Models and tools to improve absorptive capacity of Distributed Knowledge Networks

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Abstract. Today systems finalized to knowledge creation, maintenance and diffusion into a social network are pushed to accelerate growing of their performances by competitive factors. There have been few researches on how to control this growth and make it compliant with characteristics of social network. This work aims to propose a model to create knowledge networks useful to control absorptive capacity inside the variety of levels we can find into a social network. The paper discusses an application of the model to an educational system made of nodes defined at several levels. The model provides some guideline to implement software that supports the performance empowerment of network in terms of absorptive and adaptive capacities.

Keywords: distributed knowledge management, absorptive capacity, r/K selection theory, social network.

1. Introduction

A key element of competitiveness and prosperity in modern competitive scenario is organizations' ability to innovate in order to survive in an increasingly knowledge based economy. In that pursuit, new innovation policy is continuously being rolled out in a variety of forms, ranging from 'knowledge capitals' strategies bounded inside each organization, to 'knowledge capitals' strategies open to acquire knowledge useful for innovation outside organization. This knowledge flows inside the organization by channels from other innovator organizations belonging to same network of organizations building the competitive ecosystem. In this regard, innovation is often understood as merely the capacity to create new knowledge and commercialize it successfully. This is because traditionally, the focus of innovation policy has been more on the ability of places to develop and exploit new knowledge locally, and less on their capacity to access, anchor, or diffuse new knowledge acquired from elsewhere. This is despite the fact that most innovation happens by absorption. While domestic knowledge creation and exploitation are very important for a local innovation system, external knowledge will be available only in dependency from how much big is "absorptive capacity" of organization. The "absorptive capacity" is theory or model used to measure a firm's ability to value, assimilate, and apply new knowledge. It is studied on multiple levels (level of

individual, group, firm, and networks of firms). That is the capacity to absorb new knowledge that helps to acquire competitive advantage towards competitors. Companies realize absorptive capacity in many ways: investing in R&D instead of simply buying the results (e.g. patents). On one hand, internal R&D teams increase the absorptive capacity of a company; on the other hand the channel from selling organization to buying ones' helps to increase the absorptive capacity of last one. The choice of modality to increase it depends on firm's innovation performance, aspiration level, and organizational learning. The theory of firm's absorptive capacity today is mostly conceptualized as a dynamic capability [13] based on organizational learning, industrial economics, the resource-based view of the firm (it was first introduced in 1990 by Cohen and Levinthal [2]). This theory has undergone major refinement, and today two main concepts of *receptivity* and *innovative routines* have been related to absorptive capacity, where receptivity is identified as the firm's overall ability to be aware of, identify and take effective advantage of technology [11] and innovative routines are the practised routines that define a set of competencies the firm is capable of doing confidently and the focus of the firm's innovation efforts [9]. Both receptivity and innovation routines could be realized only through mechanisms of an open knowledge management system, part of the bigger innovation system of organization, but on the other site, the problem to improve a system and its knowledge management is really hard. Furthermore we guess that absorptive capacity is related to *adaptive capacity*, as the capacity of a system to adapt if the environment where the system exists is changing. It is applied to, for example, ecological systems, human social systems and markets. Here below some key items of adaptive capacity are shown in both domains of ecology and knowledge economy and their systems.

Ecological systems	**Human social systems**	**Market organizations**
genetic diversity of species reflected	The ability of institutions and networks to learn, and store knowledge and experience.	absorptive capacity of organizations
biodiversity of particular ecosystems	creative flexibility in decision making and problem solving	Shared knowledge on several specific k-ecosystems
Heterogeneous ecosystem mosaics as applied to specific landscapes or biome regions.	The existence of power structures that are responsive and consider the needs of all stakeholders.	Heterogeneous ecosystem mosaics finalized to innovation as applied to specific landscapes or knowledge regions.

Table 1. Adaptive capacity in ecology and knowledge economy

Adaptive capacity is associated with r and K selection strategies in ecology (in ecology, **r/K selection theory** relates to the selection of traits which promote success in particular environments [8]. In r/K selection theory, selective pressures are hypothesized to drive evolution in one of two generalized directions: *r*- or *K*-selection with a movement from explosive positive feedback to sustainable negative feedback loops. Typically, **r-selected** species exploit empty niches, and produce many offspring, each of which has a relatively low probability of surviving to adulthood. In contrast, **K-selected** species are strong competitors in crowded niches, and invest

more heavily in fewer offspring, each of which has a relatively high probability of surviving to adulthood. In the scientific literature, r-selected species are occasionally referred to as "opportunistic", while K-selected species are described as "equilibrium". Applying r-K theory to knowledge networks, we can summarize that innovation could be increased by r-selection of knowledge (positive feedback to absorptive capacity) and it is maintained stable through the k-selection of knowledge (negative feedback to absorptive capacity) needed to maintain equilibrium of organization to daily operate.

The r strategy is associated with situations of low complexity, high resilience and growing potential even in social systems and technologies. K strategies are associated with situations of high complexity, high potential and high resilience, but if the perturbations exceed certain limits, adaptive capacity may be exceeded and the system collapse into another so-called Omega state, of low potential, low complexity and low resilience (low absorptive capacity).

Some questions arise from concepts of absorptive and adaptive capacities: Who really does it make organization to be receptive and adaptive? Who applies innovative routines or makes changes to happen? What are the main factors of organizations for absorptive and adaptive capacities? What are mechanisms related to dynamics of these factors that allow augmentation of absorptive and adaptive capacities? How we apply r/K strategies oh these factors?

Let us to start with some considerations to identify some factors for absorptive capacity. Organizations are social networks - real or virtual – they are collections of human communities. There are several studies (e.g. [5], [7]) that examined real world/off-line social groups and have influenced our thinking about social constructions. Results of these researches are used here even if *computer mediated communication* and virtual communities are emerging into scenario of social networks and innovation is always more spread by vehicle of virtual communication and this important point is the focus of technical part of this work. As the notion of *tie strength* is an important concept in social network analysis, in social network of organizations it could be identified as one of main factors of absorptive capability of a social network. There are many studies on how it realizes and on how to identify good indicators and predictors of “strength”. In fact, strength of a tie is a quantifiable property that characterises the link between two nodes. Granovetter [5] defined tie strength as a “combination of the amount of time, the emotional intensity, the intimacy (mutual confiding) and reciprocal services which characterize the tie”. Indicators are actual components of tie-strength (closeness, duration and frequency, breadth of topics and mutual confiding), whereas contextual contingencies (neighbourhood, affiliation, similar socio-economic status, workplace and occupation prestige) are predictors. The four indicators are thought to be linear combinations of the four elements, positive and symmetric [5]. Predictors are related to tie-strength but not components of it. Granovetter's *weak tie* argument establishes that weak social ties are responsible for the majority of the embeddings and structure of social networks in society as well as the transmission of information through these networks. Specifically, more novel information flows to individuals through weak rather than strong ties (e.g. we receive more information and knowledge by acquaintances than by our close friends that tend to move in the same circles that we do and the

information they receive overlaps considerably with what we already know). Other recognized indicators are to multiplexity or frequency of contact and reciprocity.
But does structure of network influence tie-strength and absorptive capacity of sub-networks? Is it another absorptive capacity factor to consider when we manage absorptive capacity of a network?
During the last decade, a considerable number of empirical studies have suggested that structural properties in large complex networks can be identified and occur in many areas of science and engineering, including the topology of web pages, the collaborative network of Hollywood actors (where the nodes actors and the links are co-stars in the same movie), etc. The "scale-free" is one of the most conspicuous structural properties in large complex networks [10]. A scale-free social network is a connected graph or network with the property that the number of links k originating from a given node exhibits a power law distribution $P(k) \sim k^{-\gamma}$. A scale-free network can be constructed by progressively adding nodes to an existing network and introducing links to existing nodes with *preferential attachment*. The attachment rule assumes that actors in a network try to make a tie with other actors in the network who maintain high degree centrality so that the probability of linking to a given node *i* is proportional to the number of existing links k_i that node has, i.e.,
$P(\text{linking to node } i) \sim ki/\Sigma jkj$
Common characteristics of the scale-free network are 1) centrally located and interconnected high degree *hubs*, 2) small average distance among nodes, and 3) high clustering coefficient [10].
To identify a way to improve absorptive capacity of organizations adapting recent models to manage knowledge sharing [3,4], the aim of this work is to use structural properties of social networks and tie-strength as key points to start up knowledge networks inside social networks and to control their grow to avoid them to become a clique, that is an exclusive group of people who share interests, views, purposes, patterns of behavior, or ethnicity, a form of social network where less and less "fresh" knowledge flows inside.

2. A model for the improvement of absorptive capacity in a knowledge network

Probably influenced by the seminal works of Cohen and Levintal [1] [2], most work concerning the concept of absorptive capacity explore the dimensions of acquisition, assimilation, transformation and exploitation with a particular emphasis on the innovation capability of firms. However, the concept is very general and can be applied in a variety of other application domain as well. In this paper, we are interested to study absorptive capacity and adaptive behaviour in the context of distributed knowledge networks apart from the application domain. The purpose is to understand how to define general models and new ICT systems that can support the creation and the management of knowledge communities operating either to increase continually their competencies or to acquire new knowledge oriented to the introduction of innovation. In a previous work [4] a Distributed Framework for Knowledge Management (DFKM) has been introduced as a distributed version of the Knowledge Management Framework presented in [12]. As shown in fig. 2-b) in a DFKM the concept of identity, negotiation and trust are exploited to extend the

knowledge framework of Stankosky in order to qualify a Local Knowledge Manager (LKM) within a Distribute Knowledge Network. A LKM acquires the role of hub in a scale-free knowledge network. The focus of this work is instead on how the exploitation of absorptive capacity, adaptive behaviour in a scale free network can enhance significantly the capability of a social network to acquire knowledge. Since the concept of absorptive capacity regards organizations and individuals as well, we need to introduce another kind of node to build a new model from which a technological infrastructure can be designed and implemented as a support to distributed knowledge management.

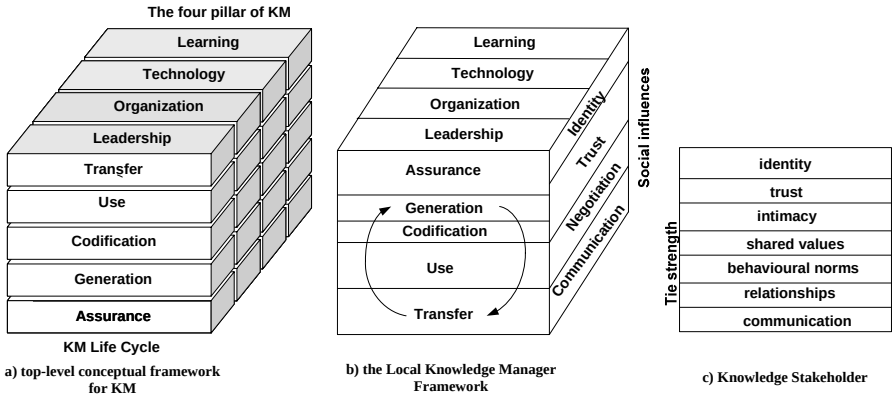

Fig. 2. The structure of nodes in a Distributed Knowledge Network.

A particular kind of LKM is the Virtual Community Supervisor (VCS); it plays a central role for the initial design and change of a social network structure as well as the its monitoring.

The second kind of node that we consider here is a representation of a *knowledge stakeholder*. A knowledge stakeholder is usually a people which desire to interact with a knowledge network in order to have the opportunity to accelerate its knowledge acquisition process at the same time attempting to reach in an easy way shared knowledge. However, a knowledge stakeholder can also be whatever entity interested, consciously or unaware of the need to increase the absorptive capacity and adaptive behavior of individuals, groups or the entire social network (e.g. local administration, foundations, central government, etc.). Of course, a LKM is itself a knowledge stakeholder but it plays a central role to build and manage the network structure.

As discussed in the introduction, aspects regarding intimacy, shared values, behavioral norms and interpersonal relationships must be considered to create models and tools finalized to support a social network oriented to increase absorptive capacity and adaptive behavior. Equally important is the notion of tie strength stated in terms of “combination of amount of time, the emotional intensity, the intimacy (mutual confiding) and reciprocal services which characterize the tie [5]. All these aspects characterize a knowledge stakeholder during its interaction with the social network

[6,7] and must be taken into account during the design and the implementation of ICT systems and specialized support software.
In fig 3 we propose a model that can be used as a reference to build infrastructures oriented to increase absorptive capacity and adaptive behavior of a social network. As it extend the meta-model discussed in previous works [4, 5], it is indeed a meta-model itself. The role of the three kinds of nodes in the network is the following:

a) LKM are the keepers of local knowledge (i.e., the one maintained by an enterprise or by a school), that are available to share their knowledge with others community participants in reference to a given application domain.
b) The role of the node VCS is of paramount importance in the start up phase of a new Distributed Knowledge Network; apart from the typical functions assigned to LKMs, it is capable to design a new knowledge network infrastructure, to assume the leadership for the government of a virtual community, to state the identity of the knowledge network, to define the four KM pillars at the meta level of DMKF.
c) KSs can be either users of a knowledge network or enablers, i.e., entities that act to promote the enhancement of competence development both at individual and systemic levels.

The virtual knowledge repository is the virtual place where shared knowledge can be stored and it is really distributed.

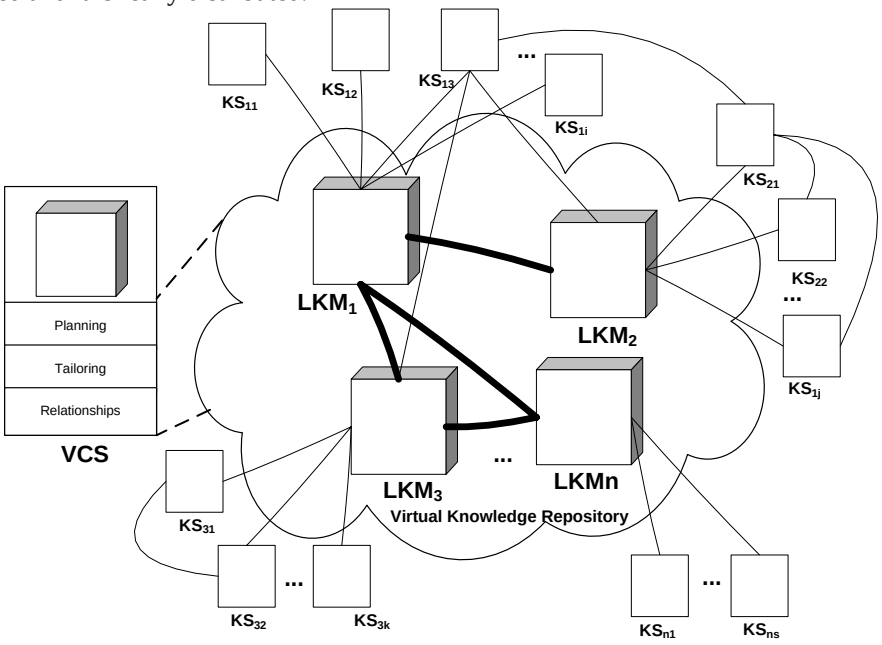

Fig. 3. A meta-model for the improvement of absorptive capacity in a social network.

Having identified the three main kinds of nodes within the generic knowledge network, the main phases for the realization of a knowledge network based on the proposed framework are:

1. **Planning**: Define the four pillars (leadership, organization, technology, and learning) at the meta-level of virtual community. This includes the social structure, the communication infrastructure and the identification of transfer protocols.

2. **Tailoring**: chose the application domain and the models for the knowledge representation; produce the first artifacts to share and disseminate.

3. **Relationships**: state identities of LKM, the negotiations and trust relationships among LKMs; define the rules that allow the LKM to consume/produce knowledge from/to the virtual repository. State the identity of KS and define the procedural aspects that allow a KS to join the knowledge network.

4. **Use**: LKMs exchange their knowledge with other LKMs. Explicit and validated knowledge is inserted and shared by means of the virtual repository. KSs receive from the virtual repository available knowledge according the transmission rules and modalities (e.g. on demand, planned transfer, asynchronous communication, e.g. announcements, notifications, etc.) or try to exercise positive influences at the level of a single participant or on the structure and organization of the whole knowledge network.

3. Application to educational systems

The problem of performance of educational systems is growing in importance due to the need of long life learning that is the strong impact of the acceleration of the big amount of new knowledge availability and of reactive and proactive adaption of organizations to continuously changing environment. Therefore, aligned with forecast, the educational system in Italy is developing towards a social network configuration. In fact, a lot of schools are aggregating in knowledge sub-networks in order to collaborate on specific projects budgeted by the national government. In this scenario the model here described could be usefully tailored and utilized to enrich the absorptive capacity of such networks, of individuals belonging or interacting with one or more of those networks, of the whole Italian educational system. The multilayer-organization of school system in Italy (Minister, regional educational government, Schools, individuals) best fits with the multi-level structure of discussed model. So the needs to improve performance rise on each of these levels:

- Empowerment of individual performance
- Empowerment of school performance
- Empowerment of network of schools performance
- Empowerment of whole Italian educational system.

The structure of school networks could be supposed to be a scale free network, where the school that has biggest knowledge available is the leader of a particular school network. It is a *hub of knowledge* for other schools in the network, it is the LKM of DKMF, (e.g. school network on a P.O.N. – Piano Operativo Nazionale- project), other schools in the network that preferred to connect with such a hub of knowledge are KS, as individuals connected to the hub or to other schools, or local government actors. They connected to the hub or to other schools due to history of network

relations or to their institutional role. Minister or regional educational government could be assimilated to the VCS. Assumed those roles in the network, the whole system can be seen as the one in Figure 3 where the regional government should perform the start-up of the network. We claim that this kind of application domain is really a good test-bed because, as opposite to other possible application domains (e.g. network of enterprises); it is not so complex to tailor the model to the operational environment and to collect data useful to the measurement of absorptive capacity. Indeed the educational system has peculiarities that allow to easily assessing the absorptive some of network's nodes. Consider for example, the educational path of a student; usually an entry test is performed ranking the student knowledge when he begins his path. Then the educational process takes place and its effect on student knowledge can be ranked again. The ranked data of each student is collected and made available to school LKM. Therefore the LKM can measure the total absorptive capacity of the school. Agglomeration of data of all the schools in the networks are available and to each of higher levels, regional educational government and Minister, so they can measure the total absorptive capacity of network.
On the other side, the adaptive behaviour can be observed, during the educational process, at both levels: individual and network. In fact, by the support of e-learning systems, forum and other web 2.0 collaboration tools, it is possible to control and improve the adaptive behaviour of individual and networks, driving them to good practices and r-k strategies implementation, which constitute the operational base for absorptive capacity growth.

4. Software Systems

As discussed before, adaptive capacity of a network can be improved from supporting technologies web2.0. Here the architecture of an Eclipse system, Eclipse learning Eclipse-L, which gathers together another three sub-systems, is shown.

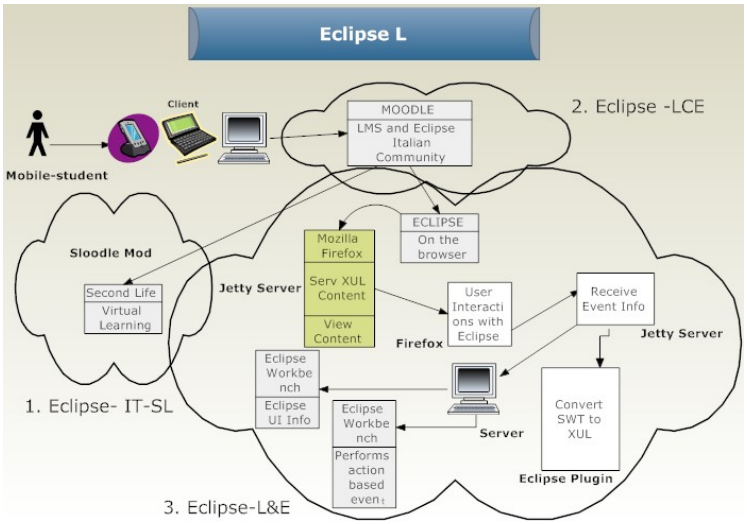

Fig. 4. Architecture of system Eclipse –L

The characteristics of whole system allow to control and improve adaptive behaviors. At state of art, the system realizes very well a support for KS node activities mainly because it realizes a student centric architecture and other adaptive behaviors of LKM and VCS are in part realized, but it can enlarge functionalities to allow it. Let describe the architecture of system as a whole and of its three subsystems. The first subsystem is called Eclipse learning and cooperative environment (Eclipse-LCE), the second is called Eclipse Italian Community with Second Life project (Eclipse-IT-SL) and the third one is called Eclipse-Lab&Exams (Eclipse-L&E). The first sub system enables the students to collaborate during a project development, homework and lab, without ever having to leave the environment that has been proposed to them; the second enables the students to interact with other members of schools network community, that is ,it enables interaction with that practice community and with that ecosystem and the third, enables the students to direct their attention to didactic activities of their school. The third subsystem, in particular, enables the students to conduct remote, multiplatform and multi-operative laboratory activities and to carry out both mock exams as well as the real exams. The system offers different didactic services to the user, who is totally independent from the platform used to access such services, from the type of connection used, from the geographic position of services and connection, etc. However the first step to implement a student formation centric versus a teacher centric is to transform the teaching paradigm, due to the *continuous presence* that is required to the teacher or his clone and the *ubiquity presence* he needs to be able to reach the user anywhere, regardless of where he/she is or of the operative platform that he /she uses. Therefore, there are a lot of advantages for such a student, who automatically becomes a Mobile-student. When university education domain is taken in account, the advantages can be better understood: the possibility of being able to freely move among the various campus/school structures; or of being able to use timely didactic services without restrictions on choice of number of topics. Within this scenario the definition of Mobile student has more meaning. A Mobile-student will not be forced to use Internet connections or prefixed technology in order to access the didactic services. In figure 4, the interaction that exists between a Mobile student and the applications that are part of the project and which permit the above mentioned conditions, which have so far been discussed is shown. The most utilized technologies are Moodle, Eclipse and Second Life. The choice of a platform which can easily host formative processes which can be engineered and re-engineered rapidly is of vital importance, especially to sustain adaptive behaviors of model. In this case, the choice necessarily fell on Eclipse. It is possible to use one of main characteristics of Eclipse: it possesses a practically infinite extensibility to every technology one can imagine to add. To use these services, the only necessary component is a browser, that is, Mozilla Firefox. Therefore, the Mobile-student has only access Internet using Firefox from any kind of terminal, be it a desktop, a laptop or a Smartphone. The system can be easily personalized by using the perspectives facilities offered by eclipse platform to allow different view for different nodes in our school network, to identify educational needs of students and tailoring of environment to what it is most useful for him/her. Moreover the architecture best fit the multi level approach of the Italian educational system as discussed in previous chapter of this work.

5. Conclusion

Knowledge Networks are increasingly recognized as a mean to pursue the acquisition of valuable knowledge either to reach a given level of competencies or to create a new knowledge oriented approach to reach innovation. In this paper, we explore the concepts of absorptive capacity and adaptive behavior in a free-scale network built to increase the capability of social network to create, share and diffuse knowledge. Our model distinguishes three types of nodes in a Distributed Knowledge Network by means of which the network can be structured, managed and used. The paper also discusses the main phases to start up a knowledge network and in particular the tailoring phase necessary to obtain an instance of the DKMF meta-model usable in a given application domain.
A possible application of a tailored model has been discussed in the realm of the regional educational system; we believe that as soon as the prototype will be mature enough, the model and the support tools will provide an adequate contribution to the enhancement of the knowledge acquisition process.

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