Cloud Computing is penetrating deeper into the mainstream of IT. It is increasingly accepted as important for both corporate and personal IT users. Despite the level of acceptance and maturing technology the majority of users are still in the early days of adoption. Implementing organisations and users may only have a few months or years of experience with live cloud computing environments. Their focus is still on adoption and implementation. Few organizations are considering long-term maintenance at this stage of their cloud computing lifecycle. More public cloud services are becoming integrated into corporate cloud based applications. The increasing number of externally supplied services is likely to lead to a requirement for replacement or alternative cloud services during the service lifecycle. Alternative cloud services will be needed in a number of circumstances, for example should a supplier cease trading users will need to replace that supplier’s service. Other problems requiring alternative or replacement services would include the failure of a service to meet requirements, modifications to a consumed service that changes some of the service behaviour or a failure of a cloud service to meet agreed service levels.

Service level agreements (SLA) between cloud service vendor and consumer frequently specify performance and availability thresholds for services listed in the SLA. SLAs are paper contracts and may contain penalty clauses allowing recompense for failure. SLAs are used as a risk management measure in many cases. Compensation for breaching an SLA threshold may be paid but does not guarantee that the required service functionality is available to users. This may cause problems for the cloud based application supplier. Their users are interested in service continuity not compensation.

Commercially supplied public cloud services come at a price and over time the cost or the terms and conditions may change. SLA breaches or cost changes may be one of the reasons for either application developers or end users, to look elsewhere for cloud services. Quality assurance and risk management processes will demand that replacement services be sourced and this will generate some questions for the consumer of cloud services:

- How can you manage an application that needs a service replacement?
- How can you compare services using characteristics beyond functionality?
- Are there any standard ways of measuring services?
- How can you decide where service data should reside in the future?

MODAClouds is a recently started research project with plans to answer these questions within the framework of a model driven development environment. Part of this framework relies on service comparison to manage service replacement. In this article we will discuss the research objectives and the plans for standardized service comparison. The MODAClouds project is the culmination of a long history of service oriented architecture research dating back for more than ten years. Some of the early service oriented architecture

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research developed from object oriented computing and later was influenced by the rise of the Internet and web services as enabling technology.

Commentators have been talking about an Internet marketplace for services from as early as 2002. This earlier iteration of the marketplace would contain large numbers of publicly available IT services discovered by searching the Internet. Key enabling technologies for this marketplace were web services and a searchable registry of services. The UDDI standard was developed to create a standard way of describing services based on the common registry format. These technologies and initiatives led to the concept of an Internet of Services. The marketplace did not really happen at that time although cloud computing’s popularity has generated an increase in the viability of a service market place. Services in the current iteration of the marketplace theory are cloud services not web service-enabled applications. Cloud computing delivers more advantages than providing services for a marketplace but for the purpose of this article we will restrict ourselves to the ability of cloud services to be published and consumed on the internet.

The European Union has had a long history in research dating back to EURATOM in 1955. The most relevant funding mechanism for ICT research is the Framework Program (FP). It is interesting to note that Framework Program 1 (FP1) had no legal basis until the passing of the Single European Act in 1987. FP7 is the current program and is due to end in 2013. Each of the framework programs issues a set of research priorities and imperatives. These are the drivers of competitive calls for proposals. The MODAClouds research project has been awarded a sizeable research grant as part of call 82(2011). Several of the calls in FP7 have been heavily weighted towards cloud computing. Cloud computing is a major part of the Future Internet research theme within FP7.

The MODAClouds research consortium includes academic and industrial partners. It has proposed a model driven approach for the design and execution of applications on multiple clouds. A model driven approach was chosen as a means of creating an easy to use and consistent development environment that can be used to deliver applications. The use of a consistent developer interface that hides various abstraction layers is consistent with a similar design strategy employed by cloud service suppliers to hide the different technology layers in a cloud environment. The MODAClouds approach is to consider the increasing availability and use of public cloud services in a potential marketplace. MODAClouds anticipates the high probability of an Internet of Services. In particular MODAClouds focuses on three overlapping challenges for systems developers and operators in a cloud computing service infrastructure and market.

**Challenge 1: Vendor Lock-in.** Vendor lock-in is a generic problem with all service models, particularly with the cloud services model. All three challenges have some relationship to vendor lock-in but from different perspectives. Difficulty in moving from the services of one vendor to another vendor’s services is the most common cause of a lock-in. Vendors of cloud solutions and cloud services often create services with proprietary features to ensure a lock-in. Often the service will store the service consumers’ data in the vendor’s cloud. This has advantages to the consumer; they don’t need to have storage capacity. The problems for the service consumer come when they want to migrate from the vendor’s service to an alternative service. In the case of large volumes of data it may be expensive, time consuming to move that data from the vendors service. There may also be contractual reasons that the data cannot be moved.
**Challenge 2: Risk Management.** Payment models, security and quality of service are significant areas of risk to be considered in any cloud service implementation even in a private cloud environment. In a multiple cloud supplier environment the assessment and management of risk becomes more complex. Risk management for traditional IT systems is well understood, even if it is not universally well applied. Consider a risk management scenario where an application uses services from three different vendors.

- The first vendor charges a flat fee for use of a service, renewable every year.
- The second vendor charges a monthly fee to use a service under normal operation and a premium fee for use of increased capacity.
- The third vendor does not charge a fee unless the service is used and then charges an hourly premium fee.

Changes to any one of those pricing models will introduce an increased risk of cost over-run that may precipitate a decision to move from one supplier to another. This challenge is also focussed on the decisions that must be made and the parameters for those decisions.

**Challenge 3: Quality Assurance.** Multiple services have multiple quality characteristics. Cloud performance elasticity may not ramp up at the rate anticipated and services may not be available for the required time period. Many people assume that in a cloud environment the only considerations are performance and availability. While these are important qualities they are not the only measure of quality. Quality metrics such as resilience, security, regulatory compliance and serviceability will need to become part of the risk profile of a service.

These three challenges are the foundation for the design of the MODAClouds research. The project will research a potential solution to the maintenance requirements that demand a change in service supplier. First, it will be useful to look at the overall proposed solution architecture to reconcile the objectives and challenges.

Figure 1: Proposed MODAClouds architecture
Two separate areas of functionality for the MODAClouds proposal are shown in Figure 1. These are design time functionality and runtime functionality. Design time functionality is based on three levels of abstraction that create an ability to develop a cloud agnostic design and the semi-automatic translation of design artefacts into code. Semi-automatic translation in this context indicates that there may be some need for human interaction to finalise the various translations. At the heart of this is the Cloud enabled Computation Independent Model (CIM). CIM artefacts are semi-automatically translated and refined at the Cloud Provider Independent Model (CPIM) where cloud concepts like IaaS and specificities of different cloud deployments are incorporated. These are also kept abstract from cloud specific implementation. Finally CPIM artefacts are semi-automatically translated into a Cloud Provider Specific Model (CPSM) that enables the creation of deployment artefacts.

Both the design-time and run-time functions are dependent upon the Decision Support System (DSS). The DSS will take the risk modelling and management data, including the quality of service data and support decisions on changes to the service profile of an application. At design time the DSS will support the initial selection of applications on metrics that will include cost. At run-time the DSS will be used to suggest alternative to the services in the application based on the monitoring of quality of service metrics.

When anyone discusses the issues of swapping services in a running environment one of the most frequent problems highlighted is the difficulty of making a decision on an alternative service. The considerations for any change in a complex environment are difficult but decisions to replace a service will be based on price, performance and availability comparisons. The decision to change service supplier will be triggered by changes to a number of monitored metrics and characteristics. To illustrate the decision process we can take a simplistic example from the regulatory compliance domain:

A company may have to be regularly audited to record their compliance to a specific regulation (Sarbanes Oxley, HIPPA, Data Protection etc.). If any of this company’s applications use public or hybrid clouds services these services and their service suppliers may have to be audited as well. If one of these service suppliers fails the audit it may also cause the consuming company to fail their compliance audit. In this circumstance an audit failure by the service supplier could trigger the service consumer’s requirement to change to an alternative service with similar or identical functionality provided by a supplier who has passed a regulatory compliance audit.

Selecting the replacement service would be difficult. The comparison of metrics and claims by both suppliers is not expected to be a simple like for like comparison. Transaction throughput may be measured in hundreds of transactions per hour by one supplier as opposed to transactions a second by their competitor. There are a number of potential solutions for the mismatch of units such as creating an ontology for machine based unit conversion and comparison. An interesting alternative to the ontological approach is the Service Measurement Index (SMI). This is an initiative led by a consortium of academics, analysts and IT industry organizations. The Cloud Services Measurement Initiative Consortium (CSMIC) is developing SMI to create a global standard for comparison of services. CSMIC has identified a number of cloud service characteristics that can be measured and monitored. The comparisons are based on the concept of “relative goodness”. In Figure 2 below you can see a screen capture of the SMI view of an email service. This indicates

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the weighting and benchmark scoring for each category. A number of email services suppliers will generate an SMI view of their service. These are then compared using a summary report for each of the email services. This summary report will allow comparison and selection on characteristics that are important to the service consumer.

Each of the categories in Figure 2 indicates an area of comparison. Each of the categories has been further decomposed into a series of attributes that is weighted according to rules so that the categories are measured on a percentile scale. The raw data and weights are put into a database by the owners of the service or by independent benchmarks of the service.

SMI is a work in progress, but it shows promise as a means to provide comparisons that will enable a decision support tool to work effectively. SMI is also generating interest in the larger standards authorities and government agencies as a potentially important tool to enable more standardized ways of measuring services. More information, papers, examples and progress reports on SMI can be gained from the CSMIC website (http://www.csmic.org)

The SMI categories and attributes are not the only measures that would be evaluated for decision support data. The MODAClouds DSS will also be based on cost and pricing model evaluations mentioned earlier in this article.
Finally, the adoption of Web 2.0 technologies has led to the capability of handling large amounts of data in the cloud. What happens to the data that is stored as part of the original service execution if we want to migrate to a new service? If a service stores data in the service supplier's environment then changing to another supplier may require migration of data which might be difficult or impossible based on current data volumes as well as reasons mentioned earlier.

For some years researchers have been working on finding technologies to handle large data volumes in the cloud. A widely explored solution is separating applications from the actual data management, i.e. cloud databases. In general, distributed databases work on shared-nothing parallel systems. This model usually implies a lot of data shipping, i.e. sending large amounts of data from one node in the network to another to solve a query, which might have a negative impact on performance. Elasticity in cloud computing is already a real problem for databases. The addition or removal of resources from the cloud implies moving a lot of data from different nodes and increasing resources might even imply a decrease in terms of performance. Thus, cloud databases present very challenging issues, where different objectives such as consistency, scalability, and high-availability or low operational cost compete for priority. There have been substantial research efforts to provide scalable database services in the cloud, as for instance, BigTable where very high scalability is prioritized, and consistency is sacrificed. Following a similar philosophy, some research works try to provide better scaling by avoiding distributed transaction or by limiting the type of transactions also favoring elasticity. Other publications have presented improved workload-aware techniques for partitioning. Similar work has been devoted to scale social networks. Another aspect that is crucial for cloud databases is workload balance. Some efforts were made to propose sophisticated cache strategies applied in cloud environments. Relational database services are being consolidated in the cloud.

This previous research aims at building cloud-based distributed database management systems, but also provides some potential for combating vendor lock-in. Replication of information in multi-cloud databases or separation from functional services and data storage services might be two interesting areas for investigation in the next years. With this, moving from one service to another might not necessarily imply moving large amounts of data. In the negative side, separating the application from the data needed to perform a certain process might bring new performance issues that will need to be considered in the next years by researchers. All of these research issues indicate that data management, location and security will be a major challenge to be understood during service selection and replacement. Monitoring and measurement of data management will be a key part of both the MODAClouds DSS and the run time monitoring. New SMI capabilities and measures may also be needed to cope with this complexity.

In conclusion it is fair to say that many organizations are in the early stages of a cloud computing lifecycle, focusing on implementing cloud computing but have seldom progressed through to considering maintenance, replacement and retirement of services. Evaluation of service performance and quality in a solution will result in some changes to both services and the suppliers of those services during the lifecycle of the solution. The decision to change services or suppliers will be affected by the data management considerations of existing services. This decision will best be supported by the use of a decision support system that must be extended to include price and cost models for services as

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part of the core characteristics that can be measured. All of these areas will be part of the research of planned for the MODAClouds project. In a short time, maintenance of cloud computing services will become more visible as a topic as more companies adopt and run environments that are a mix of both public and private cloud services. It is considered that in a cloud computing environment the ability to evaluate, replace and retire consumed services is the next stage in the maturing of cloud computing as a strategic technology.

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