Interoperability influence to network development through interoperability models

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Abstract. *Contemporary networks in information and communication technologies (ICT), as well as in science, society and economy are connected through various multiple interconnected networks – opening new connection and development opportunities. Networks' development is strongly influenced by their interoperability and interdependence. Systems based on those networks need further development and are closely interdependent, particularly influenced by their interoperability. Building networks and developing interoperability opens various questions depending on their syntactic, semantic, cross-domain and other models of network interoperability.*

Keywords. Network, influence, interoperability, development, interdependence, syntactic interoperability, semantic interoperability, cross-domain interoperability

1 Introduction

This paper emphasizes on importance of network interoperability as a part of network development influence through the various network interoperability aspects and models. In order to describe interoperability influence to network development, this paper refers to interoperability models, aiming to ensure understanding and interoperability influence relating to network development.

Network interoperability is mostly described as the continuous potential to receive and send data between two or more interconnected networks, with ensured communication quality level and negative influences excluded to the receiving and sending networks. This includes multiple functional relation, activities and continuous communication between multiple-provider, user, server, carrier and each role multiple connections (network-to-network, node-to-node, etc.). From the network theory viewpoint, we are focused to computer and network science area.

This interdisciplinary approach includes also a statistical physics, particle physics, computer science, biology, economics, operations research, and sociology. Network theory viewpoint includes Internet, logistical, social, biology networks, etc. When considering networks interoperability, we are aware of interdependency, usually when nodes of one or more networks depend on nodes in other networks.

According to Information Technology Vocabulary [30], interoperability is defined as "The capability to communicate and execute programs or transfer data to multiple functional units in a manner that requires from user to have little or no knowledge of the unique characteristics of those units". This is less strict definition, because program user can be another program, focusing on the technical side, so interoperability becomes an organizational issue.

2 Networks interoperability

Network interoperability has significant impact on the organizations and systems, raising issues of ownership and usability. The lack of interoperability regularly results in product standardization gaps during the design phase. Interoperability regularly has important economic consequences; Chapman [10] has presented inadequate interoperability cost in the U.S. capital facilities industry to be $15.8 billion annually.

There are various interoperability modes:

1. Semantic interoperability - usually defined as automatic interpretation ability, aiming to ally the information exchange accurately and meaningfully, producing targeted results, defined by the each system end users.
2. Syntactic interoperability is presented by at least two or more systems exchanging data capability, assuming ensured various data formats, communication protocols etc. - eXtensible Markup Language (XML) [65], Structured Query Language (SQL) [50], American Standard Code for Information Interchange (ASCII) [5] or Unicode [56].

3. Cross-domain interoperability – most usually presented through various organizational, economic, social, political and legal entities working together for a common interest and/or information exchange.
4. Open standards and interoperability – have to be distinguished and considered separately. Regardless of the fact that each one has the same goal – to provide efficient and effective exchange between networks, their functionalities and goal accomplishing mechanisms are significantly different.
5. Open standards imply interoperability by definition, while interoperability does not, by itself, imply wider exchange between a range of products, or similar products from several different producers, or even between past and future revisions of the same product.
6. Interoperability may be developed post-facto, as a special measure between two products, when a provider must adapt own system to make it interoperable with dominant system.
7. Search interoperability describes the ability of two or more information collections to be searched by a single query. Searching for an adequate solution for interoperability challenges, recent standards have emerged recently - The Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) [37], Resource Description Framework (RDF) [44], and Query Language for RDF (SPARQL) [49].
8. Post-facto interoperability exists in market dominance situation, considering applicable standards, or assuming that effective standards were not present at the time of the providers' product's appearance.

User wants interoperability problem solved, but the producer may continue delivering inaccurate product, newer product versions as "de facto standard", so any future change must include this fact, in order to avoid expensive remakes or new product lines.

3 Institutional framework

Considering ICT products, users may conclude that various competitors' products usually are not interoperable, due to patents, production constraints, trade secrets, coordination failures, so that may result in monopoly or market failure. Accordingly, authorities or governments need further measures to encourage interoperability. There are examples in United States - The National Information Exchange Model (NIEM) [54], in the United Kingdom - Electronic Government Interoperability Framework (E-GIF) [16].

Standards defining organizations are providing open software specifications to facilitate interoperability. Examples include the Oasis-Open [38] organization and Building SMART (formerly, the International Alliance for Interoperability) [8]. The Open Service for Lifecycle Collaboration Community (OSLC) [40] focus was on finding a common standard, aiming to an open standard for open source interoperability - Application Lifecycle Management tools (ALM) [55].

Various systems are dealing with interoperability. They have focused their activities to World Wide Web development, so to ensure semantic web. Some of them are focused on e-Business, e-Government, or plain data exchange. European Commission and its Interoperable Delivery of European eGovernment Services to public Administrations, Businesses and Citizens program (IDABC) [25] have established the European Interoperability Framework. IDABC was succeeded by the Interoperability Solutions for European Public Administrations (ISA) [29] program. They have initiated the Semantic Interoperability Centre Europe (SEMIC.EU) [47]. European Land Information Service (EULIS) [52] was established in 2006, as a consortium of European National Land Registers. In 2009 European Commission established implementation of Information System for Agricultural Market Management and Monitoring (ISAMM) [28], connecting the member states agricultural markets and systems.

Network interoperability may be developed variously:
- Product testing - products depend on standard clarity, with various implementation approaches;
- Product engineering - necessary to ensure common standard implementation products, meeting expectations upon interoperability to other standards and software implementations;
- Industry and community are implementing existing software standard in order to reduce options and that way ensuring more interoperability;
- Common technology and IP aims to speed up and reduce interoperability complexity through reducing components variability;
- Standard implementation, ensuring software interoperability, providers need a common agreement, represented as standard.

Interoperability usually is a power issue, because of market dominance. It tends to be regarded as a challenge for experts and its implications for daily living are not evaluated as critical enough.

The European Union Microsoft competition case [22] shows how interoperability deals with important power issues. In 2004, the European Commission found that Microsoft had abused its market power by restricting interoperability between Windows work group servers and non-Microsoft work group servers.

This way Microsoft could protect its dominant position for work group server operating systems, as the heart of corporate IT networks. Microsoft was ordered to disclose complete and accurate interface

documentation, enabling "competitor" providers for "the interoperability remedy".

When considering interoperability, we are focused on Semantic Web as a collaborative movement, led by international standards body the World Wide Web Consortium (W3C) [64]. It promotes common data formats on the World Wide Web. The Semantic Web stack builds on the W3C's Resource Description Framework (RDF) [44].

Conceptual interoperability, as a concept in simulation theory, is recognized particularly in Levels of Conceptual Interoperability Model (LCIM) [63]. Petty and Weisel [42] distinguish between the idea of interoperability, coping with the technical challenges, and composability, and the Virginia Modelling, Analysis and Simulation Centre (VMASC) [60], have refined these layers to define the Levels of Conceptual Interoperability Model (LCIM) [63]:
0. Stand-alone systems - No Interoperability.
1. Technical Interoperability, a protocol for data exchange between systems participating.
2. The Syntactic Interoperability, a common structure for information exchanging.
3. Semantic Interoperability, using a common information exchange reference model.
4. Pragmatic Interoperability, when the interoperating systems are aware of the methods and procedures that each system is using.
5. Data interchange, the system will change, as well as the assumptions and constraints that influence the data interchange.
6. Conceptual model, the highest interoperability level, as requested by Davis and Anderson [12].

Model Driven Interoperability (MDI) [35] is a methodological framework, which provides a conceptual and technical support to make interoperable enterprises using ontologies and semantic annotations. MDI was initiated in 2004 with the beginning of two important research projects:
- Advanced Technologies for interoperability of Heterogeneous Enterprise Networks and their Applications Integrated Project (ATHENA) [26] IPFP6-IST-507849 (EU Sixth Framework Programme) [19];
- Interoperability Research for Networked Enterprises Applications and Software Network of Excellence, (INTEROP NoE) [27] FP6-IST 508011 (EU Sixth Framework Programme).

MDI Framework within INTEROP is defined:
- From conceptual viewpoint, Reference Model providing an Interoperability Model proposed, at different levels of abstraction.
- From methodological viewpoint, Model Driven Interoperability (MDI) as a method aimed to enable interoperable Enterprise Software Applications (ESA) [17], starting from the level of the Enterprise Model.
- From technological point of view, vertical and horizontal semantic support providing, so to perform model transformations.

The Business Interoperability Interface (BII) [51] of an organization comprises all information relevant for partner organizations enacting a collaborative business process with the organization. The term was introduced by the European Commission in the European Interoperability Framework, aiming to improve the interoperability of public administrations using different standards internally.

Following the work on interoperable information systems conducted in European Research Projects, in 2010 the Architecture of Interoperable Information Systems (AIOS) [67], was published as a reference for the construction of interoperating systems and model-based enactment of collaborative business processes.

The main elements of the AIOS are:
1. A different data types included in interoperable information system, their relationships, called the structure static part of the architecture, leading organizations to information elements they have to ensure to their partners and how to correlate optimally each element.
2. A different implementing approaches or interoperable information systems adjusting, i.e. - the architecture dynamic part, so to lead organization, to develop the elements mentioned above iteratively.
3. Technical components concept, architecture implementation aimed - design tools and repositories.

The AIOS is reference architecture for the interoperable enterprise information systems development. It was described in Ziemann's work [67] and is based on the results of various interoperability research projects, combining concepts, from Service-oriented Architecture, Collaborative Business and Business Process Modelling, as shown in figure 1.

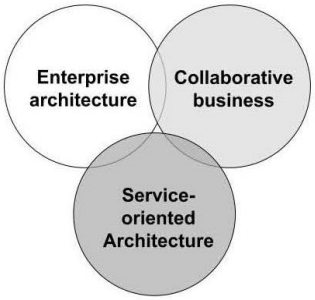

Figure 1: Development of collaborative business processes based on three research fields. Source:

Ziemann, J., Architecture of Interoperable Information Systems [67]

The AIOS represents a building model for development of interoperable systems, adjusting and extending their internal information systems systematically.

4 Related works and contemporary references

Ziemann (2010) [67], claims that complex networks describe a wide range of systems in nature and society. Various examples are including the cell, a network of chemical reactions, and the Internet, a network of routers and computers connected by physical links.

Allen et al. (2013) [1] case study on information sharing and interoperability has shown importance of network communication and development. Page et al. (1999) [43] are suggesting composability, a new term defining as the core the interoperability model and the core of the model software implementation.

Voeten et al. have applied Actor-Network Theory (ANT) (2013) [61], describing the human interaction in networks' shaping, showing why innovators in some networks behave opportunistically.

Van Mierlo et al. (2010) [59], has presented conditions for social learning such as society trust in social environment, community belief in own capacities, risk perceptions, perception of own role.

European Conference on Interoperability for Embedded Systems Development Environments [18] in Stockholm (December 2013) has shown trend of interoperability growing influence and importance in various areas, particularly in software.

Sinz (2002) [48] defined the information system architecture as the information system building plan in the sense of a specification and documentation of its components and their relationships covering all relevant viewpoints as well as the constructions rules for the creation of the building plan.

Nelson and Winter theory of nonlinear, open systems models (1982) [36], opened an economic evolutionary perspective, further developed in the Kline and Rosenberg chain link model (1986) [31], of stressing feedback loops between research, technological knowledge and the market.

Freeman (1987) [20], and Lundvall (2009) [33], advanced the theory that the process of innovation is characterized by interactive learning within an innovation system: a spatial concentration of firms and associated non-market institutions - universities, research institutes and government agencies.

Lundvall [33] has linked economic development in developing countries to innovation system analysis, claiming that misunderstanding of the innovation system in 'formal institutions' is considered as less useful concept for innovation understanding and explaining in this context. Edquist (2005) [15], emphasized his work on institutions role, explaining innovation in the innovation systems theory.

Van Kleef (2007) [58], stressed on environmental management and and sustainable development issues. Against that background Clarke and Roome (1999) [11], stressed an importance of a set of relationships connecting society organizations and stakeholders, complement formal organizational structures, linking individuals together by the flow of knowledge, information and ideas.

Network theory has become the focus of series of scientific research attention (Granovetter, 1973 [21]; Milgram, 1967 [34]; Watts and Strogatz, 1998 [62]; Barabasi 2003 [6]).

Related to the innovation systems, networks are seen as critical mechanisms for the development of knowledge and learning that leads to innovation and adaptation (Cartwright and Harary, 1956 [9]).

Networks create social capital for communities (Putnam, 2000 [43]) and individuals (Bourdieu, 1985 [7]). Networks lead to "innovative regions" (Rutten and Boekema, 2007 [45]).

Additionally, networks are building trust (Sabel (2005) [46]; Uzzi (1997) [57]) as well as economics of scale, acknowledged in cluster literature (Humphrey and Schmitz (1996) [24]). A network theory as research tool has been used effectively for various interdisciplinary studies.

5 Network development

The Global Development Network (GDN) [53] is a worldwide network of research and policy institutes working to provide new perspectives to the development challenges of our time.

A World Bank spin-off, GDN is aimed to make policy-relevant research accelerate the pace of global development. It appears that interoperability becomes more important in a situation of limited ability to share and centralize.

Establishing an interoperability framework is a way to overcome the insurmountable obstacles of rearranging

data and applications in ways that make services truly citizen-centric (Di Maio, 2013) [13].

Figure 2: Gartner Recommended Reading

Software-Defined Networking (SDN) Will Change the Data Center Network Vendor Landscape
Adoption of software-defined networking will spark a new race among traditional and new data center networking vendors with a reorganization of the supply side, creating competition and opportunities for all vendors. Impacts and Recommendations:
- SDN will simplify network device development, enabling new competition and disrupting the existing market landscape
- SDN will force traditional networking vendors to migrate from proprietary-coupled hardware and software designs to open-standard designs to shorten the innovation cycle
- SDN combined with standardized open interfaces will further enable best-of-breed offerings for networking hardware, software and services, as well as will create an environment for innovation.

Source:
Gartner, Inc https://www.gartner.com/doc/2630045 [66]

Figure 2 presents Software-Defined Networking, recent trend in networking.

6 Interoperability influence to network development

Increasingly, electronic governance involves multi-organizational ICT-enabled networks. A critical requirement for Government Information Systems [32] is that the systems of their various partner organizations are interoperable. Such systems often fail to achieve interoperability due to compliance insufficiency with the necessary standards by the partner organizations in these networks. Achieving interoperability is however a complex task sometimes appearing as a "catch 22" situation [23]. Progressing towards sustainable interoperability will require establishing some suitable level of consensus regarding how to achieve integration, pushing standards and creating a momentum for adoption. Given the strong industrial needs to overcome current integration problems, a multitude of efforts are now addressing interoperability.

They range from industrial efforts, commercial developments, Artemis research projects such as CRitical sYSTem engineering AcceLeration (CRYSTAL) [2], Industrial Framework for Embedded Systems Tools (iFEST) [3] and Combined Model-based Analysis and Testing of Embedded Systems (MBAT) [4], or other initiatives and organizations such as ECLIPSE - an integrated development environment (IDE) [14], Object Management Group (OMG) [39] and OSLC [40].

This paper aims for contribution to theoretical framework development, towards adoption of networks interoperability standards. Critical requirement for networks is their various systems interoperability. Big and complex networks hardly ever achieve interoperability, because of minimum standard compliance and harmonization.

Paper goal was also contribution to theoretical framework development for the description of interoperability influence further research. Following a relevant literature review, the paper identifies modes, relations and constructs. In order to identify key factors, the framework provides a useful viewpoint for further research on interoperability.

7 Conclusion

Internet developments, as well as other networks developments, various ways organizational developments, known, even more unknown factors are opening new questions and issues. Each network is influenced by various factors.

Ensuring interoperability to cover all those networks, their interconnections and growing interdependence, enables those networks development influencing, with strong influence to their sustainability, as their functioning strongly depends on network interoperability.

Growing number of articles, papers and works lead to conclusion of this area importance, particularly for the fact that there are critical issues for the network developments.

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