2.2
Reference modeling: Needs and basic terminology

A reference model for collaborative networks is a fundamental instrument for the smooth development of the area. It is therefore important to understand the reference modeling process and associated terminology. This chapters makes a brief historic analysis, introduces basic concepts and perspectives for reference modeling.

1. INTRODUCTION

Lack of reference models for collaborative networks or even to some of their manifestations (such as virtual enterprises) is an issue frequently mentioned in the literature, being also pointed out as an obstacle for a more consistent development of the area. The difficulties are found namely in the used terminology and associated meanings, which leads to frequent misunderstandings among members of the community with a different original background.

When a team of researchers or system designers develop a new system the output of the design phase is a model or set of models of the system to be implemented. A model, i.e. an abstract representation of the intended system, will then be used to guide the implementation. Due to a number of practical reasons the implemented system might show some (minor) differences regarding the original model (usually the case). A model is also very useful in order to guide (manage) and analyze the operation of the developed system during its life cycle.

Further to the models of specific systems we can also elaborate reference models. A reference model is a generally accepted framework for understanding the significant concepts, entities, and relationships of some domain, and therefore a "foundation" for the considered area.

If the design process starts without a reference model commonly used by all team members, what is typical in new areas, a larger effort is necessary to integrate the contributions of the various designers (Fig. 1.a). On the other hand, if all designers share a common reference model and a common set of definitions then the semantic gap is substantially reduced and the process can be much smoother (Fig. 1.b). A reference model can then be intuitively understood as a general (rather abstract) model that provide guidelines to effectively support designing and understanding a large variety of other more specific models for different target systems.

As also illustrated in Fig. 1), models can also be used as a basis for simulation and evaluation of the target system, even before its implementation (Camarinha-Matos, Afsarmanesh, 2006, 2008).

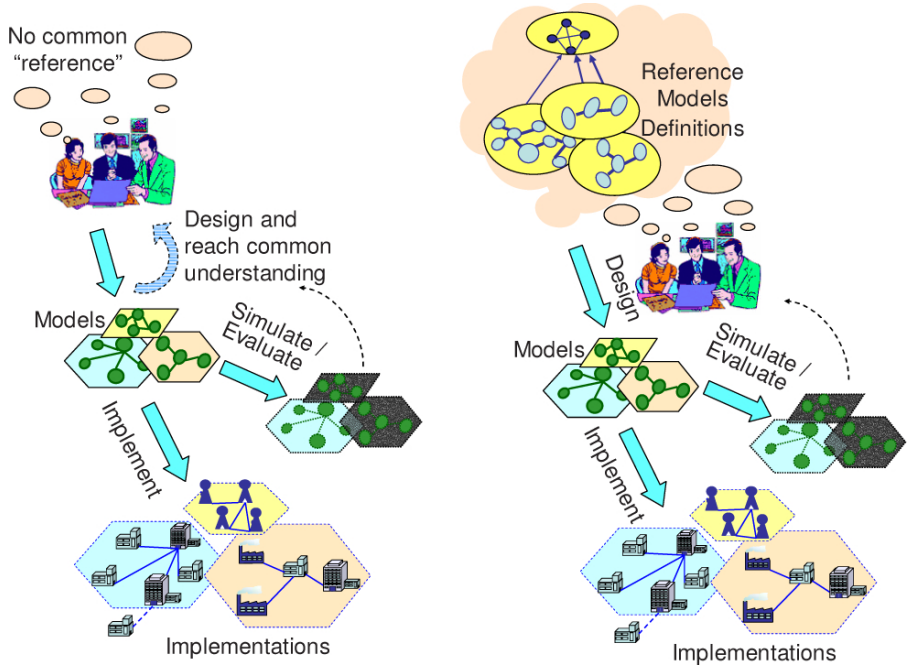

Figure 1 - a) Models and implementations b) Design based on reference models

Past projects on collaborative networked organizations mostly followed Fig.1.a as no general and commonly accepted reference model is available.

How can a reference model be generated?
If a reference model is supposed to be used as a guiding framework for the design of multiple systems then it shall in fact be an abstract representation of a large number of possible systems. Therefore, in the beginning of a new area such as CNs for which no reference model is available yet, reference models can be built via observation / analysis and abstraction of properties from emerging manifestations of the new area (Fig. 2). Complementarily, scenarios of envisaged / future CNs can also be used as input to inspire the design of a reference model. Finally, the design of a reference model can also get inspiration in other areas / theories developed elsewhere that show a good analogy with the CNs domain.

Establishing a reference model for a new entity is not an easy task since only partial inputs are available. In this context the reference model shall play a guiding / visionary role.

Once established, the reference model defines a common basis for understanding and explaining (at least at a high abstraction level) the different manifestations of the paradigm. It shall facilitate the development of particular models for specific CNOs

(Figure) (Camarinha-Matos, Afsarmanesh, 2006, 2008). These particular models will drive the implementations and also serve to simulate / evaluate the networks.

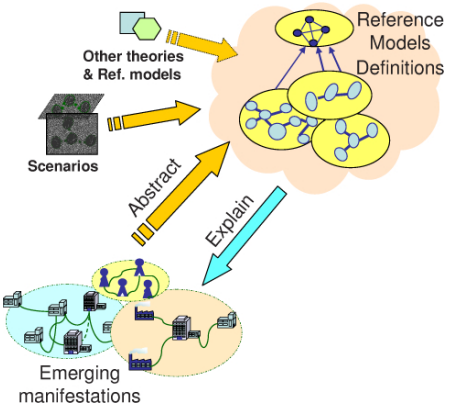

Figure 2 – Elaboration of reference models

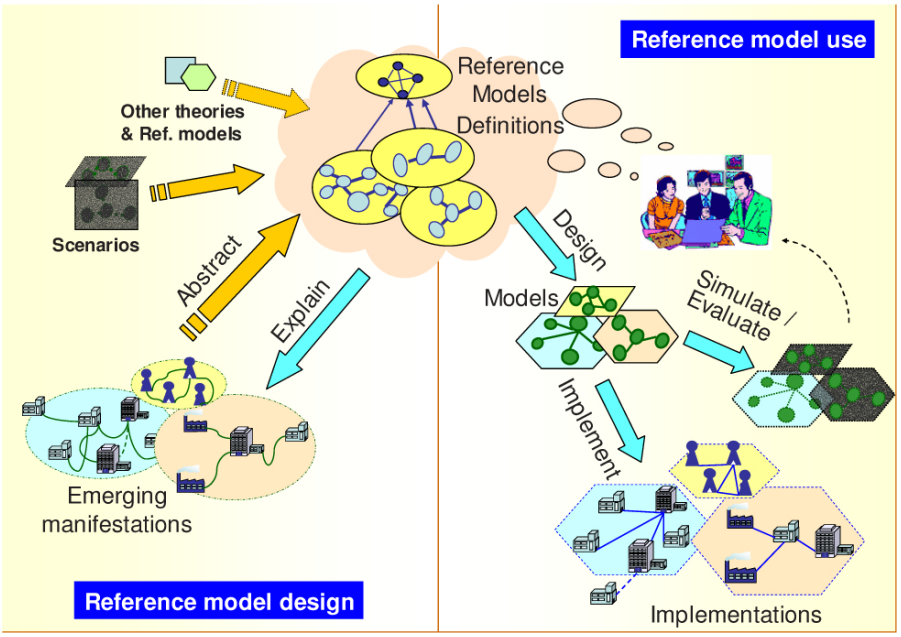

Figure 3 – Reference models in a context

2. EARLY CONTRIBUTIONS

When attempting to establish a reference model it is fundamental to consider the potential inputs and partial contributions from previous works. In fact some previous

projects have tried to contribute to reference models of some manifestations of collaborative networks, namely for Virtual enterprises / virtual organizations.

Fig. 4 illustrates the diversity of sources which can potentially be used as inputs to this activity (Camarinha-Matos, Afsarmanesh, 2006, 2008). As shown, there are two main streams:

- Enterprise-centric stream, which starts from the extensive past modeling activities at enterprise level and try to incrementally extend / adapt such models to the context of networks of enterprises.
- Network-centric stream, which puts the emphasis primarily on the networks and their properties, rather than on the characteristics of the individual elements.

These streams are not totally disjunctive and several initiatives show in fact partial elements of the two perspectives.

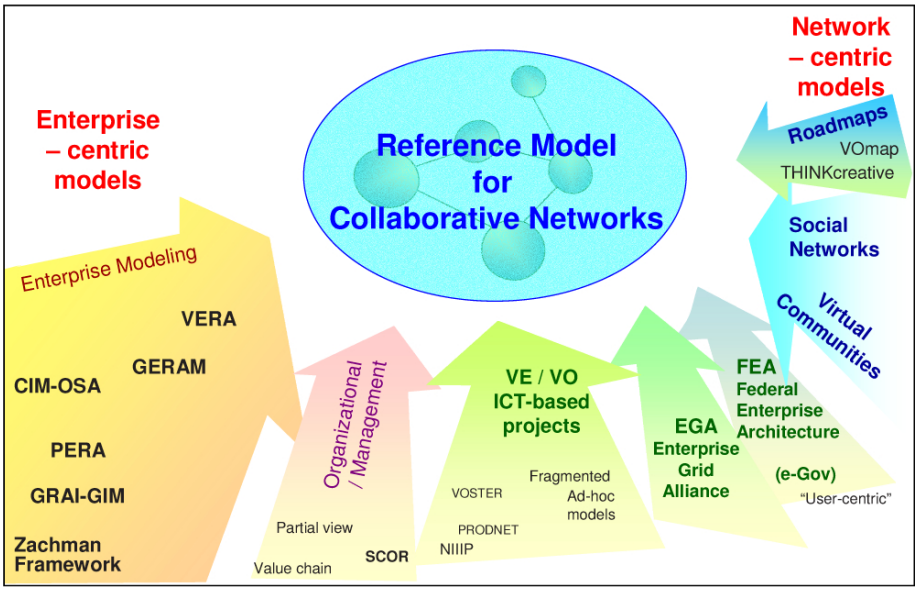

Figure 4 – Main inputs to the design of a CNO reference model

The approaches to modeling very much depend on the dominant background of people involved in each initiative. Three main groups or "schools" encompass most of the past VE/VO related developments:

i) Enterprise modeling, based on the underlying "culture" represented by the Zachman framework (Zachman, 1987), GRAI-GIM (Doumeingts et al., 1993), PERA, CIM-OSA (Vernadat, Kosanke, 1992), GERAM (IFIP-IFAC, 2003) (Noran, 2003), and related developments.

ii) Organizational / management school, which departs from traditional organizational structures such as supply chains and the corresponding SCOR model (Huan, 2004), and tries to reason about emerging organizational patterns in new collaborative forms.

iii) VE/VO ICT-based projects, which put a strong emphasis on the ICT tools and

infrastructures to support collaboration. A large number of projects have been carried out in this area that, although showing a "fragmented" and mostly ad-hoc approach, contribute with partial elements to better understand CNOs, their modeling needs and possible approaches.

Some survey works analyzing early contributions namely in the areas i) and iii) above can be found in the literature, such as (Tolle, Bernus, Vesterager, 2002), (Tolle, Bernus, 2003). The PRODNET project (Camarinha-Matos, Afsarmanesh, 1999) or the VITE model (Chalmeta 2000) are examples of ICT-driven initiatives. An example survey under perspective ii) was conducted in the VOSTER project (Katzy, Zhang, Loeh, 2005), which also included some analysis of ICT developments and common practices on VE/VO implementation (Camarinha-Matos, Afsarmanesh, Ollus, 2005). Other areas of interest include:

iv) Grid community, which has moving towards virtual organizations and is trying to consider a business perspective, as in the case of the Enterprise Grid Architecture initiative (EGA 2005).

v) E-Government, which is a wide area but has some common elements when it addresses the cooperation among different governmental organizations, as illustrated by the Federal Enterprise Architecture (FEA 2005).

vi) Social networks and virtual communities are areas that although not yet offering much in terms of reference models, have developed considerable background in terms of basic properties of networks with a strong basis on graph theory.

vii) Collaborative networks roadmapping initiatives such as THINKcreative, VOmap and others which have contributed to the identification of the research challenges in the area (Camarinha-Matos, Afsarmanesh 2004).

Fig. 5 tries to put into a simplified historic perspective some of the key initiatives and events that represent a substantial input to a better understanding of collaborative networks and therefore offer base material for the elaboration of reference models for CNs (Camarinha-Matos, Afsarmanesh, 2006, 2008).

The lower half of the diagram in Fig. 5 includes major representatives of the enterprise integration and modeling area that were particularly active in the 80s and 90s. A parallel initiative, from a different area but that can also give some hints for some cases of virtual organizations, is the Project Management Body of Knowledge (PMI 2004).

The upper half of the diagram shows initiatives that are more directly related to collaborative networks. Of particular relevance here is the heritage of a large number of VE/VO projects. VOSTER represented an attempt to synthesize part of this heritage. The PRO-VE series of conferences and the corresponding proceedings have also played a major role in the consolidation of knowledge in the area and contributing to establish some (progressive) consensus, important elements towards the definition of reference models.

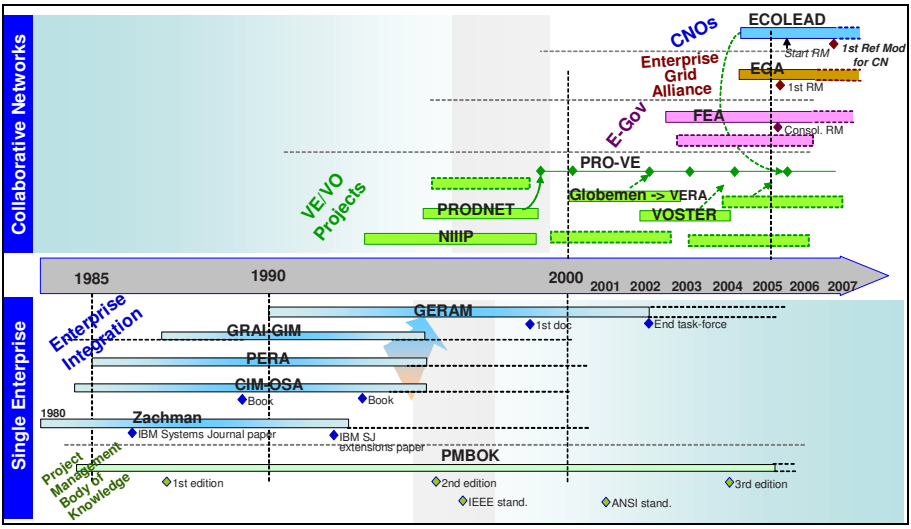

Figure 5 – Towards a CN reference model - A simplified historic perspective

The relevance given to the FEA and EGA projects in this diagram is due to being recent initiatives, almost contemporary of ECOLEAD, have published preliminary versions of reference models for their specific domains.

3. BASE CONCEPTS

The establishment of reference models for CNs is frequently pointed out as a major need for the consolidation and sustainable development of the area. However, it seems that there is not so much consensus on what this term exactly means. In fact it seems that it represents quite different things for different people and consequently it raises quite different expectations regarding its utility. It is therefore necessary to revisit the concept of reference model and its purpose.

What is a reference model?

> *"An authoritative basis for the development of specific models / systems". "An authoritative basis for the development of standards". "Generic conceptual model that formalizes recommended practices for a certain domain" (Rosemann, van der Aalst, 2007).*
> *"Provides a conceptual framework that should facilitate the creation of domain-specific application models, or descriptions of specific application domains" (Misic, Zhao 99).*

What is the purpose of a reference model?

> *"The main objective of a reference model is to streamline the design of particular models by providing a generic solution". "Reference models accelerate the modeling process by providing a repository of potentially relevant business processes and structures" (Rosemann, van der Aalst, 2003).*

> *"Reference models would be needed to foster common understanding and communication amongst members of the scientific community". "A reference model documents the emerging consensus within the scientific and industrial community, but should no constrain future work. It therefore is by nature generic and not applicable to a concrete case" (Katzy, Zhang, Loeh, 2005).*

Based on these example definitions, two main "anchors" can be associated to a reference model: Authority and re-use (Fig. 6).

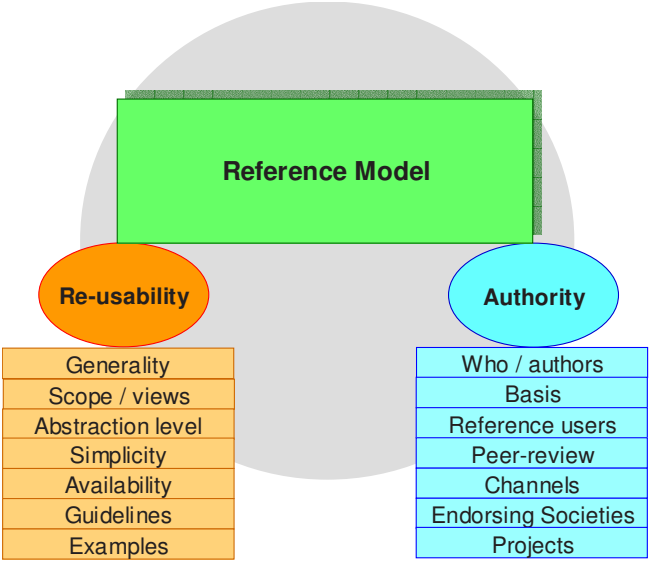

Figure 6 – Key anchors in a reference model

Establishing a model as an authoritative reference depends on a number of factors, including the authorship, i.e. the reputation / prestige of the involved contributors, the adopted bases and referenced sources, the list of early adopters or reference users, the quality of the peer reviewing process, and also the dissemination channels, professional societies and projects involved in its dissemination.

Re-usability of the elements of a reference model, with the objective of streamlining the design and development of particular models, also depends on a number of factors, including: the generality of the model, its scope and covered views, the abstraction level and simplicity, the forms of availability / easiness of access to supporting information, the existence of guidelines for use and examples of application to typical cases.

The clarification of the base concepts is however not that easy as the literature in this area is full of confusing terminology. To refer only a few, it is common to find terms such as reference architecture, reference framework, architectural framework, system architecture, etc. often used with similar or largely overlapping meanings (Fig. 7).

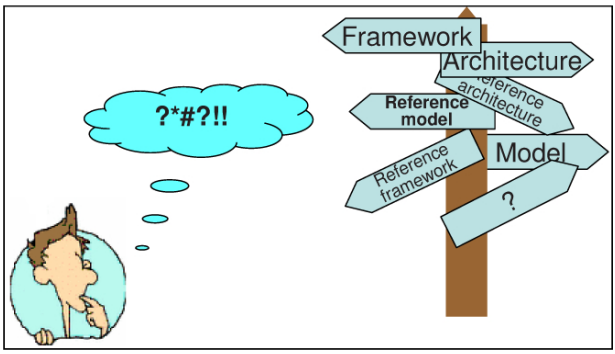

Figure 7 – Confusing terminology

For illustration purposes, let us consider a few examples:

> *"An abstract **model** (or conceptual model) is a theoretical construct that represents physical, biological or social processes, with a set of variables and a set of logical and quantitative relationships between them" (Wikipedia).*
>
> *"A **reference architecture** …is, in essence, a predefined architectural pattern, or set of patterns, possibly partially or completely instantiated, designed, and proven for use in particular business and technical contexts, together with supporting artifacts to enable their use" (RUP).*
>
> *"A **system architecture** is an abstract description of a specific system. By indicating the functions of the system components, their interactions, and constraints, it helps to (re-)develop the system. The architecture depends on engineering principles and available technology."*
> *"A **reference architecture** refers to coherent engineering and design principles used in a specific domain. A reference architecture aims at structuring the design of a system architecture by defining a unified terminology, describing the responsibilities of components, providing standard (template) components, giving example system architectures, defining a development methodology, etc." (Wyns, van Brussel, Valckenaers, Bongaerts,1996)*
>
> *"**Architecture**: The structure of components, their relationships, and the principles and guidelines governing their design and evolution over time." (DoD Integrated Architecture Panel, 1995, based on IEEE STD 610.12)*
>
> *"An **architecture** is the fundamental organization of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution." (IEEE STD 1471-2000)*
>
> *"An **architecture framework** is a tool… It should describe a method for designing an information system in terms of a set of building blocks, and for showing how the building blocks fit together. It should contain a set of tools and provide a common vocabulary. It should also include a list of*

recommended standards and compliant products that can be used to implement the building blocks." [TOGAF 8, OpenGroup]

In some other works it is possible to find some attempts to clarify the meaning of the used terms, as in the following examples:

- In software engineering:

  "A (software) ***reference model*** *is a description of all of the possible software components, component services (functions), and the relationships between them (how these components are put together and how they interact"*
  "An ***architecture*** *is a description of a subset of the reference model's component services that have been selected to meet a specific system's requirements. In other words, not all of the reference model's component services need to be included in a specific architecture. There can be many architectures derived from the same reference model"*
  *"****Implementation*** *is a product that results from selecting (e.g. Commercial-off-the-shelf), reusing, building and integrating software components and component services according to the specified architecture" [TAFIM, Carnegie Mellon University, 2004]*

- In computer integrated manufacturing and shop floor control:

  "A ***system architecture*** *is the manner in which the components of a specific system are organised and integrated".*
  "A ***reference model*** *is a generic manner to organize and integrate system components".*
  "A ***reference architecture*** *is used for the framework in which system related concepts are organized". "An enterprise reference architecture is a framework in which enterprise related concepts are organized" (Zwegers 1998).*

In order to facilitate the following work it is important to clarify these concepts in our context. Therefore, without the aim of giving a "final" definition, the following working definitions are currently established in ECOLEAD:

- **Model**: A model is an abstract representation of an environment, system, or entity in the physical, social, or logical world.
  Typically a model refers only to some aspects of the phenomenon being modeled, and two models of the same phenomenon may be essentially different. This may be due to: different requirements, differences in conceptual approaches, esthetic preferences, and also different past experiences. Therefore, users of a model need to understand the model's purpose and the assumptions or limits of its validity. Furthermore there can be models at various levels of abstraction, from very abstract theoretical constructs, to (detailed) representations very close to the modeled entity or implementation.

- **Framework**: In general a framework is a structure for supporting or enclosing something else. In the modeling area, a framework can be seen as an

"envelope" that might include a number of (partial) models, collections of templates, procedures and methods, rules, and even tools (e.g. modeling languages).

- **Reference model**: A reference model is a generic abstract representation for understanding the entities and the significant relationships among those entities of some area, and for the derivation of other specific models for particular cases in that area. Preferably a reference model is based on a small number of unifying concepts and may be used for education, explaining purposes, and systems' development.

  A **CN reference model** is thus a generic conceptual model that synthesizes and formalizes the base concepts, principles and recommended practices for collaborative networked organizations. It is intended as an authoritative basis (guide) to streamline or facilitate the creation of focused models for the various manifestations of CNs as well as architectures and implementation models for particular systems development. A reference model is generic and not directly applicable to concrete cases but rather provides the basis for the development (derivation) of other models closer to those concrete cases.

- **Architecture**: An architecture is an abstract description of a specific system, i.e. a particular model that even at a logical level tends to indicate the system structure, functions of its components, their interactions, and constraints, and can be used to develop the system. Architecture is focused on "building a system" and must be complete at its level of abstraction; therefore not all models are architectures. Although there is a difference between engineering and architecture (compare with roles of civil engineer and building architect), to some extent the architecture depends on engineering principles and available technology. An architecture can be formulated in a descriptive or in a prescriptive style. Descriptive style defines an enumeration of design elements and formal "arrangements" between them. Prescriptive style establishes constraints, namely by limiting the possible design elements and their "arrangements".

- **Reference architecture**: A reference architecture aims at structuring the design of architectures for a given domain by defining a unified terminology, describing the functionality and roles of components, providing template components, giving example architectures, and defining a development methodology. It corresponds to architecture as a style or method in the sense that it may represent a coherent set of design principles to be used in a specific area. The reference architecture is the basis for designing the specific architectures for particular instances of systems in the class of systems covered by the reference architecture.

  In the CNO domain, a reference architecture for VO management systems would represent the "structure" and principles to be followed by particular architectures of concrete VO management systems. The concept of reference architecture also induces the creation of generic re-usable "building blocks".

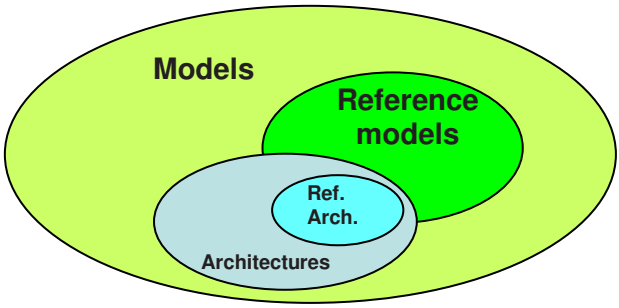

Figure 8 – Relationships among concepts

It is also important to distinguish between reference models and standards. Both share some common aspects, namely aiming at simplifying the creation of new systems and providing some stable conceptual background or building blocks. Regarding the process, both start with building consensus but then they evolve into different directions:

- Standards are basically focused on "normalizing existing knowledge" and thus tend to be conservative.
- Reference models, on the contrary, aim at "pointing a direction" and providing guidelines, and thus tend to be more visionary.

However the differences and commonalities between the two concepts depend on the level of maturity of the area. For instance, in the domain of enterprise modeling – a very old domain since enterprises exist for a long time – it took many years to distil some consensus among proponents of alternative reference models (as shown in Fig. 3). Ultimately these initiatives contributed to some standards. In the case of CNs, a much younger field in which many examples and forms of collaboration are only emerging, it does not make sense to put the emphasis, at this moment, on "standardization" but rather on providing a "direction".

4. PERSPECTIVES AND APPROACHES

Lenses or perspectives

A complex entity such as a collaborative network can be observed and analyzed through different lenses or perspectives (Fig. 9).

Each lens can provide complementary elements that help in achieving a better understanding of the paradigm. It is however important to note that lenses might also cause distortions. Particularly if one tries to explain all aspects of CNs through the perspective of a single lens, not only it leads to dangerous over-simplifications, but even introduces some misconceptions. Therefore a holistic perspective is needed.

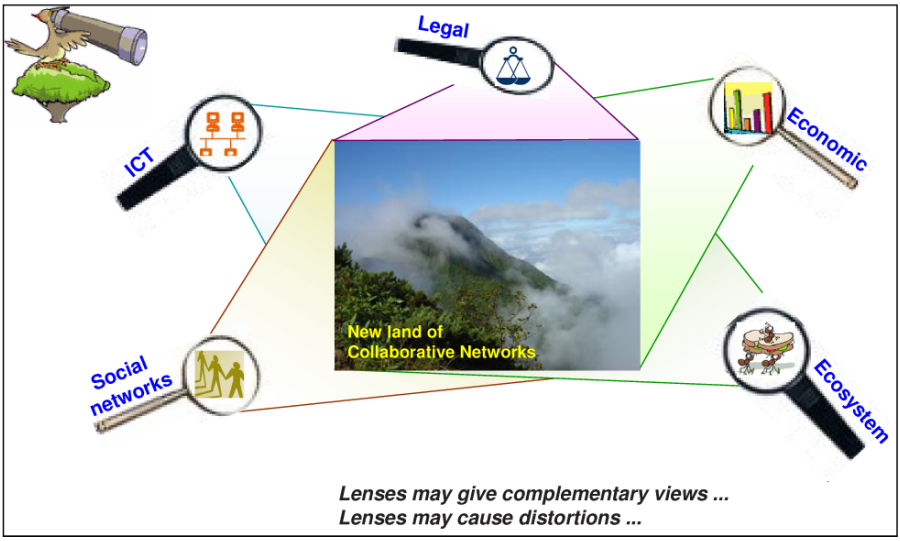

Figure 9 – CNs viewed from different lenses

Most of the previous publications towards a reference model for a CN (or some of its manifestations) are either technology-biased (e.g. Tolle, Bernus, 2003), or business-biased (e.g. Katzy et al, 2005). A holistic approach, combining both perspectives (Fig. 10) would guarantee a better alignment of business (including economic, legal, and ecosystem aspects) and technology.

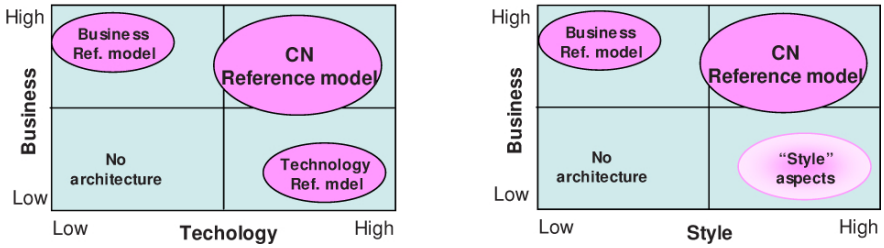

Figure 10 – Partial reference models

On the other hand, we shall not ignore other aspects such as culture, values, norms and principles, trust, etc. (often addressed in the social networks and ecosystems works) that can represent another dimension – the "style"[1] of the CN. These aspects are less addressed in previous modeling works but shall be considered in a holistic reference model for CNs.

Therefore, Fig. 11 gives a qualitative idea of the main perspectives that need to be considered on a holistic development of a CN reference model. The colored small cube is the target positioning for such model.

[1] A term borrowed from the area of architecture / civil construction.

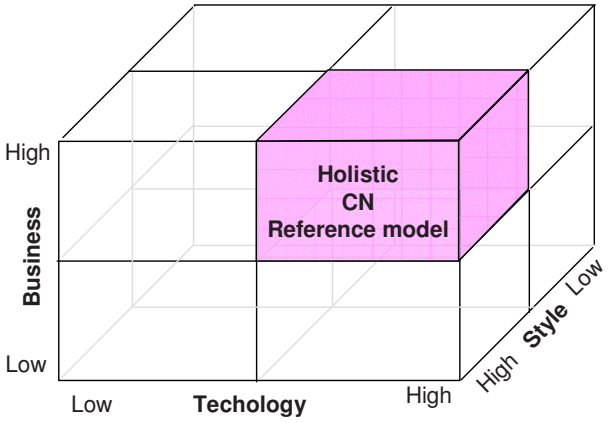

Figure 11 – A simplified holistic reference model frame

ECOLEAD does not cover all fields of expertise, namely in some areas of the *style* dimension, and the development of a full scale reference model is certainly a long term goal. Nevertheless the performed activities had this frame as guidance.

Scope or entities

Collaborative networks manifest in a diversity of forms including virtual organizations, virtual organization breeding environments, professional virtual communities, virtual teams, etc. As a first priority, general abstract models are needed in order to capture the most fundamental underlying concepts and principles of collaborative networks.

A related issue is the number of reference models: does it make sense to pursue a single global reference model or various (more focused and less general) reference models (Fig. 12)?

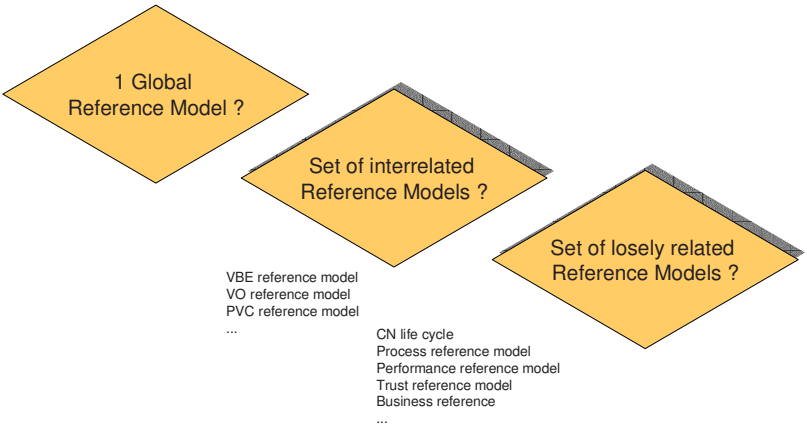

Figure 12 – One or various reference models

As suggested by Fig. 13, it is justifiable to have intermediate reference models for the entities VBE, PVC, VO, and VT as they correspond to different sectors of the

represented "cube".

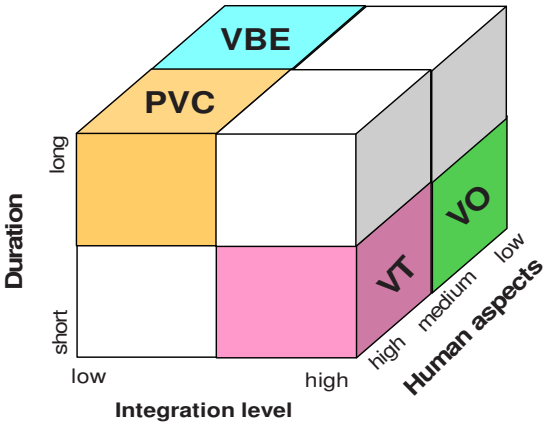

Figure 13 – Base entities and their relationship

There are, however, some common elements to the various entities, which are not evident in this cube, (e.g. actors, inter-relations, life-cycle, etc.) and therefore it makes sense to also think of a higher level of abstraction including all common features.

Target users

The nature and form of representation of a reference model (including the modeling formalisms used) depend on the target users.

The addressed user groups considered in this work are mainly researchers, educators, and other experts in the area of collaborative networks. Although one of the general goals for any reference model is to contribute to the consolidation of knowledge and to facilitate the communication among the actors involved in a specific area, the reference model itself shall not be misunderstood as a text book. Therefore, the users of the CN reference model(s), whereas researchers, engineers, or decision makers (e.g. coordinators of SME networks), are expected to have basic knowledge on the area.

The general public, workers and other professionals without background on CNs will require simplification of the model and basic intuitive representations, which will be out of the scope of the current work.

Elements of a reference model

A simple analysis of reference models developed in other areas makes it clear that there are a large number of potential elements to consider in a reference model (Fig. 14). These include elements related to the structure and behavior of the CN, but possibly also supporting elements (e.g. software systems' architecture), or elements related to applicability and life cycle of the reference model itself.

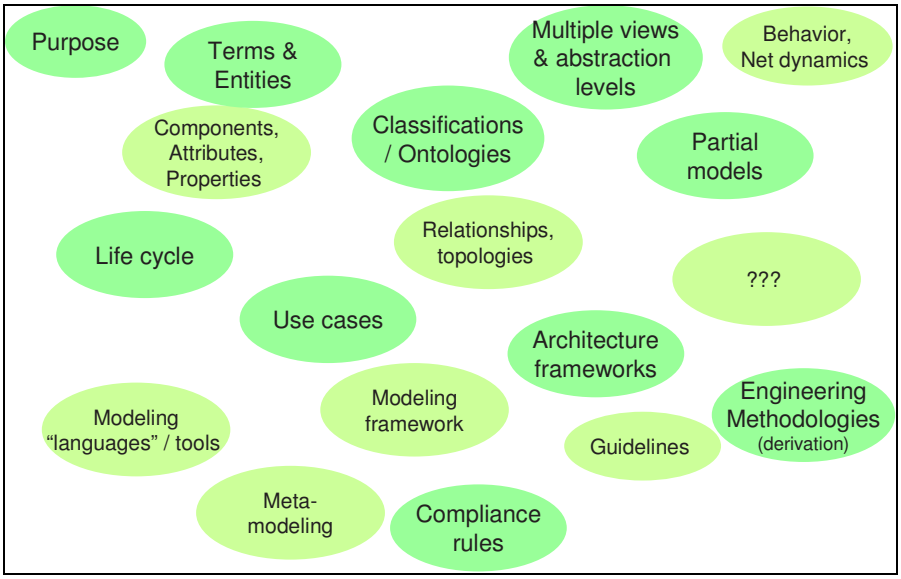

Figure 14 – Which elements for a CN reference model?

The elements exemplified above belong clearly to two distinct groups:

- "Logistics" of the reference model, e.g. purpose, modeling language/tools.
- Reference model purposes, e.g. terms and entities, behavior, life cycle, relationships.

The second group comprises four major **modeling dimensions**:

- Structural dimension, addressing the elements of structure of the CN such as actors and roles, relationships.
- Componential dimension, covering resources, ontologies, and (represented) data and knowledge.
- Functional dimension, which includes functions, processes, procedures and methodologies.
- Behavioral dimension, including the various elements of behavior and what constrains or "gives form" to that behavior (e.g. policies, contracts, agreements).

Level of granularity

In addition to the modeling dimensions presented above, it is necessary to consider, for instance, which modeling sub-dimensions shall be considered and at what level of detail. More detailed models are potentially closer to a practical use, but they tend to become too complex, reducing their understandability and thus their acceptance. Very detailed models also tend to become less general. The degree of integration among the various perspectives / dimensions is another relevant question.

Time horizon

The ECOLEAD project activities on reference models as part of its contribution to the theoretical foundation for CNs - and that are the basis for this work - is just one step in a longer term process. If we take as reference the history of the development

of reference models for enterprises (considered in isolation), an effort that spanned over more than 20 years, it becomes clear that it would be unrealistic to expect that in the life span of ECOLEAD a fully developed reference model could be developed for this emerging paradigm.

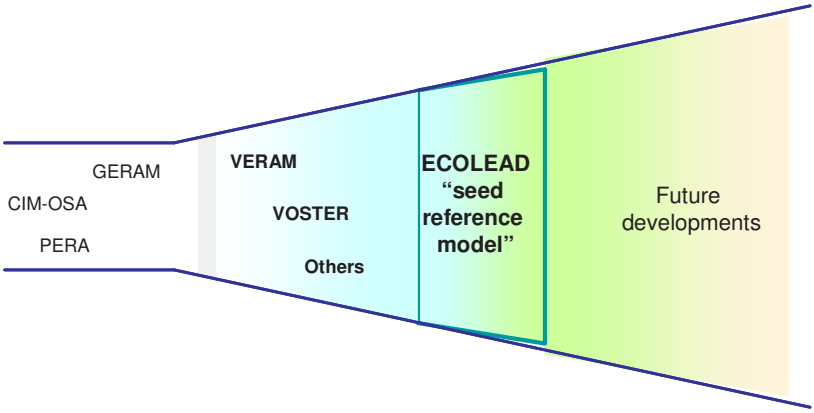

Figure 15 – Time horizon for CN reference models development

The goal was therefore the elaboration of "seed" reference model(s), based on the existing knowledge, and the establishment of the basis for future refinements and further detailing of the initial models.

Level of completeness

The discussion on the time horizon rules out the hypothesis of aiming at reference models with a high degree of completeness. In addition to the time constraints, it is also necessary to consider the limits of the available expertise and the set of CN cases considered in the project. However, ECOLEAD was driven by a holistic perspective and therefore the reference model(s), at some (high) level of abstraction, should be comprehensive and covering multiple focus areas and their inter-relationships.

A seed reference model, on top of which further developments can be pursued in the future, shall be defined at a high level of conceptualization. This model(s) shall not be confused with architectures which are more "static" and closer to implementation of systems. In an analogy, the seed reference model can be seen as a kind of "constitution". Like in country's governance, the constitution provides the global principles and has to be then instantiated in concrete laws and directives (equivalent to architectures and implementation models).

Endorsement

Although not playing the role of a standard, a reference model shall seek some level of endorsement from relevant actors and institutions in order to get wider acceptance. The aim, in the current phase of the developments of the area, is not to seek the support of a standardization body. However the support from specialized working groups (working in the area) in the framework of professional and scientific societies such as IFIP WG5.5 or SOCOLNET is important.

In the current phase, the developed modeling framework and reference models were extensively discussed in the technical events organized by the mentioned societies.

The ARCON modeling framework and the ARCON reference model (Camarinha-Matos, Afsarmanesh, 2007, 2008) for collaborative networks introduced in the following chapters of this book were driven by these general principles.

5. CONCLUSIONS

A reference model for collaborative networks synthesizing and organizing the base concepts, principles and recommended practices, is a fundamental instrument for the growth of the area.

Clearly the establishment of a reference model for CNs is a long term goal that goes well beyond the duration of a single research project, as demonstrated by many other large initiatives in related areas. Furthermore, the establishment of such a model needs a comprehensive modeling framework able to capture the multiple perspectives under which collaborative networks can be considered.

Acknowledgements. This work was funded in part by the European Commission through the ECOLEAD project.

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