Cerebrum and Integration Architecture at the University of Oslo

INF 5210 Fall 2015: Deliverable 2

Group 2:
Maghsoud Morshedi Chinibolagh
Elena Eryomina
Kevin Tilahun Jammeh Hjelmtveit
Stian Leander Wiken

Contents

1. Introduction

This report is for the course Information infrastructure (INF-5210), which is a elective master course for 2015 fall semester at the University of Oslo. It is a report about University of Oslo's information infrastructure (II) and related functionality, called Cerebrum, and the surrounding integrations.

We started by doing research on how the IT system at UIO looks like and found good materials on the university's homepage. We looked into what kind of systems were involved in the cerebrum development before we had an interview with IT department. IT department gave us a brief overview over their system and how they all communicated with each other, we further had questions concerning the development process.

2. Case background

Cerebrum works a centralized component in a service oriented infrastructure meaning it transports data between different IT system. One of many roles of Cerebrum is identity management system (IdM) which allow users to be identified in the IT system at UIO. The main problem with Cerebrums is that a lot of UiO systems are integrated with Cerebrum making it a complex solution.

We decided to look more into this complex solutions to find out what UIO is going to handle this and how this will affect the future of UIO IT system.

2.1 Information Infrastructure theories

2.1.1 Installed base

Most II if has not been developed from scratch, but have been improved on. This technique is referred as *installed base.* Installed base implies that infrastructure are considered as always already existing, never developed from scratch (Hanseth and Monteiro 1998). Installed base is seen as an improvement or a replacement of old system or components,
when designing an infrastructure you want to use equipment that will last for some years before have to replacing them, and also find equipment that is widely used and easy to replace to prevent a lock-in situation.
Installed base infrastructure should also have a supporting or enabling functionality to help support a wide range of activities and not especially tailored to one (Hanseth and Monteiro 1998).

It is important that an install base to enabling, making it more effective for future development. What moste organization wants to create is a system that is capable to communicate with other system without too much complications, this has something to do with standards and preventing lock-in situations

2.1.2 Standardization

In the IT world's existence there were developed many different behaviors of computers. Each manufacturer had its own solution for how computers worked. This went without problems when the computers mainly stood for itself and should not communicate with others. As we started to connect computers to different networks, the need for compatible equipment became more urgent. This meant for computers to connect and communicate together, regardless of vendor hardware and software and eventually different networks began to communicate with each other. This led to an even stronger need to create common solutions. On this basis it was gradually developed standards so that the producers could make equipment that worked regardless of provider. Then you could connect equipment from different manufacturers and get this to work without any major problems.

"Communication systems cannot function without standards"
(Hanseth and Monteiro 1998, p. 56).

Standardization has been essential for the rapid progress we have made in data communications until today. This despite the development of new standards is usually a time consuming process that can take up to several years. How long it takes depends on how comprehensive the standard is, and can vary widely. Not all standards have been developed in the traditional way. "One may also classify standards according to the processes whereby they emerge. A distinction is often made between formal, de facto and de jure standards (Hanseth and Monteiro 1998, p. 57)

There are also so-called de- facto standards such as TCP / IP. The world is full of standards. Standards regulate, simplify and make possible an extensive division of labour which should be recognized as a necessary basis for far-reaching modernization processes (Hanseth and Monteiro 1998, p. 56). Who is it that determines which standards are developed? There may be companies that are early adopters with new technology, or get a kind of monopoly. If their solution is widely accepted, they can put de- facto standards. Users can influence the standards by choosing to pursue a particular technology. This has greatly influenced the development of TCP / IP protocol family. Or users can influence developments by working within some of the major international standardization organizations. Many companies lend staff to work within such organizations to promote just their own solutions and to know where the trend is moving.

2.1.3 Lock-in

"Lock in is a situation when customers are dependent on a single manufacturer or supplier for some product and cannot move to another vendor without cost or inconvenience considerate" [11]. Many companies is trying to avoid the lock in situation since it can be very hard and expensive to get out of, but it is not as easy since one do not know what the future holds. This is why following a standardized equipment or software makes it much easier to avoid lock in situations. In case of IT a free software that is available for anyone at no cost, but also making the source code freely available to anyone to use for any purpose could be a solution for lock in situation. Using free software is much safe pickup itself and complies well with free standards.

A good lock-in example is when a company is developing file format that makes it difficult for its users to convert their data to other formats. This is a typical lock in situation where the users would have to pay for new software to convert the file types. On company's point of view it’s best to invest in something that will keep the customers happy and still offer a good service. With the digital infrastructure a way to avoid some of these lock in situation is by bringing the service or application with the user by integrating or download it to their devices. This could be services like documents, pictures, audio books or music available with them at any time. With fast mobile communication technology makes it so we have internet access wherever we go. VPN technology offers companies and their employees to access company documents on the run.

2.3 our organizations II

2.3.1 UIO Install base

UiO try to always consider the installed base when they want to introduce a new service. E.g. they have a policy of requiring that if you can log on to a system with a username, then the users must be able to use their central UiO username and password.
When UiO wants to implement a new service, they consider two options:

1. Change/extend existing system in the infrastructure
2. Implement a new system that will fit into the infrastructure

If an existing system is considered to be sufficiently tied to what the new service will do, they will evaluate whether it will be more efficient to just extend the functionality of the existing system (i.e. as long as they /can/ change that system) rather than implementing a "separate" system. When doing a separate system, it won't actually be really separate from the rest of the infrastructure, but they will try to only loosely couple it to the existing infrastructure. For separate systems they also prefer "off-the-shelf" systems that require little local development, to reduce the risk of ending up with high maintenance costs in the future.

In the past, USIT did much more of extending existing systems because they found it convenient, e.g. quicker to get the new service up and running. Their current view is that this has made systems grow too large and covering areas which are far from the core of what the system originally was conceived to do, resulting in it being hard to change the system because of lots of tight couplings between subsystems. E.g., one change to Cerebrum may require coordinated change of a dozen different (sub)systems that are connected.
So their policy now is to make smaller services, more in line with a Service Oriented Architecture (SOA) principle. These services are then connected by means of well-documented APIs (REST/HTTP), so that the actual implementation of a service can be swapped with a new one without other systems breaking.

2.3.2 UIO Standardization

Within our organization windows platform is used, windows platform has better integration tools than other operating systems. There is also many more Windows machines being used at school by students that brings them to school. It has previously been used Mac, but not so much anymore since Apple does not have big focus on enterprise. Our organization works as a hybrid between different platforms, after which there are both advantages and disadvantages. With a hybrid platform combination causes the consultants who starts working to have it a bit tough after which most are accustomed to working with a specific platform, this means that the employee must have a very high level of expertise.

Cisco infrastructure is seen as the leading supplier of network equipment. There are also other suppliers, but when it comes to purchasing new equipment from another supplier, if one looks at how much change of the infrastructure and training of staff. Cisco will have a great advantage since most people have worked with Cisco infrastructure.

We have also some disadvantages of the standards. Since the process of developing new standards is so time consuming, it can prevent new technology to be put to use. Many users are so conservative that they do not want to adopt new technology before it is standardized. That means they adhere to the old technology and are waiting to adopt what is new. If the standardization process takes too long, the development may be delayed. Besides, they can be a newer technology before the previous one is finished standardized. Standardization process can in some cases be in the way for new technology. When it comes to standards and the question why not "the best" solution are selected by default. It is because they do not exist a standard that is best in all situations. All the different standards that exist, has its strengths and weaknesses, and we must assess in each case which standard we want to use. The answer depends on what kind of qualities we are looking for, and will therefore vary. We must pay attention to individuals, businesses and nations, which all have a particular interest in communication. This is reflected in how the standard is developed. If a standard is developed in one country was adopted as a world standard, would this country get a huge competitive excel above all other countries. So here there are many interest groups that attempt to safeguard their own interests.

2.3.3 UIO Lock-in

To prevent lock in situations our organization is using "off-the-shelf" software which make it easier and cheaper to tweak and change on rather than buying a new system, and agile structure where it is fast and easy to fix and replace.

A lock in situation that has happened in our organization is Cerebrum which is an identity management system that also acts as an integration point, as an integration point it has connections to other systems. Cerebrum functionalities could have been replaced with "off-the shelf" IDM that would have made it cheaper to operate.

3. General information and motivation

According to the University Board's decision on "Organization and standardization of the University's IT activities" from June 18, 2012 a proposal for architecture and integration framework had to be prepared in cooperation with the management at the faculties and departments. The motivation behind this is that integration today happens almost exclusively in connection with introduction or upgrading a system. Integration is not maintained or managed unified, rather it is distinctive for each product. It is estimated that the integration will become increasingly costly and time-consuming because a number of special adaptations continuously increases [1]. This has already resulted in the situation when some software is difficult to replace, and consequently, integration around the software is expensive and idiosyncratic. In addition, there are seven overarching principles that serve as a set of common guidelines for all work with IT in the public sector. Flexibility and scalability are among them. [2] The integration methodology used by the UiO today is not in line with the government guidelines.

A more modern approach to integration is considered to be a prerequisite for UiO to exploit tomorrow's IT systems. IT in general is moving away from being "self-provider" (when all services are concentrated in the organization's own engine) to the effective use of standard products at a lower price. For example in the "cloud" technology the Internet puts framework for communication between systems. There has emerged de facto standards for how to integrate the web, and UiO will benefit tomorrow on meeting them. Besides, the expertise exists only among individuals today, and it is difficult for the external consultants to start working (see question 1 from the interviews' results applied to this rapport). It is thus also assumed that by standardizing on the established and well-known technology it will also be much easier to make use of external expertise than it is today.

Today much of the work related to integration performed by University Center for Information Technology (USIT). USIT is the UiO central IT department that is responsible for delivering infrastructure and IT services UiO need to reach their goals for education, research, communication and administrative work. USIT is also a competence center for IT research and education at the national level as well. If we have a look at how our II has evolved during the time, it is important that the exchange of data has been centered around core components Cerebrum, SAP and FS. Some system owners have spent considerable resources to make integrations on their own, but for the large number of systems integration is done by USIT. In addition to the limited external expertise, mentioned above, one can point to another negative consequence of this. The cost of integration work is often hidden. The most common scenario here is that the systems get SAP and FS data from Cerebrum instead of talking directly with the source systems. By integration with source source systems done by USIT and through Cerebrum, the real integration costs become invisible to the system owner.

Since USIT plays a crucial role in the evolving of our II, we have conducted two interviews with two representatives of USIT staff: Anders Vinger (Section

Manager, Department for Client Management) and Mathias Meisfjordskar (Senior Engineer, Development of Administrative IT Services Group). The Department for Client Management is responsible for operation frameworks, software distribution, uniform configuration and organization of services for client computers and mobile devices. The department is also responsible for local IT support and organization and operation of support and operations centers. Development of Administrative IT Services Group develop functionality in IT services that support the administrative processes at UiO. The main goal of the interviews was to obtain information regarding how II has evolved, its features, strong and weak points, as long as why the existing system has failed to face the today's challenges and what the strategies for a new integration architecture for UiO are.

3.1 Cerebrum project and its problems

Cerebrum follows today a hub-and-spoke model where Cerebrum is the centralizes component (hub) which transports data between IT systems. It makes Cerebrum integrated with many systems. Thus, Cerebrum has many roles. In integration architecture context these roles are: identity management system (IdM), User Management System (BAS) and ESB (Enterprise Service Bus) modules for other data and functionality which do not have other places to be.

Cerebrum has become a complex solution due to the fact that all functionality has been integrated into the system over time and too little has been treated as separate elements. In many integrations Cerebrum data goes together with data from other systems. Since integrations are adapted to each system, any changes require detailed knowledge of the systems the system is integrated with. This means that Cerebrum developers must use lots of resources on systems they are not supposed to work with. Competence development therefore has a momentary value. The number of individual integrations leads to the situation when nobody knows everything about Cerebrum, and further development takes therefore much more time.

Thus, in the face of tomorrow's challenges the Cerebrum project fails to deliver, and the need for a better approach to integration has been identified.

3.2 Cerebrum and a new approach to integrations

Establishment and change of integrations between IT systems at UiO is currently costly and time consuming. The current situation is characterized by little control and oversight. The consequence is delayed projects, unexpected costs and degraded user experience. The organization's ability to adapt to necessary and desired changes, including innovation, is considered to be inhibited. According to the new strategy, it is necessary to separate work with IT architecture and enterprise architecture.

Cerebrum is to become easier and more efficient to develop and adapt. To achieve this, they want to go back to what Cerebrum really is – a pure IdM system – in order to keep the roles and functionality separated. Therefore,

they decided to cultivate Cerebrum as an IdM system in a way that only Cerebrum only be further developed for IdM-related functionality. The role of ESB will be transferred to other services in accordance with the guidelines of the new integration architecture.

Under transition to a new approach to integration at UiO a new central component – ESB – is introduced. This component is supposed to implement the functions that exist in today's solutions, as well as new features that will make the integration at UiO more effective. It is admitted that the organization has not enough experience in this respect. This is why it is recommended that the first iteration of ESB at UiO be focused on the familiar features which there is need for with certainty, such as Single Point of Integration. [8]

One more thing has to be pointed emphasized. It is proposed to apply cost-benefit analysis for each integration and module in order to make a decision whether this integration or module should be phased out, moved to another system or retained in Cerebrum as today. At the same time, it is admitted that some things are difficult to estimate in money terms, like effort to implement a solution. In addition, it is very difficult, almost impossible, to make exact estimates for returns on investments for the architecture work. But the role of the finance department makes it an important actor in this context.

Further, we will try to identify the pitfalls of the Cerebrum project and to judge about the proposals for a new integration project at UiO in the context and in terms of II theory.

4. Our II in terms of II definitions and characteristics

We find II theory to be highly relevant to our project. First of all, II at hand can be described with the use of II characteristics and definitions. In this part we refer to Ciborra et al (2000) who provide general aspects of II paradigm-related characteristics. In our project there are no services that have been designed from scratch (only some programming and scripts), i. e. all services are built on the existing units that are currently in use. Even in the new approach to integration Cerebrum plays an important part, and the new ESB system is supposed to be based on the existing components. Thereby, the *installed base* cultivation principle is applicable here. Ciborra et al (2000) argue that the old (namely, the installed base) heavily influences how the new can be designed, i.e. infrastructures develop through improving and extending the installed base. Thus, II requires substantial additional investments to be used, and it is "locked in" with respect to replacement parts, services, upgrades, etc.

Next, we are dealing with not with an system tool, but with a *shared infrastructure*. According to the definition provided by Ciborra et al (2000), *shared* means the same single object is used by different groups which makes infrastructure irreducible, i.e. it is impossible to split an infrastructure into separate parts to be used independently. This could be done only for analytical or design purposes. To a large extent it is obvious that USIT in their original approach to the Cerebrum project treated it only as a system tool, but not as a

shared infrastructure. But if one takes into account the multidimensional nature of the system at hand (diversity of users, changing requirements, changing conditions for development, heterogeneity of technologies, etc.), one end up with the idea that the resources might be pooled and spread among independent nodes to achieve optimized performance. Thus, we are dealing with a shared infrastructure.

Our II is not a closed system, rather an *open network*. What makes an open network different from a closed system is that the number of actual and potential users, stakeholders involved, technological components, application areas is unlimited. At every time a new actor can enter. It is best exemplified by the identification of the need for a new approach to integration in the face of upcoming technological challenges. The very technology in this case comes into the network as a new important actor.

The II at hand is *heterogeneous* in the sense that larger components are built upon existing smaller independent components. This is the case when we consider the Cerebrum project as a system of interdependent components. The new integration architecture is also to be based on existing units, while is supposed to be scalable when needed.

Our II is *evolving continuously*: it has evolved and beyond any doubt will evolve in the future. Our II has evolved to the state when the existing Cerebrum project failed to meet the tomorrow's requirements for integration, but then, building over existing components, Cerebrum is going to transit to a new IdM role driving the whole II to a new state. The more components will be added (by introducing EBS system, in particular), the more complex II might become.

Moreover, a *reinforcement mechanism* is inherent in our II. The Cerebrum project matches the pattern when larger installed base leads to more complements produced which in their turn create greater credibility of standard, reinforcing thereby value to users, that ends up with further adoptions and, as a result, larger installed base. It might happen that the new integration architecture will become a de-facto standard which will result in an even more complex, self-reinforcing system.

Based on the characteristics above, we see a developed complex II used by a variety of stakeholders, with sometimes conflicting needs, and evolving continuously. Thus, a broader *socio-technical aspect* comes in here, requiring a better understanding of II, some new approaches to manage higher risk to II and new methods for control it.

Consequently, our II matches a new paradigm of II making it different from closed, designed from scratch system tool. Further, we will try to identify how particular concepts from II theory can be applied to our II.

4.1. Cerebrum and Complexity Science

The fact of integration leading to complexity became apparent during the interviews. First, we describe the complexity as it is perceived by USIT

providing two examples of complexity from the USIT's point of view. And then try to analyze the complexity of II in terms of complexity science.

At the outset Cerebrum was supposed to serve as an identity management system (IdM), i.e. to describe the management of individual identities, their authentication, authorization, roles and privileges within and cross-network in order to increase security and productivity while decreasing cost, downtime, and repetitive tasks. But as the II has evolved, Cerebrum has mixed up roles in IdM and ESB which has resulted in greater complexity. Some modules in Cerebrum has little or nothing with IdM to do. Some examples include functionality for printing data, VoIP, DNS data and host policies. For example, DNS data is collected from host master and imported into Cerebrum. Then host master and other stakeholders, such as local IT, modify information through BOFH before BIND files are exported to DNS machines. DNS has minimal with IdM to do, but one of the reasons why these integrations have been added into Cerebrum/BOFH is the structure of rights for delegating permissions to local IT. This complicates the system.

Another example is Fronter. Fronter needs a lot of study-related information in addition to student data, such as semester, subjects, study groups and teachers. All this information is in the FS. Cerebrum retrieves it from FS and makes changes in Cerebrum based on this before Fronter gets information. This complicated logic complicates the system as well.

It was a kind of culture at USIT to collect functionality in a centralized tool, namely Cerebrum. Nobody was able to anticipate how resource-intensive the complexity management in such a "mass management tool" would be. This situation might be the consequence of too narrow view on complexity, namely taking complexity of the system for complexity of the II. One can try to analyze the II in terms of complexity science and may come to the following ideas and recommendations. First, Cerebrum appeared to be a de-facto standard for USIT, thereby giving rise to self-reinforcing processes which resulted in installed base as complex evolving system. Ciborra et al (2000) argue that such system is now difficult to control and costly to manage because with increased complexity the risk to II has also increased. The need for effective risk management tools might arise. In this perspective, we might recommend the USIT to develop such a tool in order to reduce the risk to the II in the future. Some risk mitigation techniques have to be introduced in order to reduce the complexity.

Secondly, according to Ciborra et al (2000) information infrastructures are more than pure technology, rather socio-technical networks. In this perspective, USIT obviously treated Cerebrum as a pure technical tool, ignoring the fact that people are not only users, but elements of the system. So, on the one hand, it is important to regard our II as a heterogeneous phenomenon taking into account people as elements of II. On the other hand, USIT ignored how the technology could play in as an actor and complicate the II as a socio-technical network. Hanseth, O. & Monteiro, E. (1997) argue that the very technology might become one of the decisive actors in the II. Further, Ciborra et al (2000) claim that numbers of users, stakeholders, components and use areas imply among other things changing conditions for development

and changing requirements. We see that in the face of future technological changes and changed requirements and conditions (ability to exploit tomorrow's IT systems, as discussed earlier) the de-facto standard (as it is) appeared to be inappropriate. As a recommendation, USIT might analyze its II in the socio-technical networks' perspective, taking into account the role of people as elements of II and regarding the technology as an influential actor to meet the requirements of II as a heterogeneous phenomenon.

Thirdly, obviously, "lock-in" situation has arisen under evolving of the II. The paradox of the situation is even stronger because of the fact that USIT had considered this "lock-in" trap to be an effective one during a long period of time. Further, our II will continue to be locked-in since Cerebrum is going to be used purely as an IdM system in the future. Ciborra et al (2000) claim that many lock-in situations require both huge switching costs and coordination tasks to get out of them. In our case, USIT decided to phase out irrelevant Cerebrum modules instead of totally abandoning Cerebrum in favor of some possible more effective and cheaper solution. This might have something with cost-benefit ratios to do (it might be less costly to phase out the modules irrelevant to IdM as compared to introducing a completely new IdM system). That is, alternative (switching) costs are estimated to be too high. On the other hand, it might be due to the coordination problems related to change of II.

4.2 Actor Network Theory (ANT)

4.2.1 ANT and network externalities

We can study Cerebrum system from an actor network perspective in order to describe the information infrastructure in the USIT. It is clear that IdM implementation and maintenance is inherently a technical process. Actors with different interests sometimes succeed to translate their interests into the development and use of the ICT applications. Information system innovation is the contingent result not by the properties of the technology, but by the result of contested interests of actors linked together in complex networks. Application of this theory can help to illustrate the project as a heterogeneous network of actors which implemented as successful application [5].

An actor network is literally the network of heterogeneous materials that make up the context.
The ANT provides an effective platform from which critically to assess and unravel a set of problematic explicit and implicit assumptions made from the management perspective on
information infrastructure. In ANT, design is translation users and others interests may be translated into specific need and those specific needs as further translated into more general and unified needs and consequently they can be translated into one and the same solution [6].

The actor network perspective illustrates that the designers of the Cerebrum project considered the translation process which may occur among the different type of the users. While in the Cerebrum Project, the USIT

team members are not heterogeneous engineers that build the network that will lead to technical innovation and system implementation then they considered other entities that should be enrolled. The students and the employees have some common interests while management staff has a different interest translation of this project.

In this project, the management team interest concluded in the identity management in order to
allow authorized access to appropriate data while the employee and students expect to access their data through the university network. Meanwhile, the USIT team interest concluded into the automation of the identity management process.

As ANT perspective, these groups may translate their interests into non common point which might fail the project. The main problem raised when the users should access to multiple different resources which each one required specific authentication. At a time, this behavior of the system would be a destabilizing actor in the project, which might lead the Cerebrum project got failed. The users should enter the username and password several times during the day and this could be increased if the user should access to more different resources. This destabilizing
actor might threaten the existence of the project while there were other IDM systems in the market at the time, which managerial staff might though about them as the solution. But the USIT team introduces a feature which re-stabilized the project. The re-stabilizing solution was to introduce Single Sign On (SSO) feature to the Cerebrum which enabled users to access different resources only with one time sign on. This feature led to save time while accessing different resources which were considerable time among the whole institute during the working day.

As we can see in this specific case, the multiple login was a non-human actor in this project which might influence the project success. The USIT team as human actor in this network re-stabilized the project while they considered all the actors and their impact on this information infrastructure.

The cerebrum project, has introduced an IDM system which all of the users in the university must use it as the only choice offered. Thus, there is no value in the network for the users in order to that they could choose any other option. However, the only things that motivated the users to use the Cerebrum IdM was administrative mandate. Actually, based on the network externalities definition which have been defined as a change in benefit, or surplus that derives from a good when the number of consumers of same, good changes this project has no network externalities while introducing the IdM service to the users [7].

After successful implementation of the Cerebrum project in the university and the large number of it's the users increased its value. Later on, the other universities intended to use the Cerebrum IDM in their own institutes while the Cerebrum project could handle a large number of users in university of Oslo. As perspective of the information infrastructure, this is the network

externalities of the Cerebrum project. However, this project had no internal effects because of its mandatory implementation, but the successful implementation and the number of users made it an option for other universities to work with it and get an idea about it.

In this case, we can see that the project had network externalities while the value of this project increased while it implemented in a big community with a large amount of users. Therefore, the value of information infrastructure tightly coupled to its number of users and we should increase the number of users by means of encouragement and mandate in order to increase the value of information infrastructure.

4.2.2 ANT and 'inscribed' behavior

In the process of introducing new element to the II, that is ESB, and changing the role of Cerebrum the difficulties of establishing a new principles of II might be easily underestimated. Especially, when coupled with high expectations about future benefits of exploiting cheaper integration solutions. In this respect, it seems extremely important to take into account socio-technical difficulties in order to restrain complexity and come to a working II.

Hanseth, O. & Monteiro, E. (1997) claim and prove that the notion of inscription can help in dealing with the complexity of II and develop more appropriate standards. Inscription might describe how concrete anticipations and restrictions of future patterns of use are evolved in the development and use of technology. And to achieve a stability it is crucially important to translate others' interests into one's own. We try to show how the notions of inscription and translation can be applied for the benefit of our II.

In our case we consider Cerebrum as an element of II before changes which was successful in constraining others, that is, it inscribed a certain pattern use. This was first of all pre-determined by inscriptions in its technical nature, on the one hand. On the other hand, USIT regarded this pattern as the most effective through time and, while enjoying the expertise related to Cerebrum, made such an II stable. But new challenges, described earlier, identified additional requirements to the II to work. According our point of view, changed requirements and renewed expectations require reconsidering the socio-technical aspects of II.

As an example of how influential socio-technical issues might be, we consider the role and interests of those who will conduct cost-benefit analysis of integrations and modules. During one of the interviews we found that the department responsible for conducting cost-benefit analysis might appear to play even a decisive role whether this or that solution is to be implemented or not depending on cost-benefit ratios. It seems obvious that the interests of this department have to be taken into account and translated appropriately.

One of the main goals of the new architecture integration project is to reduce complexity. But since several thing are difficult to put price on (like effort estimation, for example), the provided cost-benefit ratios might be misleading. This can result in significant mistakes in the decision-making processes. For

example, some important modules might be phased out or some unimportant integrations might be left untouched. This may increase the complexity of the solution. Thus, it is important not to put exaggerated emphasis on the results of cost-benefit analysis. Otherwise, cost-benefit ratios, being given a status of the main criteria at the outset, may beat the technology which in its turn is supposed to be an actor by imposing its inscribed program of action on the users to achieve greater performance in the future.

Thus, our II might be considered in the context of ANT, inscription and aligned interests.

4.3 II in the context of reflexive modernization

One of the main goals of introducing the new approach to integration is to overcome the problem that today the situation is characterized by little control of complex processes. Since the need for control is recognized, one must be very careful in order to avoid a trap when an attempt to strengthen control results in higher risk and unpredictability. This is due to the socio-technical nature of complexity. The complexity with integration will continue to grow, and when the knowledge is incomplete, the situation might become even more uncontrollable.

5. Challenges, improvements and strategies

5.1 Cerebrum information infrastructure challenges

The Cerebrum project has developed gradually and it evolved during the years. USIT expands the Cerebrum in order to cover whole university Identity management expectation. It became core component in some of the university managerial applications like HR, accounting and user management. The Cerebrum project is one of the main Information Infrastructure in the University of Oslo which has been successful in order to fulfill the project goals. Even though the USIT reach to the project goal, it has network effects and the other universities and colleges interested to use the Cerebrum as their primary Identity Management system.

However, Cerebrum project like many IT project has its own problem and challenges. The Cerebrum project face new challenges while it is growing and getting sophisticated during the time. In the first interview, the support team expressed that:

"The USIT in house developed Cerebrum identity management system also functions as an integration point; this has effectively created a lock in situation because of all the systems integrated with Cerebrum."

This presents that Cerebrum project face real challenges while it is growing. One of the main challenges is the cost of maintenance that is growing while the Cerebrum growth. In accordance to interview with support team they expressed that:

"Most of Cerebrum's functionality could probably have been replaced with the off-the-shelf IdM system that would be less expensive to maintain. The Cerebrum require more support team in order to maintain and troubleshoot."

The Cerebrum IdM system operate as a Hub-and-spoke design which receive input from several sources and publish its output to many target applications. The Hub-and-spoke design make Cerebrum as a bottleneck when the project scale up to service many application. We can describe this behavior with information infrastructure theories in order to make better understanding of the challenges. We can use Actor Network Theory as one of the information infrastructure theories in order to describe this behavior of the project.

As the Schman (1987) proposes, in relation to development of a working information infrastructures we should think about actors networks, where are they, and how should they be identified? Nevertheless, Graham et al. (1996) mentioned that establishing a working II is a highly complex socio-technical task with designing a large collection of communication standards. Hence, defining the actors in the project will smooth the understanding of the project and its problems.

Here, the Hub-and-spoke design is an actor which influence whole the project and rather destabilize the project. This is one of the main actors that influence the project stability and may direct the project to failure. Now the question raised here that why one non-human actor would highly challenge the Cerebrum project. There are different information infrastructure which has many actors that cannot destabilize the Internet. Indeed, Eric Monteiro (in Ciborra et al. 2000) presented that large systems, like the Internet, are built by many independent actors. Such systems appear as independent living actors for several reasons.

- The number of actors shaping the system/network is so high that it is impossible for any of them to overlook the actions of all others. This makes the network change in unpredictable.
- Side effects of known as well as unknown actions make the network change in unpredictable way.
- One change—including it's died effects—to the network triggers new changes.

Hence, we can see that Cerebrum project with many actors make the network changes unpredictable. Therefore, the USIT team could not predict the bottleneck problem in Cerebrum while they had developed it since 2002.

In the Cerebrum case, complexity has high impact over the actors. Ole Hanseth and Eric Monteiro(1997), explained that the experiences from standardization exchange in healthcare illustrates that the actor networks constituted by standards easily grow very complex. So long as the Cerebrum project expanding precipitous thus it will create unwanted complexity which produce unpredicted problems.

The USIT in this project has tried to re-stabilize the project by changing the Cerebrum design. Indeed, the USIT has tried to change the Hub-and-spoke

design to event-based design and re-stabilize the Cerebrum while solve the bottleneck problem. Nevertheless, this re-stabilizing action is completely challenging while they developed the Cerebrum with a tightly coupled design.

Hanseth and Braa (2000) explained that you can change your software just by pushing a few buttons on the keyboard of your PC but changing large software systems from one to a different version, which is working and useful is often extremely difficult. Some systems may be more flexible than others. In another argument Winner (1977) describe that needs change is only one perspective on technology, another perspective is to see technology and technological development as autonomous. Therefore, any change to the cerebrum core design will affect high range of application and changes will lead the whole project toward failure.

According to Hanseth and Lyytinen (2010), the paradox of change defined by opposing logics of stability and flexibility that operate across infrastructural layers and components. Digital infrastructures need to be stable to allow enrollment of new artifacts, process, and actors, on the other it must possess flexibility to unbounded growth. The Cerebrum project is not a software which the USIT can change it easily and its change has high impact on the other actors. In according to Hanseth et al(1996); Monterio(1998), infrastructures are layered upon each other just as software components are layered upon each other in all kinds of information systems. Infrastructures are also heterogeneous in the sense that the same logical function might be implemented in many ways.

This heterogeneity in the Cerebrum project make it difficult to change its design. While different application with different interests uses Cerebrum in order to complete their Identity management. Ole Hanseth(2000), explained that building large infrastructures takes time, the whole infrastructures cannot change instantly. Infrastructures never developed from scratch. When designing a new one, it will be integrated into or replace part of an existing infrastructure. Hence, the Cerebrum cannot change instantly and require a sophisticated planning in order to change its design.

5.2 Conclusion

The Cerebrum is a complex information infrastructure that this complexity make it difficult and challenging to improve. Therefore, any change and improvement requires lots of resources that consequence to increase the cost of information infrastructure. Now, these challenges bring the idea in mind to re-domain the whole IdM information infrastructure. However, re-domaining of information infrastructure is a costly procedure which basically does not guarantee the success of the change. Hence, re-domaining of an information infrastructure is a critical decision and in this specific project may introduce many unpredicted problems and challenges.

If UIO/USIT decide to follow the development to improve cerebrum and are willing to change the infrastructure of their IT system, it will have many advantages. The biggest advantages will be to structure their new

infrastructure to get out of a lock in situation making it loosely coupled infrastructure and able to communicate with other systems.

There are other organizations that are using cerebrum in their IT system. if any other schools are going to use the same solutions depends on their currently system. They might use other systems that suit their system better Cerebrum has the option to add different kind of functionality and what functionality is needed depends on their currently system.

This question is hard to answer since we don't have an overview over their system, but if there infrastructure is identical as USIT, using the same solutions might be the right thing to do. They can even see what kind of problems USIT is facing before they make a decision about change it and tweak their own system.

6. References

[1] https://www.usit.uio.no/om/it-dir/ihr/iverksetting/resten/rammeverk/workshop/arbeidsgruppe/arbeidsdokumenter/etter-workshop/skait/rapport.html

[2] http://www.difi.no/veiledning/ikt-og-digitalisering/it-arkitektur

[3] https://www.usit.uio.no/om/it-dir/ihr/iverksetting/resten/rammeverk/workshop/arbeidsgruppe/arbeidsdokumenter/etter-workshop/skait/vedlegg/dagens-situasjon.html

[4] Ciborra, C., Braa, K., Cordella, A., Dahlblom, B., Failla, A., Hanseth, O., Hepsø, V., Ljungberg, J., Monteiro, E. & Simon, K.A. (2000) From Control to Drift: the Dynamics of Corporate Information Infrastructures. Oxford University Press.

[5] Stanforth, C. (2007). Using Actor-Network Theory to Analyze E-Government
Implementation in Developing Countries. Information Technologies & International
Development is an interdisciplinary open-access journal, 3(3), 35-60

[6] Claudio U. Ciborra, Kristin Braa, Antonio Cordella, Bo Dahlbom, Angelo Failla, and Ole
Hanseth. 2000. From Control to Drift: The Dynamics of Corporate Information Infrastructures.
Oxford University Press.

[7] Liebowitz, S. J., & Margolis, S. E. (1998). Network externalities (effects). The New
Palgrave's Dictionary of Economics and the Law.

[8] http://www.usit.uio.no/prosjekter/uio-integrasjonsarkitektur/visjonsnotat-esb/index.html

[9] Hanseth, O. & Monteiro, E. (1997) Inscribing behavior in information infrastructure standards, Accounting, Management & Information Technology, vol 7 (4) p. 183-211.

[10] Øyvind Hallsteinsen, Bjørn Klefstad og Olav Skundberg, Innføring I data kommunikasjon,

[11] http://www.linfo.org/vendor_lockin.html 10.10.15

Hanseth, Ole & Lyytinen, K (2010). Design theory for dynamic complexity in information infrastructures: the case of building internet . *JIT. Journal of information technology (Print)*. ISSN 0268-3962. 25(1), s 1- 19 . doi: 10.1057/jit.2009.19

Suchman, L. (1987) *Plans and situated action*, Cambridge Univ. Press.

Graham, I., Lobet-Maris, C., and Charles, D. EDI impact: social & economic impact of electronic data interchange (EDI), 1996. TEDIS project C9, report prepared for the European Commission, http://www.ed.ac.uk/ ehjar36/tedis.html.

~~Claudio U. Ciborra, Kristin Braa, Antonio Cordella, Bo Dahlbom, Angelo Failla, and Ole Hanseth. 2000. *From Control to Drift: The Dynamics of Corporate Information Infrastructures*. Oxford University Press.~~

~~Hanseth, Ole, and Eric Monteiro. "Inscribing behaviour in information infrastructure standards." *Accounting, management and information technologies* 7.4 (1997): 183-211.~~

Winner, L. Autonomous technology. Technics-out-of-control as a theme in political thought. MIT Press, 1977.

Hanseth, O., Monteiro, E. and Hatling, M. Developing information infrastructure standards: the tension between standardisation and flexibility, Science Technology and Human Values, 1996 (To appear).

E. Monteiro. Scaling information infrastructure: the case of the next generation IP in Internet. The Information Society . 14(3):229 - 245, 1998, Special issue on the history of Internet)