

# Virtual Health Care Infrastructures: Markets and Hierarchies

Ann Séror

*eResearch Collaboratory*

*annseror@erresearchcollaboratory.com*

## Abstract

*The objective of this review is to develop a conceptual framework for analyzing the evolution of large scale virtual infrastructures in ideologically diverse health care systems. Market dynamics and system control mechanisms define the logic of system structures, processes and ideologies. Ideology, defined as the integrated theories and values that constitute a coherent socio-political system, is expressed in patterns of stakeholders' participation in the financing, administration, and regulation of health care, including the roles of government and health care enterprise, both public and private. Large scale grid and cloud computing systems are considered as well as the emerging influence of global social networks. The analysis suggests alternative paths to health care service delivery motivated by professional, citizenship, consumer and managerial values expressing ideological diversity among institutional systems.*

## 1. Introduction

Few studies have addressed large scale e-infrastructure in the health care sector, probably for a number of important reasons. Health care systems require multi-disciplinary perspectives from health economics, medical and bio-informatics, computer science and sociology, as well as organizational psychology and theory. The resulting complexity of the research enterprise has discouraged development of this knowledge domain, while the disciplines engaged have maintained their distinct theoretical and methodological boundaries. There is little or no consensus among the greater scientific community to serve as a foundation for integrated theoretical frameworks or methodological innovation required for development of this knowledge domain. As complex technological change challenges institutional capacities for adaptation, the need for this research has grown, particularly to guide national and global health care system reforms in progress. This study presents an

multi-disciplinary conceptual review from the fields cited above to construct a framework for analysis of large health care systems and their e-infrastructure in their respective ideological settings.

## 2. Research Problem

Virtual infrastructures refer to an environment characterized by overlapping distribution networks accessible through Internet portals and websites designed to facilitate integrated use of available resources.[1, 2] Design of these infrastructures is motivated by professional, citizenship, consumer, and managerial values underlying the dynamics of markets and hierarchies.[3] The contributions of medical informatics and bioinformatics enhance evidence based health care service and system management as well as the integration of genomic research in these health care models. [4-9] These virtual infrastructures also support evidence based policy making. [10]

Large scale virtual infrastructures enable decentralization while at the same time extending economies of scale and scope in allocation of system resources.[1] The exponential growth of collaborative capacity and computational power requirements in health care systems is addressed by large scale e-infrastructure including cloud and grid computing systems. These complex changes raise important questions concerning the evolution of diverse health care systems, such as the convergence hypothesis in sociology suggesting that over time organizations may tend to resemble one another through processes of isomorphism that divert them from objectives of optimization or efficiency towards legitimacy in inter-organizational relations.[11, 12] Information technologies including grids and virtual institutions add another level of analysis to be considered with respect to this hypothesis. The systems under consideration may adopt, for example, business models to facilitate trade in international health care services markets, or they may create boundaries to protect the integrity of internal – national or institutional -

markets. Such markets evolve as a function of ownership and control of system institutions and virtual infrastructures.

While the grid is defined as a distributed computing infrastructure providing direct access to computing power and software with coordinated resource sharing and problem solving in dynamic, multi-institutional virtual organizations, cloud computing offers scalable access to infrastructure as a service (IaaS). [13-17] Grid and cloud infrastructures may be understood according to their functions, types of ownership, and market dynamics of the communities they serve. [18]

Computational grids create a virtual supercomputer by aggregating the computing power of a large number of individual computers to derive a platform for advanced high-performance applications. Data grids focus on sharing vast quantities of data while information and knowledge grids extend these capabilities by supporting data mining and analysis, information discovery and ontologies. These grid infrastructures offer data gathering, processing and presentation with an interactive interface for translation of information into complex knowledge, planning, management, and raw data exploration through simulation. Collaborative grids enable virtual environments supporting individuals or groups in pursuit of shared objectives. These grids may support virtual laboratories as well as remote control of medical technologies for medical imaging and sensing.[19] While these grid functions may be distinguished, it is important to note that they are increasingly integrated with cloud infrastructures in extensive national and regional systems, particularly in the United Kingdom and the European Union.

Collaborative problem solving and resource brokering also define the nature of the virtual organization.[20, 21] Grid and cloud computing technologies address the challenges of heterogeneous computing environments, scaling access to decentralized systems and resources, as well as high IT infrastructure costs. These environments rely on connectivity, resource and coordination protocols for communication, resource allocation and system integration. The multi-level virtualization of resources means that the same abstractions and mechanisms can support collaboration across organizational domains and within hosting environments of a single domain spanning multiple system tiers. Grid technologies enable dynamic and scalable cross-organizational sharing to create markets for computing and storage resources otherwise constrained in static configurations. Ideology is expressed in these infrastructures as differences in visibility and accessibility controlled by

resource ownership rather than interaction mechanisms.[22, 23] Grid infrastructures may be understood according to types of ownership and market dynamics of the communities they serve[18, 24]:

- Private grids are managed by a corporate or professional owner to mobilize the computing capacity of idle desktop computers or unused servers within the corporate entity. Such capacity may also be outsourced for computing on demand. An example is the Archimedes disease model.
- National or regional grids create large laboratories serving communities based on institutional membership or citizenship. There are many initiatives in this category contributing to development of the eScience infrastructures in the United Kingdom and the European Union
- Virtual grids serve communities of researchers and professionals requiring specific resources such as instrumentation for research, medical imaging and diagnostics.
- Public grids emerge from markets for computational resources guided by consumer groups as well as specialized service providers. Such markets depend on effective commoditization of computing resources.

These infrastructures support a variety of market dynamics for integration of health care services including research and education. Centralized local IT environments are thus transformed by market pressures inducing collaboration, data sharing, research, and clinical as well as managerial decision making founded on access to distributed resources within and across institutional systems.

In addition to the structure of networks, ideological context particularly affects the social and hierarchical relation between health care professionals and their patients as well as the emphasis on individual choice with respect to collective or institutional interests and priorities.[25] Social media may link market actors in ways consistent with or complementary to the prevailing system ideology.[26, 27] Free health care market dynamics promote de-professionalization of health care and greater information symmetry among physicians, patients, and other health care services market actors.[28] On the other hand, a more socialized model of health care delivery creates powerful centralized government institutions as in the British NHS. [29, 30]

		DOMINANT CONTROL STRUCTURES AND PROCESSES	
		Norms and Standards : Behavioral Control- CLANS	Institutional Infrastructures : HIERARCHIES
MARKET DYNAMICS : HEALTH CARE PRODUCTS AND SERVICES	SUPPLY-PUSH : PROFESSIONALS	<p style="text-align: center;"><b>PROFESSIONAL COVENANTS</b></p> <ul style="list-style-type: none"> <li>* PROPRIETARY NETWORK STRUCTURE (WAN/LAN).</li> <li>*Distributive multi-agent system architecture.</li> <li>*Associative clinical process integration. (medical specialties)</li> <li>*Access controlled by healthcare professionals.</li> <li>*Decentralized professional authority.</li> <li>*Professional criteria for presentation of Web content and other electronic healthcare information.</li> <li>*Professional certification of healthcare workers, services and institutions.</li> <li>*Virtual grids: MammoGrid (EU): <a href="http://www.cems.uwe.ac.uk/cccs/project.php?name=mammogrid">http://www.cems.uwe.ac.uk/cccs/project.php?name=mammogrid</a></li> </ul> <hr/> <p>PROFESSIONAL VALUES Example: American Medical Association - AMA (US): <a href="http://www.ama-assn.org/">http://www.ama-assn.org/</a> AMA Institute for Ethics: <a href="http://www.ama-assn.org/ama/pub/category/2558.html">http://www.ama-assn.org/ama/pub/category/2558.html</a></p> <p>PRINCIPLE: Professional norms, Hippocratic oath.</p>	<p style="text-align: center;"><b>NATIONAL CONSTITUTIONS</b></p> <ul style="list-style-type: none"> <li>*PROPRIETARY NETWORK STRUCTURE (WAN/LAN).</li> <li>*Federation architectures.</li> <li>*Federative structural integration.</li> <li>*Access controlled by institutional and telecommunications network structures.</li> <li>*Centralized national and regional hierarchies.</li> <li>*Institutional standards for presentation of Web content and other electronic healthcare information.</li> <li>*Institutional certification by network affiliation.</li> <li>*National/regional grids: eScience (UK-EU) European Grid Infrastructure: <a href="http://www.egi.eu/">http://www.egi.eu/</a></li> </ul> <hr/> <p>CITIZENSHIP VALUES Example : National Health Service –NHS (UK): <a href="http://www.nhs.uk/">http://www.nhs.uk/</a> NHS Core Principles: <a href="http://www.nhs.uk/NHSEngland/thenhs/about/Pages/nhscoreprinciples.aspx">http://www.nhs.uk/NHSEngland/thenhs/about/Pages/nhscoreprinciples.aspx</a></p> <p>PRINCIPLE : Universal service and citizen equality. Social contract. System performance effectiveness.</p>
	DEMAND-PULL : CONSUMERS	<p style="text-align: center;"><b>FREE MARKETS</b></p> <ul style="list-style-type: none"> <li>*OPEN INTERNET NETWORK STRUCTURE.</li> <li>*Mixed architectures with autonomous agent systems</li> <li>*Search engines.</li> <li>*Dynamic associative integration.</li> <li>*Access controlled by individual consumer choices and availability of products and services in the market.</li> <li>*Decentralized and deprofessionalized authority with individual consumer participation.</li> <li>*Certification of products and services by independent evaluators.</li> <li>*Criteria for individual consumer evaluation of web content and other electronic information developed with consumer participation.</li> <li>*Public grids: Berkeley Open Infrastructure Network Computing (US): <a href="http://boinc.berkeley.edu/">http://boinc.berkeley.edu/</a> ;</li> </ul> <hr/> <p>CONSUMER VALUES Example: WebMD (US): <a href="http://www.webmd.com/default.htm">http://www.webmd.com/default.htm</a> EHealth Ethics Initiative: Internet Healthcare Coalition (US): <a href="http://www.ihealthcoalition.org/ehealth-code-of-ethics/">http://www.ihealthcoalition.org/ehealth-code-of-ethics/</a> Health on the Net Foundation (INT): <a href="http://www.hon.ch/HONcode/Conduct.html">http://www.hon.ch/HONcode/Conduct.html</a></p> <p>PRINCIPLE: Responsible self-regulation. Emergent norms.</p>	<p style="text-align: center;"><b>BUSINESS CONTRACTS</b></p> <ul style="list-style-type: none"> <li>*PROPRIETARY NETWORK STRUCTURES (WAN/LAN).</li> <li>*Federation architectures.</li> <li>*Corporate gateways.</li> <li>*Federative business process integration. (business transactions)</li> <li>*Access controlled by collective choices and network structures.</li> <li>*Managerial authority with enterprise hierarchies governing institutions and consumer organizations.</li> <li>*Certification of products and services by institutional evaluators, consumer organizations, and accreditation agencies.</li> <li>*Criteria for collective consumer evaluation of web content and other electronic information by accreditation agencies.</li> <li>*Private grids: Archimedes Model (US): <a href="http://archimedesmodel.com/">http://archimedesmodel.com/</a></li> </ul> <hr/> <p>MANAGERIAL VALUES Example: Kaiser Permanente (US): <a href="http://www.kaiserpermanente.org/">http://www.kaiserpermanente.org/</a> Kaiser Permanente Care Management Institute (US): <a href="http://www.kpemi.org/">http://www.kpemi.org/</a> National Committee for Quality Assurance (US): <a href="http://www.ncqa.org">http://www.ncqa.org</a> Joint Commission on Accreditation of Healthcare Organizations (US): <a href="http://www.jointcommission.org/">http://www.jointcommission.org/</a></p> <p>PRINCIPLE: Business contract with consumers. efficiency.(cost/benefit)</p>

Figure 1 : Health care system models

### 3. Health Care System Models

Figure 1 above presents a conceptual framework for interpretation of health care system models. Virtual infrastructures contribute to control mechanisms of health care management systems through network structures and transaction services offered directly on the Internet. The classic concepts of clans and hierarchies in economics and organizational theory are useful to the understanding of control processes in virtual infrastructures.[3] Clan control is expressed through norms and standards emergent in behaviour on the Internet. Examples of clan control include codes of professional conduct and codes of ethics governing cyberbehavior as well as norms for presentation of Web content and criteria for consumer evaluation of electronic information. On the other hand, grid and cloud technologies, telecommunications networks and the Internet may give rise to institutional hierarchies of control.[1, 31]

Technological control mechanisms may effectively regulate access to health care services and ensure social or business contract security, confidentiality and integrity. For example, diverse physical databases may be integrated into a single federated unit. Federation enables unified access to any digital information, in any format, structured and unstructured, among such diverse databases appearing as a single resource. [1, 31] In the case of clan control, autonomous and distributive multi-agent architectures contribute to associative system assembly and integration as well as commoditization of health care services in response to consumer demand, particularly in the Free Market model. Hierarchical control in the National Constitution and Business Contract models yields structural or process integration through federation architectures.[32, 33]

These models interact in health services markets to produce convergence or divergence of their respective configurations. It is very important to emphasize that market dynamics described in this framework are not mutually exclusive but integrated in complex patterns across hierarchical levels and system boundaries.

### 4. Discussion and Conclusions

The framework developed in this review proposes to show how virtual infrastructures contribute to health care services markets depending upon forms of control, market dynamics of supply and demand and corresponding system ideologies. Information is the foundation of future health care management systems including genomic science and evidence based medical practice, global public health watch and research

governance. The framework suggests alternative paths to health care service delivery motivated by professional, citizenship, consumer and managerial values expressing ideological diversity among institutional systems:

- Interdisciplinary integration, particularly genomic medicine and bioinformatics are refocusing attention on basic research at the foundation of medical practice. Bioinformatics and medical informatics create information systems and infrastructures to bring vast amounts of evidence to shape clinical practice. Grid and cloud computing are emerging in health care markets to address exponential increases in computing power requirements according to market dynamics: virtual, public, enterprise, and national or regional e-infrastructures.
- While health care systems are motivated by professional, citizenship, managerial and consumer values, health care websites and portals often offer integrated services for all health care stakeholders including physicians, other health care service providers, patients, their families, and the general public. For example, websites founded by professional associations such as the American Medical Association, business corporations such as WebMD, national health care systems such as the British National Health Service and public agencies such as the US Centers for Disease Control and Prevention propose specialized services responding to the needs of these stakeholders. Such integration creates synergies by creating markets and linking health care providers and their patients or consumers of their services.
- The open source software movement is influencing the software industry and the emergence of grid computing in the health care sector, particularly in the National Constitution model of the UK and European Union. The open source movement contributes not only to the commoditization of software and grid infrastructure components, but also to the commoditization of health care services delivered through such technologies.
- Examination of the framework reveals the diversity of health care systems and their underlying ideologies. The ideology of Free Markets guided by individual and collective consumer choice suggests decomposition and commoditization of health care services on industry markets with reassembly of such services according to consumer needs and evaluation criteria. On the other hand, centralized National Constitution models such as the NHS and other European systems offer universal service and access

through federated national and regional infrastructures integrating research and education.

- Grid computing with scalable access to cloud-based infrastructure and software as services facilitates management of resources to integrate the benefits of both economies of scale and scope in decentralized health care systems.

This discussion suggests significant questions for future research on virtual infrastructures in health care systems:

- How will the commoditization of computing resources in health care services markets affect system ideology, evolution and service delivery?
- What patterns of isomorphism will characterize grid infrastructures in the health care sector?
- How will the layers of virtual infrastructures be commoditized and what will be the consequences for the convergence hypothesis on health care infrastructures?
- How will the ideologies of infrastructures affect health care services? Will the open source model in the software industry be extended to health care products and services?
- How will medical informatics and bioinformatics be integrated in health care systems of the future?

The National Constitution health care model expresses the values of equity and universal access to health care services as well as system integration exemplified in the regional European Union context. National and regional grid infrastructures emerging in the European Union facilitate integration of research, access to federated data grids, education and health care service delivery, while fragmented proprietary grids emerging in North America may create barriers to such broad integration.[34] Research exploring the above questions will contribute to an understanding of ideological diversity among health care systems and how such diversity might be integrated to protect the integrity of system contributions in the global economy of health care services markets.

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