization	advanced services restricted to collaboration and awareness; basic support for integration and workspace management
KM instruments	basic skill management	none
specifics of knowledge	mainly stable, documented but also ad-hoc, co-authored knowledge; customizable meta-data for contextualization; no support for stages of knowledge	focus on ad-hoc and co-authored knowledge including text and voice communication; no meta-data; no support for stages of knowledge
strategy	codification	personalization
organizational design	central	decentral
content	lessons learned, (approved) knowledge products, secured knowledge as well as ideas, experiences and individual contents	individual contents, ideas, results of group sessions and experiences
organizational culture	both types of culture (restrictive or loose user privileges)	open, trustful, collective

Livelink is a KMS that offers a comprehensive platform and functions at every level of the centralized architecture. With roots in document management, Livelink's focus is on explicit knowledge, with advanced functions for contextualization, publication and discovery across formats, platforms and the boundaries of a corporate LAN. Also, Livelink supports collaboration based on joint authoring and sharing of documents. Although Livelink can be used (almost) out-of-the-box as a basic KMS platform, most implementations adapt the user interface to corporate style guides and extend the integration and infrastructure capabilities to cover organization-specific data and knowledge sources. It is certainly more ambitious to combine and integrate Livelink's knowledge services into KM instruments. Open Text's offerings here are limited to a basic skill management instrument.

Groove can be characterized as a peer-to-peer collaboration tool that in its current form lacks a number of functions required in a KMS, but is certainly a promising candidate for an integration of the missing functions, e.g., discovery services like full-text search or navigation of workspaces, a taxonomy or ontology that integrates the knowledge currently scattered across multiple workspaces, customizable meta-data, personalization and a tighter integration of the tools in a workspace, e.g., the review cycle and files tool.

However, there are still serious technical challenges that have to be overcome in peer-to-peer computing in general. These challenges concern connectivity, security and privacy, especially the risk of spreading viruses, unauthorized access to confidential and private information and the installation of unwanted applications, fault-tolerance, availability and scalability (Barkai 1998:264ff). There are also organizational issues that have to be resolved before a peer-to-peer KMS can be fully deployed in an organization, e.g., the coordination issue meaning that structuring and quality management of the knowledge contained in a peer-to-peer network have to be supported.

Consequently, a centralized KMS like Livelink seems to be better suited for a KM initiative that can be described as a codification initiative restricted to the organization's boundaries, managed by a central organizational unit and fostering the handling of all types of knowledge. A peer-to-peer information sharing system like Groove targets a KM initiative that can be described as a personalization initiative involving members from a number of institutions. Thus the initiative is managed decentrally requiring an open, trustful, collective organizational culture and a focus on the exchange of individual knowledge, ideas and experiences.

5 Conclusion

This paper has studied the notion of the term KMS. Ideal architectures for centralized and peer-to-peer KMS were contrasted and illustrated with the help of two example systems. The systems' ability to support KM initiatives was discussed using the main characteristics required for KMS, specifics of knowledge, comprehensive platform, advanced knowledge services and the provision of KM instruments. Each of these systems targets a different type of KM initiative. Summing up, it seems that centralized KMS offered on the market more and more live up to the expectations of organizations ready to apply ICT to support a KM initiative. Peer-to-peer KMS promise to resolve some of the shortcomings of centralized KMS, especially concerning the time-consuming effort to build and maintain a central knowledge repository. However, major challenges still lie ahead until peer-to-peer systems can truly be called KMS and used to support the still growing share of users involved in knowledge work.

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