MEDINFO 2010
C. Safran et al. (Eds.)
IOS Press, 2010

doi:10.3233/978-1-60750-588-4-1339

Reaching for the Cloud: On the Lessons Learned from Grid Computing Technology Transfer Process to the Biomedical Community

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Abstract

Natural scientists such as physicists pioneered the sharing of computing resources, which led to the creation of the Grid. The inter domain transfer process of this technology has hitherto been an intuitive process without in depth analysis. Some difficulties facing the life science community in this transfer can be understood using the Bozeman's "Effectiveness Model of Technology Transfer". Bozeman's and classical technology transfer approaches deal with technologies which have achieved certain stability. Grid and Cloud solutions are technologies, which are still in flux. We show how Grid computing creates new difficulties in the transfer process that are not considered in Bozeman's model. We show why the success of healthgrids should be measured by the qualified scientific human capital and the opportunities created, and not primarily by the market impact. We conclude with recommendations that can help improve the adoption of Grid and Cloud solutions into the biomedical community. These results give a more concise explanation of the difficulties many life science IT projects are facing in the late funding periods, and show leveraging steps that can help overcoming the "vale of tears".

Keywords:
Healthgrid, Grid computing, Technology transfer.

Introduction

The Argon National Laboratory and CERN played leading roles in the breakthrough of Grid computing. Both institutes share a history in performing basic research in IT and providing IT services for users from the natural and applied sciences – mainly physics. In contrast, developing Grid services for life scientists has been carried out by numerous healthgrid initiatives. We use the term "healthgrid" to refer to the different initiatives developing Grid e-science services for the biomedical community, like caBIG, WISDOM, the French Medigrid and the German MediGRID. These initiatives are transferring the Grid computing technology into the life sciences [1].

"Technology transfer" is a concept which first appeared in literature in 1960s [2]. The term "technology transfer" is widely used to refer to transferring the technology developed in universities and governmental laboratories to the industry. Inter domain technology transfer was also addressed in several studies. We distinguish between knowledge transfer and technology transfer. According to Gilbert and Cordeyhayes [3], knowledge transfer refers to the ''scientific knowledge used by scientists to further science''. Technology transfer refers to the ''scientific knowledge used by scientists and others in new applications''. Healthgrid initiatives are conducting both.

The Grid computing technology transfer process is being carried out by academia and facilitated by government funding agencies. This has been an intuitive process using an exploratory approach. Some difficulties facing the biomedical community during this transfer can be understood through the Bozeman "Effectiveness Model of Technology Transfer" [4], which summarizes the research work on technology transfer. Grid and the emerging Cloud computing technologies are still in flux and thus their inter domain transfer process is subject to problems which are not considered in classical technology transfer models. Taking these differences into account, we can better understand some difficulties facing the transfer of Grid and Cloud technologies. In this paper we show to which degree the principles of technology transfer apply to building an e-science infrastructure for the biomedical community and make recommendations for an improved transfer process.

Materials and Methods

Dynamic-technology transfer

A common view of "technology" is to consider it as a physical entity, a "tool", which is the outcome of a production process and which can be transferred easily (for example by moving it to the target setting) [4]. In contrast, Sahal and Bozeman [4, 5] consider technology as the product as well as the knowledge and methodology to use this product. In our case, the Grid knowledge transfer is not separable from the Grid technology transfer process. Alike Sahal and Bozeman anyhow, we do not consider the applications of the (Grid) technology a part of the technology transferred. The biomedical use cases follow different goals than applications in physics or astronomy. The latter are foremost data grids. Biomedical Grid computing applications are combinations of three types of Grid: data Grid, knowledge Grid, and compute Grid (see Figure 1).

Technologies in development are critical for the transfer process. This was questioned by Bozeman but not incorporated into his model: "a technology is changed because there is an active attempt by its users or creators to change it. In other cases, the technology is changed by characteristics of its use or by changes in the physical and social setting within which the technology exists. When the functions and application environment changes, does that affect the meaning of the technology or its transfer?" [4]. We believe this question is crucial in our case, as the Grid and Cloud technology is designed to be extendable from the beginning. Known technology transfer methodologies, including Bozeman's model consider static technologies. Technologies under development are dynamic and require different methods. In the discussion, we present our experience and lessons learned with such transfer.

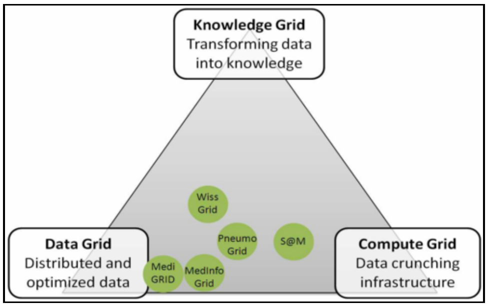

Figure 1- The three generic applications of biomedical Grid computing. A healthgrid is a combination of compute, data, and knowledge grids. MediGRID represents the first phase in transferring the Grid technology to the biomedical community in Germany. Services@MediGRID (S@M), PneumoGrid and MedInfoGrid are successors of MediGRID. WissGrid (Science Grid) is a third phase D-Grid project and involves different communities including life sciences.

The effectiveness model of technology transfer

Bozeman provided a "Contingent Effectiveness Technology Transfer Model'' to summarize the research work on technology transfer. "The model focuses on effectiveness, a perspective well-matched to a literature so often motivated by the search for what works" [4]. With the "what works" approach it is meant how to measure success in a technology transfer process. Five dimensions determine the effectiveness: the transfer agent, the transfer media, the transfer object, the demand environment, and the transfer recipient. The interaction between these dimensions determines the effectiveness of the transfer process. Therefore, the impact of technology transfer should be understood in terms of who is doing the transfer, how they are doing it, what is being transferred and to whom. The novel thing here is that there is no single notion of impact of a technology transfer process. We need to understand the effectiveness in terms of different dimensions, i.e. the goals of one participating party is not necessarily the same (sometimes even contra effective) for other parties. The effectiveness of the transfer can be classified in six deferent criteria: ''Out-the-Door'', Market Impact, Economic Development, Political Reward, Opportunity Costs, and Scientific and Technical Human Capital. Table 1 describes the dimensions of the effectiveness model and Table 2 describes the effectiveness criteria. More details about the model can be found in [4]. We focus on the special case of having Grid computing as the transfer object with the recipient being the biomedical community.

Technology transfer research agenda

Bozeman divided the political agenda to perform technology research into three paradigms:

The market failure technology policy paradigm assumes the free market "will lead to optimal rates of science production, technical change and economic growth" [4]. The government role is to remove barriers to the market, e.g. by providing regulations for intellectual property. The duty of universities is education and providing public domain research.

The mission technology paradigm premise is that the government supports research and development activities "in service of well-specified missions, in which there is a national interest"[4]. Examples are funded R&D from governments for national security, energy production and conservation, medicine and public health. This paradigm has expanded the role of universities to builders of the national technological interests.

The cooperative technology policy paradigm presumes that government's and universities' role is to perform research and to supply applied technology to society and industry. The cooperative technology paradigm emphasizes cooperation among industry, government, and university in the development of new and infrastructure technologies.

D-Grid and MediGRID

The D-Grid Initiative aims to assemble, set-up and operate a Grid infrastructure in Germany in three stages. D-Grid-I, 2005-08, was launched to design and develop Grid services for scientists. D-Grid-II, 2007-10, is designated to design IT services for scientists, industry, and business. D-Grid- III, 2009-11, extends the infrastructure with a knowledge management layer. The aim of MediGRID is to develop a Grid infrastructure for biomedical research. The MediGRID consortium is organized in modules distributed on academic departments and governmental laboratories. The D-Grid/MediGRID funding began following the mission paradigm and looking for a "market pull" of the technology. Unfortunately, the dissemination of the technology was difficult. Especially in life sciences, the requirement for high security and data protection standards proved to be a hindrance [6]. This resulted in a delay in creating a critical mass of users for the infrastructure. In order to enforce a market oriented infrastructure, the funding agency changed the paradigm later to a cooperative technology transfer approach. In the discussion, we show why this shift was early and not ideally suitable for healthgrids in Germany.

Results

The transfer agent – academia and healthgrid initiatives

The technology paradigm is the leading aspect in choosing the right transfer agent, whether it is a university, a governmental laboratory, or an industry partner. D-Grid started with a mission paradigm; it was natural to involve universities as the leading transfer entity. After the shift to the cooperative paradigm, the transfer agent continued to be the universities. Universities are basically sittings for research and education. The enforced technology policy forced them to take new responsibility in the technology development. In our case, MediGRID started as a research initiative from a department of Medical Informatics at the University of Goettingen. Academic medical informatics departments usually carry out interdisciplinary research in the intersection of computer science and life sciences. They are capable of importing new IT technology in an inter-domain technology transfer process. But they are not necessarily market oriented institutions. Whether academia succeeded in developing a market oriented infrastructure is still an open question. Nevertheless, MediGRID was able to attract some users from industry in its second phase.

The transfer media of Grid computing

This includes objects, like software and literature, and human activities, like meetings and workshops. ***Software:*** Grid middlewares were primarily developed for physicists, who mainly required storage capacity and job farming capabilities. There are three common Grid middleware: Globus, gLite, and Unicore. All are open source, which makes it easier to deploy, modify and adapt them, however this means they are in flux and are not stable technologies. An organizational framework, e.g. Service Level Agreements, is also still missing. ***Science Park:*** MediGRID consolidated the Grid computing activities in Goettingen campus to establish a Grid computing Science Park. Scientists from multiple disciplines formed the GoeGrid, in which physics, bioinformatics, humanities, libraries, computer science, and medical informatics are represented. Participants established an interdisciplinary academic course, in which discussions, demonstrations, and invited talks enriched the understanding of the technology. ***Literature:*** the available literature on Grid computing is vague and complex. The middleware documentations are not complete and contain mistakes. A solid experience with Linux and software development is a requisite to be able to work through the documentations. This has been a major hindrance in the transfer process.

The transfer object – e-science using Grid computing

The goal of building a healthgrid is to perform e-science in biomedicine. While this is a scientific aim, one enduring focus of technology transfer is whether the transferred technology has commercial potential [4]. The question in our case is rather whether Grid computing for medical application is currently ready to be commercialized (we offer our opinion in the Discussion). The second and third phase of Grid computing funding in Germany focused on developing business models for the use of the Grid. This was meant to enforce economical sustainability in a highly dynamic system that is still under development. While the fundamental research in Grid computing is more or less finalized, the methodology of importing life sciences IT applications, from the closed local environments into the open Grid environment, is still under development. Organized and focused interaction with industry is a prerequisite for technology transfer from basic research [4, 7]. Therefore, it is important to cooperate with and engage the life sciences industry to gain trust in the transfer object, before hard commercial criteria are used to evaluate the end objective. This is being tackled currently by Services@MediGRID.

The demand environment

The critical mass of demand for the technology is a major factor in determining the success of technology transfer, especially in life sciences [8]. We faced different difficulties in introducing the Grid technology to the life sciences community: the technology was new to the market and missing ready-to-use applications, the overhead to import existing IT-solutions into the Grid was high, and using the Grid for low level services (like data storage) demanded new skills of the user. This was led to a low acceptance of the technology. To overcome this, MediGRID moved to a market push policy in its second phase by building contacts to the biomedical firms and offering the needed support to import the application into the Grid.

Characteristics of the transfer recipient

The traditional recipients of healthgrids technology are researchers in academia, i.e. non-profit organizations. They depend mainly on public funding, which makes it challenging to develop an economically sustainable infrastructure similar to what e.g. engineering grids do - selling services to industries. The market push policy should help to reach a wider user group in industry and academia.

Table 1- Dimensions of the Contingent Effectiveness Model with corresponding in healthgrid initiatives.

Dimension	Focus [4]	Examples [4]	In Healthgrids
Transfer Agent	The institutions seeking to transfer the technology.	Government agency, university, industry and their characteristics	Mainly academia
Transfer Medium	"The vehicle", by which the technology is transferred	License, copyright, person-to-person, formal literature	Literature, Grid computing software, workshops
Transfer Object	The content and form of what is transferred	Scientific knowledge, technological device, know-how, and specific characteristics of each	The methodology of performing e-science using the Grid technology
Transfer Recipient	The organization or institution receiving the transfer object	Firm, consumer, group, institution, and associated characteristics	Biomedical/healthcare professionals, researchers, and companies
Demand environment	Factors (market and non-market) pertaining to the need for the transferred object	Price for technology, substitutability, relation to technologies now used, market shelters	New tools for physicians, E-marketplace for medical service providers, collaboration concept for researchers, new possibility for knowledge management [1]

Discussion

We show that the answer to whether the Grid technology transfer process was successful or not is multi-layered. Our experience shows that the Grid computing is mainly being evaluated according to market-oriented criteria. This is not suitable for measuring the success of healthgrids. Healthgrids should be evaluated according to the produced scientific and technical capital as well the new created research opportunities. Hence, the mission paradigm is more suitable for starting healthgrids. Especially for technologies under development like Grid or Cloud computing, funding in the mission paradigm shall last until a clear political reward is reached. This will pave the way for a market impact and the move to a cooperative funding paradigm (see Table 2 and Figure 2).

‘‘Out-the-door’’ criterion in healthgrids

The assumption here is that "transfer itself equates with success" [4]. As D-Grid-I followed this criterion, the technology was not ready to fulfill the needs of life scientists. Security extensions, information privacy concepts, and workflow extensions were missing. Therefore, MediGRID followed its own course, which was different from other D-Grid community projects, including physics, engineering, and astronomy. MediGRID put emphasis on analyzing the middleware, providing concepts for data protection, and building prototypes applications. In other communities' projects, scientists used "out-the-door" approach and were ready to use of-the-shelf Grid technology. Thus, "out-the-door" is a success criterion for most Grid technology transfer projects, but not for healthgrids.

Why do life science grids not have a market impact, yet?

Market Impact measures the effectiveness of the transfer process according to the commercial success of the technology in the new environment. In our case, the question is not whether the success of a healthgrid can be measured in terms of the market impact, rather when to do so in general. Whether a technology is ready for the market depends largely on the acceptance by the transfer recipient. In MediGRID one major factor influencing the acceptance was simplicity of access, thus, in MediGRID a main emphasis was put on having a web portal as main gate to the Grid resources. Portals for other D-Grid community projects were not an issue, since their users possessed enough IT skills to operate the resources on the command line. That physicists are willing to pay for Grids accessed via the Linux shell, does not mean life scientists will do the same. In technology transfer, it is wrong to put the technology in the market before it is ready. We believe the enforced change from the mission to cooperative paradigm in the German D-Grid was early for MediGRID. Not being ready for the market means little market results, and thus a false negative result. "… technology transfer with little market result has no place in the [cooperative technology policy] paradigm" [4].

Why is the political reward still minimal?

Receiving further funding is the main result of a political reward. Although healthgrids in Germany received further funding from the Federal Ministry of Education and Research, the funding was strategically dedicated towards commercializing the infrastructure. Despite of the involvement of users from industry in the second phase of MediGRID, we are still far from economical sustainability. The necessary political reward would be further funding from the Federal Ministry of Health or from partners from the biomedical industry, due to their roles in healthcare and life sciences. This is not yet reached.

Which opportunities do healthgrids establish?

Each transfer process yields alternative local benefits beside the intended goals of the transfer itself. Examples are the researchers who receive PhDs while working for a technology transfer project, using the received funds for a better internal evaluation of the institute, or changing the profile of the transfer agent. This is common in technology transfer projects. This criterion overrides the common concept of success to provide the effectiveness from the transfer agent's point of view. The various opportunities offered by D-Grid included PhD research, establishing new specialized research groups, starting follow-up projects, and offering infrastructure for academic courses. We believe that more emphasis should be put on considering and supporting such opportunities as a strategic goal in the future. Because Grid computing in life sciences is a young inter-disciplinarily field, the dissemination and establishing the field is an important part of the transfer process.

Table 2- technology transfer effectiveness criteria [4] with corresponding in healthgrid initiatives.

Criterion [4]	**Focus** [4]	**Relation to practice** [4]	**In healthgrids**
‘‘Out-the-Door’’	One organization receives the technology provided by another, no consideration of its impact	Common in practice	Uncommon
Market Impact	Has the transfer resulted in a commercial impact, a product, profit or market share change?	Pervasive in practice	Not yet reached
Economic Development	Similar to Market Impact but on a regional or national economy rather than a single firm or industry	Pervasive in practice	Not yet reached
Political Reward	Based on the political reward flowing from participation in technology transfer (e.g. increased funding)	Pervasive in practice	Minimal
Opportunity Costs	Examines alternative uses of resources and possible impacts on other missions of the transfer agent/recipient	A concern among practitioners, rarely considered	Common
Scientific and Technical Human Capital	Considers the impacts of transfer on the enhanced scientific and technical skills, technically-relevant social capital, and infrastructures (e.g. networks, users groups)	A concern among practitioners, rarely considered	Common

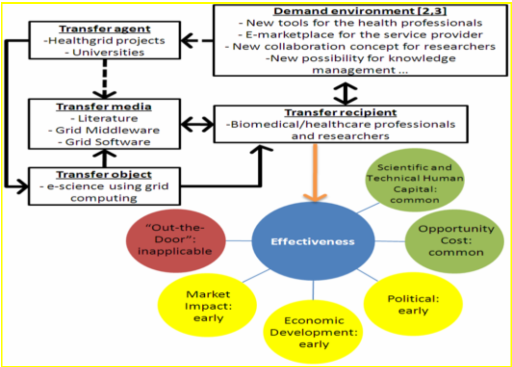

Figure 2- Contingent Effectiveness Model applied on the Grid technology transfer to the biomedical domain.

Scientific and technical human capital in healthgrids

Building up human scientific and technical capacity is as important as producing specific impact from a project [9]. Similar to Bozeman et al., we believe that scientific and technical human capital is a neglected criterion for measuring the technology transfer effectiveness in general [9], and in healthgrids in particular. An important mission of the technology transfer process is to increase the scientific human capital. Such capacities could be within a geographic area, a scientific and technical field, or an institution [4]. D-Grid/MediGRID was a vehicle to reach achievements in these three categories. Within Goettingen campus MediGRID initiated a Grid science park: the GoeGrid. Healthgrid started in Germany 2005 with one project; by 2009 four follow up projects are funded from the federal government. The department of Medical Informatics at Goettingen increased the number of scientific assistances and publications during this period. The "network-based concept of effectiveness" is another important concept [4], which couple the evaluation of technology transfer with impacts on interconnected scientific and commercial actors. The ongoing relations among networks of technology partners are more important to transfer effectiveness than the market factors [10]. MediGRID established in 2008 the "Grid Forum" to coordinate German Grid computing activities in the fields of medicine, medical research and life sciences. These achievements are not the defined goals of the intended technology transfer, but they are a significant and vital part.

Conclusion

Unlike classical Grid users, life scientists are not yet used to sharing computing resources. The government funded three step cross-pollination achieved interesting results, but fell short in some aspects. During the first funding periods it is accepted that the Grid platforms still suffer from stability and sustainability issues. According to the Bozeman-approach it was timely to reinforce industry involvement in the follow up funding periods in order to foster the market impact. However, different organizational and stability issues have hindered a broad market penetration. So the vale of tears still has to be stridden for life science Grids. This is about how collaborative work will be organized in the life sciences in the foreseeable future. Technology labels like Grid or Cloud do not make any difference in the subjacent problem. The problem lies in transferring a dynamic technology using the models and experiences of static technology transfer. In absence of well established models for dynamic technology transfer, we proposed a three steps strategy based on our experience with MediGRID/D-Grid: 1- building a strong scientific and technical human capital, 2- reaching a clear political reward while in the mission funding phase, 3- reaching out to the market and gradually ascent toward a market cooperative paradigm.

Acknowledgment

This work was partially supported by the e-Science research program of the Federal Ministry of Education and Research – BMBF (D-Grid Integration Project 2 – DGI-2: 01IG07014, MediGRID: 01AK803A-H, Services@MediGRID: 01IG07015A-G, WissGrid: 01IG09005A).

References

[1] Olive M, Rahmouni H, Solomonides T, Breton V, Legre Y, Blanquer I, et al. SHARE road map for HealthGrids: methodology. Int J Med Inform. 2009 Apr: 78 Suppl 1: 3-12.

[2] Åberg S. An Interactive View on Technology Transfer. Proceedings of the 16th Nordic Workshop on Interorganisational Research; August, 18-20; Herning, Denmark. 2006.

[3] Gilbert M, Cordey-Hayes M. Understanding the process of knowledge transfer to achieve successful technological innovation. Technovation. 1996: 16 (6): 301-12.

[4] Bozeman B. Technology transfer and public policy: a review of research and theory. Research Policy. 2000: 29 (4-5): 627-55.

[5] Sahal D. Alternative conceptions of technology. Research Policy. 1981: 10: 2-24.

[6] Mohammed Y, Viezens F, Dickmann F, Falkner J, Lingner T, Krefting D, et al. Data Protection and Data Security Regarding Grid Computing in Biomedical Research. In: Cannataro M, ed. Handbook of research on computational grid technologies for life sciences, biomedicine, and healthcare. Hershey, PA, U.S.A.: Medical Information Science Reference; 2009.

[7] Hameri A-P. Technology transfer between basic research and industry. Technovation. 1996: 16 (2): 51-7.

[8] Azzone G, Maccarrone P. The emerging role of lean infrastructures in technology transfer: The case of the Innovation Plaza project. Technovation. 1997: 17 (7): 391-402.

[9] Bozeman B, Dietz JS, Gaughan M. Scientific and technical human capital: an alternative model for research evaluation. Int J of Technology Management. 2001: 22 (7/8): 716-40.

[10] Lynn LH, Mohan Reddy N, Aram JD. Linking technology and institutions: the innovation community framework. Research Policy. 1996: 25 (1): 91-106.

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