

# The Structure of the New IT Frontier: Aneka Platform for Elastic Cloud Computing Applications – Part III

Karthik Sukumar<sup>1</sup>, Christian Vecchiola<sup>2</sup>, and Rajkumar Buyya<sup>1,2</sup>

<sup>1</sup> Manjrasoft Pty Ltd

ICT Building, Room 5.31, 111, Barry Street, Carlton,  
Melbourne, Australia

{karthik, raj}@manjrasoft.com

<sup>2</sup> Cloud Computing and Distributed Systems (CLOUDS) Laboratory

Department of Computer Science and Software Engineering  
The University of Melbourne, Parkville Campus, Melbourne, Australia

{csve, raj}@csse.unimelb.edu.au

*Stateful applications (transactional, high-performance and data-intensive) are growing at an increasing pace, solving scalability and high performance issues are a prime concern of application designers and developers. In this article, we suggest a novel approach in which applications are divided into smaller processing units, and present a Market-Oriented Cloud Computing (MOCC) development and management platform with rapid application development and workload distribution capabilities as a practical implementation of this approach. We demonstrate that Manjrasoft Aneka a Cloud Application Platform (CAP) leveraging these concepts and allowing easily developing Cloud ready applications on a Private/Public/Hybrid Cloud. It provides means to harness your local infrastructure and transparently scaling to the Public Cloud providers such as (Amazon, GoGrid and etc) when needed by boosting your application performance and optimizing your allocated IT budget. Leveraging a solid and enterprise technology, the .NET framework, “Aneka CAP” offers facilities for rapidly developing Cloud applications and extensible platform where additional services can be easily integrated to fully develop your business over the Cloud.*

## 1. Introduction

In the previous two articles [1, 2], we have discussed Market-Oriented Cloud Computing (MOCC) as a promising approach for building and scaling IT infrastructure and applications in an efficient and cost-effective manner. MOCC allows coherently and promptly reshaping your IT resources according to the size of your business, thus leading to considerable savings in capital expenditures. Many enterprises already have an established information technology infrastructure that they want utilize at best rather than leveraging external infrastructure providers for any IT need. Still, Cloud computing represents an opportunity for huge savings in terms of IT capital, management, and administration costs, which cannot be missed. Thus, integration of Cloud-based services (infrastructure, applications, and services) is the right solution for enterprises that want to elastically and promptly address their scalability needs without massive upfront payments but still require delivering a high quality service to their customers. In the previous article we presented a review of the Infrastructure-as-a-Service (IaaS) market offering compute and storage as a commodity. We also introduced the fundamental concepts of MOCC and discussed how it can leverage the IaaS market to provide infrastructure on demand on a competitive basis. This market segment is now a mature layer on top of which is possible to build advanced services fostering the mainstream adoption and integration of Cloud computing. The Platform-as-a-Service (PaaS) market is the right venue where such services can be implemented and offered on a competitive, and market-oriented, basis. This market is estimated to have a huge development potential in the next future years, and in this article we will present

Manjrasoft Aneka, an innovative solution for Cloud computing that provides seamless integration with the major IaaS providers, elastic scalability for applications, and QoS-based application delivery.

Manjrasoft Aneka [3] is a Platform-as-a-Service solution for developing Cloud aware applications that scale on demand, optimize the use of allocated budget, and transparently provide the desired quality of service. Aneka fosters a new approach that eliminates both the technical and business challenges in comfortably and affordably leveraging Cloud computing. By smashing significant technical hurdles, like managing an interconnected network and distributed application, it provides “out of the box” solutions for software development, deployment, and management over private, public, and hybrid Clouds. A .NET-based Service Oriented Architecture lays the foundations of the entire framework and constitutes the robust enterprise technology on top of which Aneka delivers its core capabilities: adaptability, flexibility, extensibility, rapid application development, and ease of management. All these features concur in providing an immediate return on investment and considerable savings in IT management and development. The platform is a perfect solution for enriching applications with elastic scalability both in private Cloud environment, which could be your corporate IT, or over public Clouds, such as Amazon EC2 and GoGrid. More importantly, Aneka seamlessly supports hybrid deployments by dynamically provisioning IT resources from the major IaaS providers when the desired QoS cannot be guaranteed anymore simply by leveraging the local premises [4]. This is indeed, the most comfortable and reasonable approach for enterprises who develop their own applications in house and want to securely and smartly leverage Cloud computing for empowering their business.

Aneka already acknowledges and provides immediate solutions for the inherent problems faced by the industry verticals such as: Entertainment and Media; GIS; Manufacturing and Engineering; Academic Research; Business Intelligence (Data Mining); Life Sciences; Financial modeling; Investment risk analysis; Energy; and Drug discovery. In the following we will discuss the major feature of Manjrasoft Aneka, and how it can enhance the enterprise business by presenting some reference case studies.

## 2. Manjrasoft Aneka: An Innovative Solution for Cloud Computing

Aneka is a Platform-as-a-Service solution for Cloud computing. It provides a framework for developing distributed application that are Cloud aware and can scale on demand in a completely seamless fashion. Its service oriented architecture provides a flexible and adaptable middleware that can be easily empowered with additional services and thus tailored for a specific deployment scenarios or application requirements. Flexibility is at the core of the platform and it is reflected across all layers of the framework; not only in the infrastructure middleware building the Aneka Clouds, but also in the application development models. Aneka offers different ways to express application logic thus covering a wide variety of paradigms for distributed programming. This is one of the key features of the frameworks and allows developers to optimize their development experience and being more productive. In addition, if the available options cannot satisfy the needs of the enterprise, it is possible to design and integrate new models that can leverage existing models and take advantage of the collection of services available in the Aneka Cloud. Flexibility is also in the different deployment scenarios supported from desktop Grids, clusters, datacenters, and public virtual infrastructures, thus making Aneka a suitable solution for different market segments, which are explored and presented as case studies for the framework.

### 2.1 Why Aneka?

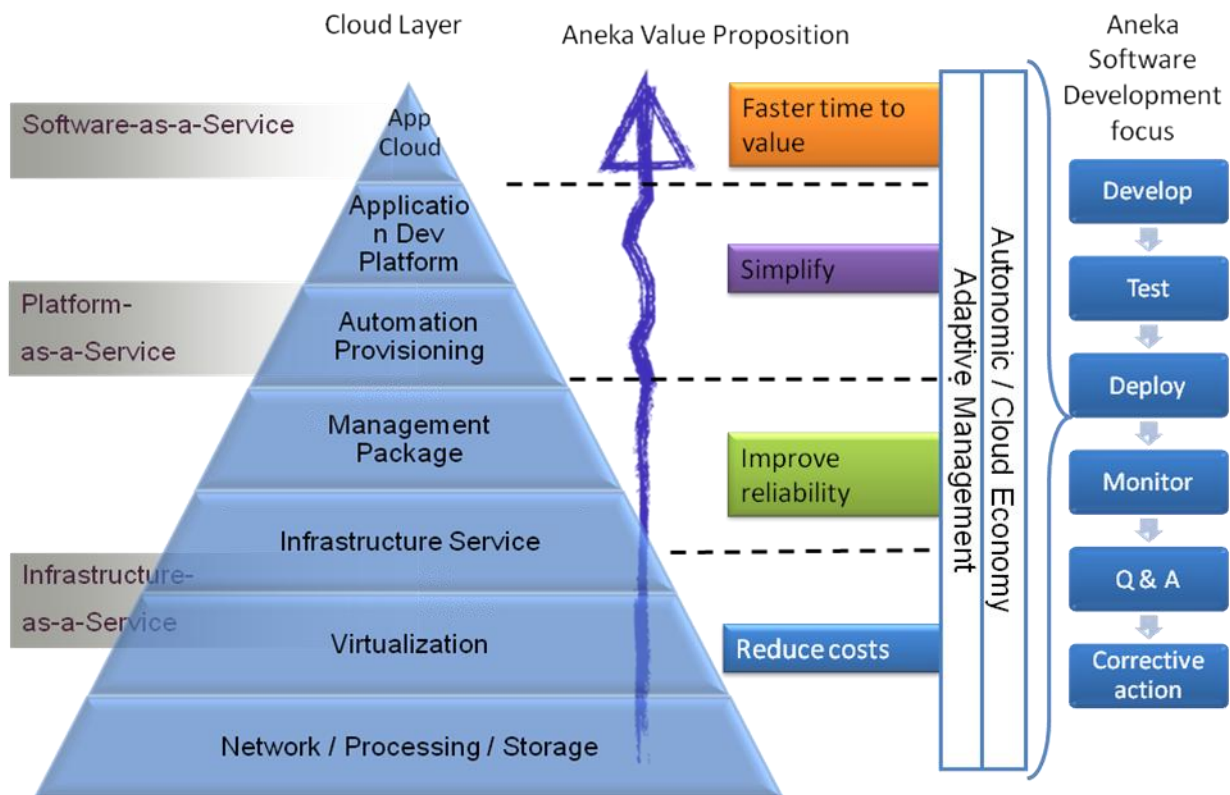
Every CIO faces the need to optimize his budget to support the adoption of Cloud technology. Despite the economic downturn and the challenging business climate, considerable investments are allocated for infrastructure and software technology development. Cloud computing provides significant revenues with a minimum upfront commitment and the ability to comfortably control their expenditure according to the health status of the managed business. Choosing the right option in such a vibrant market is a challenging task that cannot be delayed anymore, given the ever growing popularity of the trend. Aneka Platform as a Service provides a comprehensive and unmatched solution for Cloud adoption by bringing several advantages to enterprises:

**Reduced Costs.** Any successful enterprise business knows the significance of appraising, managing, and optimizing the Capital Expenditure and Operational Expenditure and necessities to achieve cost economies. Aneka adeptly leverages your current infrastructure assets and Cloud management tools with a low cost guarantee.

**Improved Reliability.** As one of its kind, Manjrasoft's Aneka is the most comprehensive and mature path for Cloud adoption based on the .NET technology. Aneka's ability to design and create a solid fault tolerant system infrastructure without having to build topology level knowledge base into applications simplifies the application development and automatically manages application load over Clouds, Grids, clusters, or desktops. This gives a newfound level of resiliency with a guaranteed quality of service and effective metering and monitoring for all the service.

**Simplicity.** Moving to a Cloud based model requires the software development team to assume responsibility of delivering their application in a utility fashion, making them to tightly integrate with salient software development approaches and focus on IT efficiency. Aneka offers the most flexible and robust APIs framework that cleanly handles .NET based enterprise application management and development with lightweight technology and flexible application integration approaches. This enables software development team to be more productive by enabling the developers to focus on business logic, instead of being stifled by technology barriers.

**Faster Time to Value.** By unraveling both the immediate technical and business challenges of Cloud integration, Aneka allow enterprise business to effectively adopt Cloud based application through faster time to market scenario with minimal budget. Aneka leverages a solid and widely adopted technology such as the Microsoft .NET framework; thus, enterprise customers can capitalize their existing .NET base application and engineering expertise over Cloud environment. With regards to the technical development team, Aneka's support of multiple programming and application environments helps them to leverage their current expertise over software development without having to sunk huge effort on capabilities to adopt new technology and learning new processes.



**Figure 1.** Aneka value proposition.

**Seamless Scalability.** Aneka helps enterprise customers to enrich their applications and services with support for distributed and scalable runtime environments for multicore desktops, servers and a network of computing systems that are presented as Clusters, Grid, and Clouds. Aneka empowers the enterprise application stack to

achieve end-to-end performance, scalability and high availability thus meeting the service levels agreement and providing the desired quality of service. This process is completely transparent to applications and relies on dynamic provisioning multiple virtual and/or physical machines for accelerating applications in a scalable manner from a single multi-core desktop computer to a large-scale elastic Cloud computing infrastructure such as Amazon EC2.

All these features make Aneka a winning solution for enterprise customers in the Platform-as-a-Service scenario. There exist other different solutions in the PaaS market, most notably Google AppEngine and Microsoft Windows Azure. While AppEngine is mostly concerned with providing a scalable runtime environment for web applications for Java and Python applications, Aneka aims to be more general and empower any kind of application that suffers from performance degradation and lack of responsiveness under huge pressure. Microsoft Azure is a giant in the market of Cloud services development and provides a wide range of services for developing and deploying services on the Cloud. It leverages the infrastructure provided by Microsoft to host these services and scale them. Aneka provides a more flexible model for developing distributed applications and provides integration with external Clouds such as Amazon EC2 and GoGrid. Moreover, Aneka is a middleware that can be deployed in the private infrastructure thus maximizing the use of the local existing infrastructure and allowing enterprises to comfortably scale to the Cloud when needed.

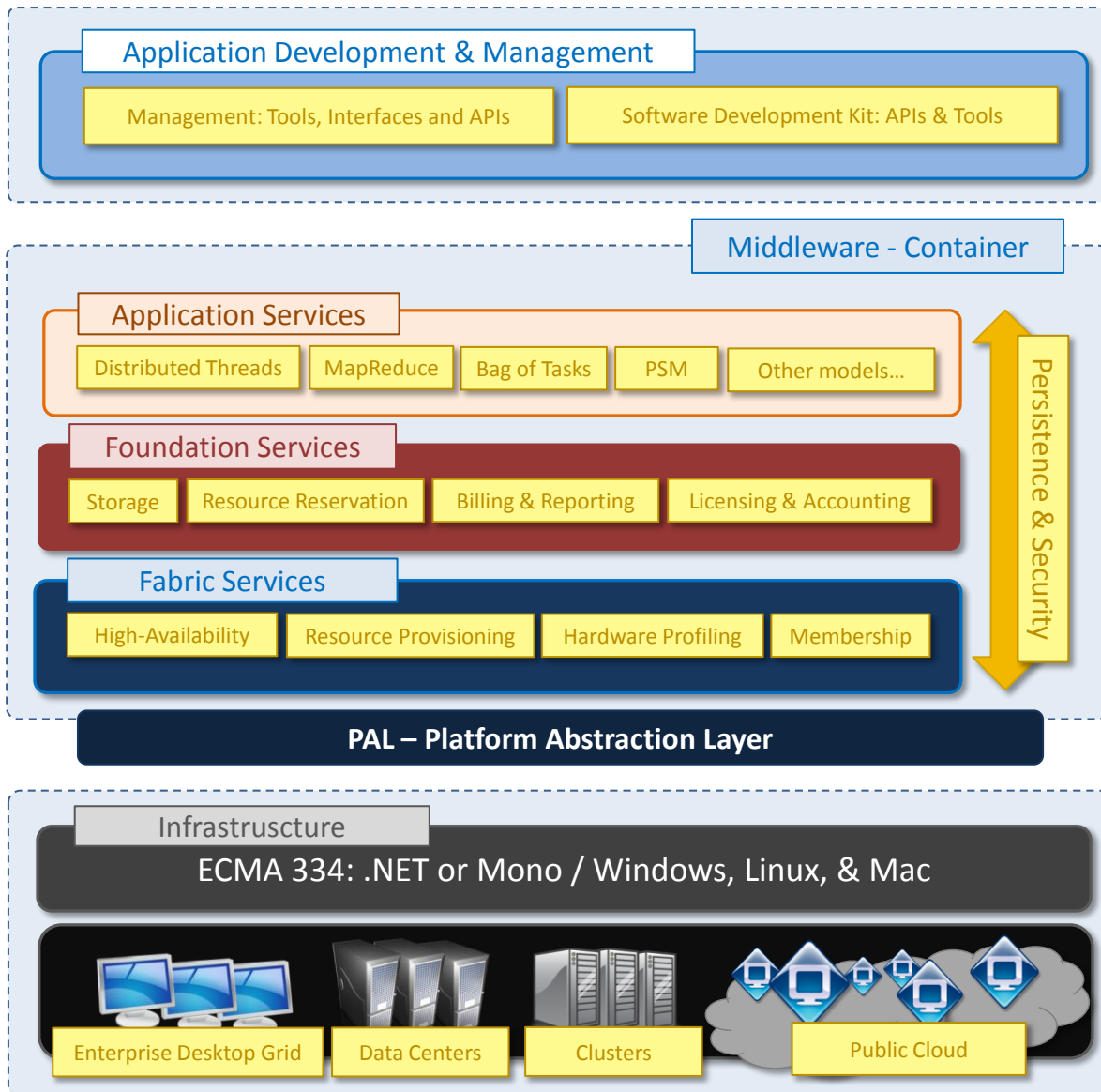
## 2.2 Overview

Aneka is a distributed platform for developing Cloud based applications. It can harness a huge variety of physical and virtual resources, ranging from desktops, clusters, to virtual datacenters, to provide a single logical “application execution layer”. Applications can be expressed by means of intuitive patterns and popular models or rapidly prototyped with the support of advanced visual tools. Application execution, monitoring, and management are transparently handled by the runtime infrastructure that ensures that applications are executed under the specified Quality of Service, whether they are leveraging a dynamically provisioned Cloud or a static deployment. An extensible collection of services constitutes the added value of the framework providing advanced management capabilities such as reporting, billing, remote deployment, and total control of both the infrastructure and applications.

The key components of the platform are depicted in Figure 2, which gives an overall view of Aneka from its foundations to the applications and the end user services. The platform is based on an extensible Service Oriented Architecture (SOA), which makes the integration of new components, incremental development of new features, and infrastructure deployment and configuration seamless tasks. This architecture is realized by means of a portable runtime environment hosting the execution of services over different operating systems and hardware: the *container*. The container constitutes the basic building block of the middleware and hides all the heterogeneities of different deployments thus making Aneka being able to harness different resources such as Windows-based desktops and servers, Linux workstations and servers, on both physical and virtual nodes. The container hosts the execution of services which are made available to client applications and users.

Together with the middleware the infrastructure components and the application development and management tools complete the value offering of Aneka. Security, persistence, flexibility, and extensibility are quality features across the entire platform, thus making Aneka the right solution for different kind of needs and economic sectors: education, enterprise applications, and scientific computing.

**Infrastructure Support.** Aneka provides the capability of harnessing disparate resources and to be deployed on heterogeneous hardware and operating system platforms. Current supported deployment involve: enterprise desktop Grids, Data Centers, Clusters, and public Clouds such as Amazon EC2 and GoGrid. The supported operating systems include several editions of Windows (Windows Server 2008, Windows XP, Vista, and 7), Linux distributions such as Fedora, Ubuntu, and Suse, and Mac OS X. Potentially, any operating system that provides an implementation of the ECMA 334 and ECMA 335 specifications, can be used as hosting environment for Aneka. ECMA 334 and 335 specification defines the Common Language Infrastructure and the C# language, which constitute the technology leveraged by Aneka. Currently, the platform has been extensively used on their two most popular implementations: .NET framework (for Windows based platforms) and Mono (for Windows, Linux, and Mac OS X platform).



**Figure 2.**Aneka framework architecture.

**Middleware.** The platform features a homogeneous distributed runtime environment for applications. Such environment is built by aggregating together physical and virtual nodes hosting the Aneka *container*. The container is lightweight layer that provides the interfacing with the hosting environment and manages the services deployed on a node. The interaction with the hosting platform is mediated through the Platform Abstraction Layer (PAL), which hides in its implementation all the heterogeneity of the different operating systems. By means of the PAL it is possible to perform all the infrastructure related tasks such as performance and system monitoring. These activities are vital to ensure the desired quality of service for applications. The PAL together with the container, represent the hosting environment of services which implement the core capabilities of the middleware and make it a dynamically composable and extensible system. The available services can be aggregated into three major categories:

- **Fabric Services.** Fabric services implement the fundamental operations of the infrastructure of the Cloud. These services include: high-availability and failover for improved reliability, node membership and directory, resource provisioning, performance monitoring and hardware profiling.

- **Foundation Services.** Foundation services constitute the core functionalities of the Aneka middleware. They provide a basic set of capabilities that enhance application execution in the Cloud. These services provide added value to the infrastructure and are both of use to system administrators and developers. Within this category we can list: storage management, resource reservation, reporting, accounting, billing, services monitoring, and licensing. Services in this level operate across all the range of supported application models.
- **Application Services.** Application services deal directly with the execution of applications and are in charge of providing the appropriate runtime environment for each application model. They leverage foundation and fabric services for several tasks of application execution such as elastic scalability, data transfer, and performance monitoring, accounting and billing. At this level Aneka expresses its true potential in supporting different application models and distributed programming patterns. Each supported application model is managed by a different collection of services that by interacting with the underlying layers and services carries out application execution. In general the middleware counterpart of each application model features at least two different services: scheduling and execution. In addition, specific models can require additional services or a different support. Aneka provides support for the most known application programming patterns such as distributed threads, bag of tasks, and mapreduce.

Additional services can be designed and deployed in the system. This is the way in which the infrastructure is enriched with additional features and capabilities. The software development kit provides straightforward interfaces and ready to use components for rapid service prototyping. Deployment and integration of new services is painless and immediate: the container leverages the Spring framework and allows for dynamic integrations of new components such as services.

**Application Development and Management.** Aneka provides advanced features for developing and managing applications on the Cloud. The Software Development Kit and the Management Kit are the two components exposing such capabilities. They provide means for interacting with the middleware and managing it with advanced user interfaces and bindings for applications. By means of the Software Development Kit developers can quickly develop distributed applications, integrate the scaling capabilities of Aneka into existing applications, or implement new services to extend the potential of Aneka. The Management Kit exposes allows deploying, managing, and tuning Aneka-based Clouds. By using a visual approach provides means to access and control every aspect of the middleware and also provides access to advanced features such as application reporting, accounting, billing, user management, and performance monitoring. The Software Development Kit and the Management Kit are the tools that enrich the user experience of developers and administrators respectively.

## 2.3 Cloud Application Development

Aneka position itself as a Platform-as-a-Service solution for Cloud Computing. Its core feature is to provide models and APIs for simplifying application development on the Cloud. The key advantage of Aneka over the other solutions is to offer an *extensible* framework for developing distributed applications supporting *different* application models. Even though extensibility is a design feature of the entire platform, within this context it means that Aneka provides interfaces and APIs for developers to integrate additional and new application models that best suit their needs. Such extensibility is a proven and solid feature of the framework internally used to support the available application models.

An application model is a way to express a distributed application in Aneka. It contains abstractions and components that put together allow developers to design and implement applications that leverage Aneka Clouds for their execution. There are two major perspectives from which an application model can be seen:

**User view.** This view focuses on the abstractions that developers use to design and implement the logic and the behavior of applications. These are the most visible element of difference between the several supported application models: each model has its own abstractions that are eventually mapped to Aneka specific components. At this level the Aneka APIs expose the concept of application and several sub-classes that can be used according to the specific application model implemented.

**System view.** This view focuses on the runtime support needed for the execution of applications in the Aneka Clouds. Generally three different components are expected to be implemented: client components; scheduling and execution services. Client components interact with the middleware and allow users to manage and monitor the execution of the application. Scheduling services are in charge of coordinating the execution of the application on the Cloud. Execution services provide an appropriate runtime environment for the units of execution of applications.

Aneka provides ready to use components that can be extended to specialize the behavior of these components for a specific application model.

The software development kit contains all the basic building blocks for developing new models and applications with the available ones: bag of tasks; distributed threads; and MapReduce.

## 2.4 Building Blocks: Built-in Application Models

Aneka provides several application models covering different application scenarios. These models implement the most common abstractions in distributed and parallel computing and provide developers with familiar abstractions to design and implement applications. Each model addresses one or more classes of applications and simplifies the development of solutions tackling the problems in different scenarios whether these are intensive computing, high communication, or huge data processing.

**Fast and Simple: Task Programming.** Task Programming provides developers with the ability of expressing applications as a collection of independent tasks. Each task can perform a different operation, or the same operation on different data, and can be executed in any order by the runtime environment. This is a scenario in which many scientific applications fit in and a very popular model for Grid Computing. This application model allows to quickly prototype distributed applications with minimum implementation and management efforts and is particularly suited for compute intensive applications where the computation can be organized in several units of execution. Also, Task programming allows the parallelization of legacy applications on the Cloud. Several application domains propose challenges that can be solved by using Task Programming, among them we can consider scientific computing, financial applications, media rendering and transcoding, and so on. This model is the most popular and general in distributed computing and can be used a starting point for implementing models with more complex requirements such as workflows or parameter sweep.

**Concurrent Applications: Thread Programming.** This application model provides developers with the capability of running multithreaded applications on a distributed environment such as the Aneka Cloud. The main abstraction of this model is the concept of *thread* which mimics the semantic of the common local thread but is executed remotely in a distributed environment. This model offers major control on the execution of the single components of an application but requires more management if compared with Task Programming, which is based on a “*submit and forget*” pattern. A thread support almost all the operations available for local threads, more specifically an Aneka thread has been designed to mirror the interface of the *System.Threading.Thread* .NET class, so that developers can easily move existing multi-threaded applications to the Aneka platform with minimal changes. Ideally, applications can be transparently ported to Aneka just by substituting local threads with Aneka threads and introducing minimal changes to the code. This model covers all the application scenarios of the Task Programming and solves the additional challenges of providing a distributed runtime environment for local multi-threaded applications.

**Data Intensive Applications: MapReduce.** This model is an implementation of the MapReduce model, as proposed by Google, for .NET and integrated with Aneka. MapReduce has been designed to process a huge quantity of data by using simple operations that extracts useful information from a dataset (the *map* function) and aggregates this information together (the *reduce* function). Developers provide the logic for these two operations and the dataset and MapReduce will do the rest and made results accessible when the application is completed. This application model has often been named as the paradigm for developing applications for the Cloud because its natural support for large distributed infrastructure and ease of scalability in presence of massive amounts of data. MapReduce can be a winning solution for data mining and analytic applications, bulk media processing, and content indexing. Aneka provides a solid support for the model and integrates it with all the other foundation services such as accounting and reporting, thus making this solution a competitive alternative within the same market segment.

**Rapid prototyping: Parameter Sweep.** Parameter Sweep is an extension of Task Programming allowing the rapid prototyping of application that are constituted by a single job that is iterated over several datasets. Several applications fit into this category: common scientific applications are often composed by one or more legacy console applications that process a specific domain, the same pattern can be found for some financial applications. Within these scenarios the scalability needs of the applications are generated by the combinatorial explosion of different parameter settings. Fundamental in this case the concept of parameter, which identifies a specific dimension of the application domain; by varying the value of each of the parameters within their range of admissibility the entire application domain is explored. Aneka provides advanced user interfaces to visually compose such applications as

well as powerful APIs to integrate this model within existing applications. This model is also an example of how existing application models can be further extended and specialized for a specific class of applications. In this case the user view of the Task Programming model has been modified, while the runtime infrastructure has remained unchanged. Once more Aneka proves to be an extensible platform where it is possible to integrate additional value without significant efforts.

## 2.5 A Step Beyond: Customer-based Application Models

The key feature of Aneka is its ability to be extended with additional features. In particular, its flexible design allows for seamless integrations of new application models. The available API have been specifically designed to support this feature and the SDK provides complete support for implementing new abstractions for distributed applications and leveraging existing solution for rapid development of such abstractions.

There are two ways in which a new application model can be designed and integrated into the platform: by further customizing an existing application model or by developing a new model directly from the base classes provided by the framework. The first solution can be used when minimal changes have to be done or additional features need to be added to an already suitable model. An example of this practice is the Parameter Sweep model which has been designed on top of the Task Programming and with a minimal implementation effort and by simply changing the user view of the model. The second solution requires a complete implementation of new abstractions, client components, scheduling and execution services. This approach provides the maximum flexibility and power but at the same time requires a considerable effort especially for what concerns the design of the runtime infrastructure supporting the application model.

An interesting case is the implementation of support for *workflows* in Aneka. A workflow application can be easily expressed as a collection of tasks whose dependencies can be expressed by means of a graph. Such model can be designed as an additional layer on top of Task Programming thus providing a workflow orchestration component as an abstraction to express the logic of applications together with tasks. Another solution implies designing the support for workflow as a separate model by providing appropriate support within the infrastructure for the scheduling of task and the movement of data according to the dependency graphs. The first option is a quick solution for adding a desirable feature into the platform but could not be optimal from a performance point of view, while the second option exhibits a better performance but implies more development efforts. Once again, Aneka by means of its flexible and extensible architecture allows software engineers to select the best trade-off between their needs and their available resources.

## 2.6 Deployment: Unleashing the Power of Aneka Clouds

The high flexibility of Aneka allows the framework to be deployed over different operating systems and hardware, these include: clusters, desktop machines, Enterprise Grids, and datacenters. Thus, Aneka is the perfect solution for managing private and public Clouds deployment as well as hybrid Clouds through cloud-bursting.

Figure 3 depicts a classic deployment scenario for Aneka. As previously introduced, the Aneka Cloud is a collection of internetworked nodes that can elastically grow and shrink according to the demand and the load pressure of currently executing applications. Different resources can be integrated into the infrastructure as managed uniformly, from a single point of control. Enterprises want to maximize their revenue from capital costs and exploiting at maximum the local existing infrastructure is a must. Aneka allows to take advantage of your corporate IT and to optimize its utilization. A private Cloud can harness the resources of your local premises and to exploit the sleeping computing power of desktop machine into a Computing Cloud able to process low priority workloads and applications with relaxed quality of service constraints. This infrastructure can be eventually expanded with resources coming from the local computational cluster of your department, a virtual machine manager such as Xen or VMWare can maximize the utilization of the cluster by providing a resizable computing capacity. Aneka can seamlessly provision Xen and VMware-based virtual instances on demand in order to guarantee the desired quality of service for applications with stringent requirements.

When enterprise requirements are too demanding and the current workload cannot be sustained by the existing infrastructure Public Clouds can offer virtually unlimited resources in terms of storage and computation. Aneka provides enterprises with seamless integration of public cloud resources by leveraging Amazon EC2 and GoGrid, thus creating a hybrid cloud that is constantly shaped to address the business needs of your enterprise. *Dynamic provisioning* is the fundamental feature allowing Aneka to react in real time to the workload pressure by optimizing your allocated IT budget and providing a simple and straightforward management of your resources. The



provisioning service can leverage several resource pools and provide integration with different IaaS providers; it is possible to configure as many resource pools as needed to cover all the possible provisioning scenarios. This is the way in which Xen, VMWare, Amazon EC2 and GoGrid resources are transparently integrated into the Aneka Cloud. Provisioning can be paired with advanced policies that select the optimal resource pool for addressing the needs of applications or compose several pools to guarantee the requested Quality of Service of a given application. Moreover, the service oriented architecture of Aneka allows the provisioning service to be available to any other component of the Aneka Cloud thus giving the opportunity of exploring new scenarios where dynamic resources are not only provisioned on demand when needed, but also booked in advance by means of reservation. These possibilities open new perspectives that can make a profitable integration of Cloud Computing into your business.

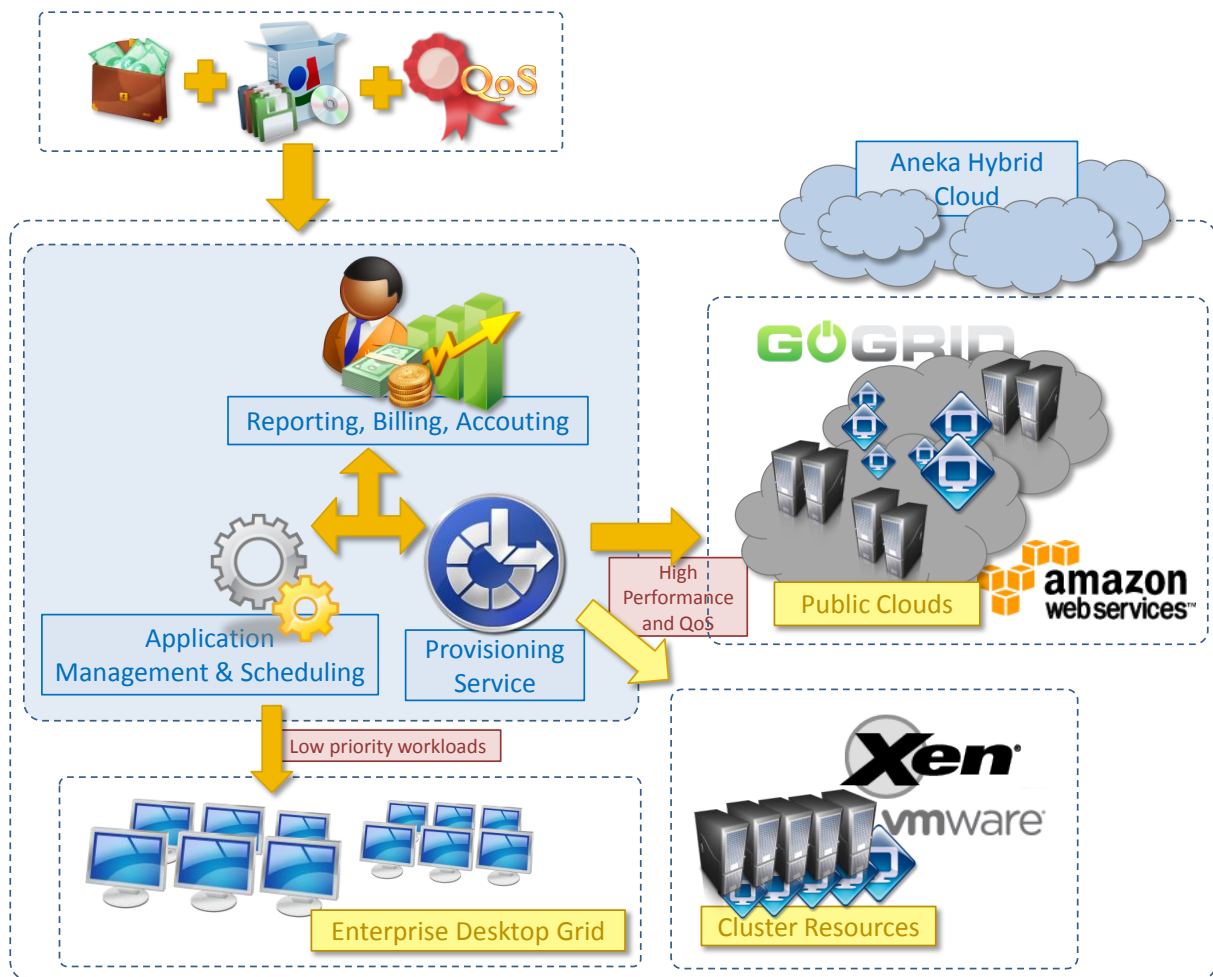
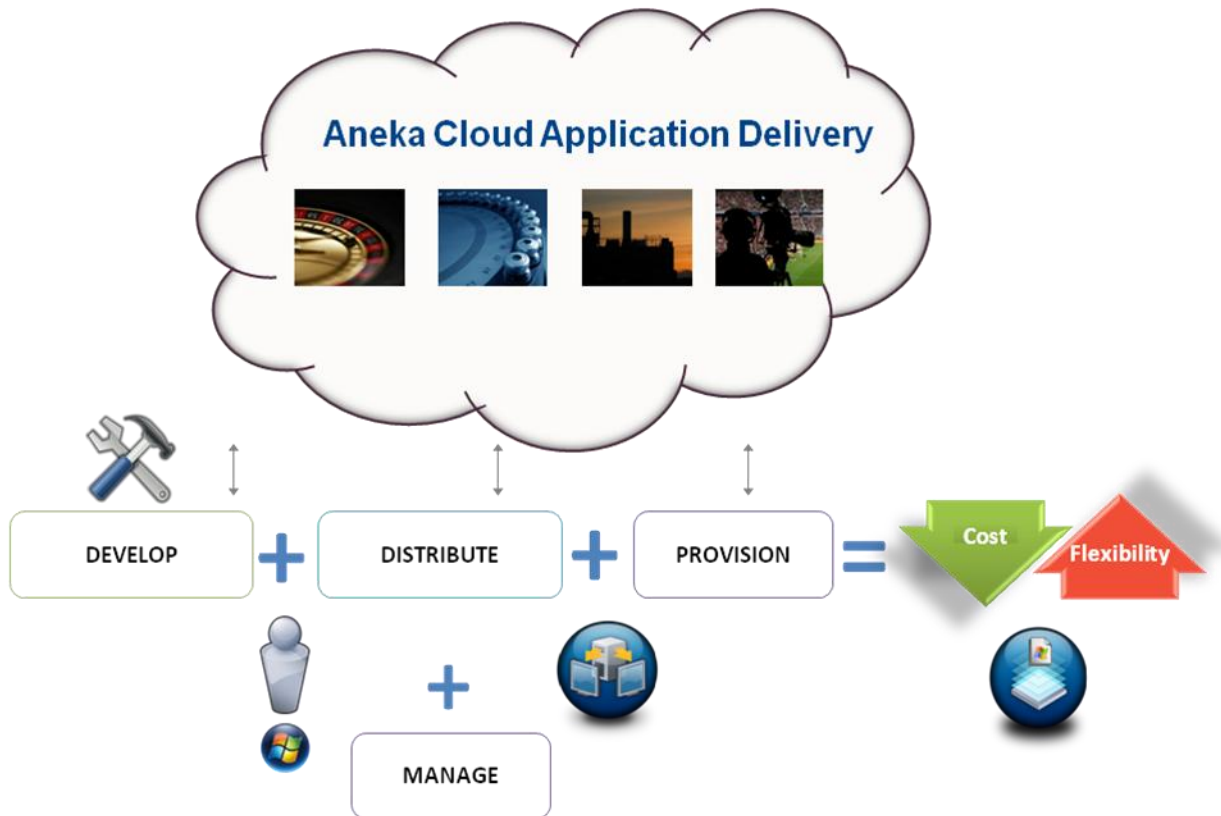


Figure 3. Aneka hybrid Cloud deployment.

### 3. Aneka Cloud Application Delivery

Aneka has been proven to be a successful technology in several market segments and application scenarios. This section presents a brief overview of the case studies in which Aneka has been an effective solution to challenging technology hurdles and application requirements. We also propose some possible future uses of Aneka in important industry sectors such as the telecommunications market with innovative solutions such as MapReduce.

**GIS Sciences and Technologies.** As a result of the continuous growth of GIS sciences and technologies, there is a need to manage even more geospatial and non-spatial data due to the increase in number of data sources and advancement of data collection methodologies. Spatial analysis and Geo-computation are getting intricate and computationally demanding. The Department of Space, Government of India, showcased the utilization of Aneka to exploit Cloud technology [5]. Our platform Aneka has been used for developing cutting-edge GIS applications over the Cloud. By twining with the Microsoft technology a large number of high computing resources interconnected via high-performance networks have been aggregated together into an Aneka-based Cloud. Aneka represents a new approach to complex analyses of massive data and computationally intensive environment and has the chance to satisfy all the requirements of a high-performance and distributed GIS environment over the public, private and hybrid Cloud.



**Figure 4.** Aneka Cloud application delivery.

**Entertainment and Media Industry.** Entertainment and Media industries pervade everything; they're ubiquitous in today's world. Increasing the expectations and leveling delivery models up for a grab to showcase the contents efficiently and faster. And it is essential that the media files are to be formatted and converted from a raw file to the required proper version or encoded to allow digital media formats distributed through internet or mobile devices. Business solutions involving digital media transcoding to HD video, 3D image rendering, and gaming, require plenty of time to process and utilize vast amounts of computing capacity to encode and decode the media. These business users demand immediate turnaround for streaming of on-the-air content, live news coverage, etc. Aneka is designed to optimize networked computers as a private Cloud or leverage public Cloud such as Amazon EC2 or Go-Grid. Aneka acts as a middleware that efficiently distributes the media decoding application which allows businesses to harness the power of multiple nodes in private or public Clouds.

**Financial Services.** Financial applications such as Portfolio and Risk Analysis tools, credit fraud detection, option pricing, portfolio optimization, risk analysis, etc. require the use of high-performance computing systems and complex algorithms. Aneka is ideally suited to simplify application development; improve performance, and delivers reliability, scalability, and performance to financial applications over tCloud based infrastructures. Aneka brings a breakthrough among the Industry standard tools for financial modeling such as Microsoft Office Excel by

overcoming its computational performance barrier. Aneka with Microsoft's technology can simplify the application development life cycle significantly; reduce hardware investment, and lower ongoing operational expenditure. In addition The Aneka technology toolkit is built on top of Microsoft .NET and is deeply integrated with the Microsoft development framework. Aneka provides access to all the development capabilities through the tools developers are familiar with such as Microsoft Visual Studio and thus eases the life of software development teams.

**Telecom Industry with Map Reduce.** The rapid development of telecommunications and the Internet facilitates the coming of a "global village", which has led to massive increase in subscriber's base. However, there are several challenges ahead in meeting the constantly growing demand of voice and data communication. From the collection of raw billing data (billing engine) to monthly bill generation, large Telecom providers such as AT&T Mobile with its 66 million subscribers exercise immense amount of computational power on a daily basis and most likely experience sudden spike in their workload at peak billing period. The majority of Telecom providers have several disparate systems and not enough capacity to handle the utilization and to access information to optimize their use. In the current bullish market trend most of the Telecom providers are constantly looking for service differentiators and market opportunities to distinguish themselves for dominating the market segments. Their vision is to offer solutions or services which are scalable, reliable and robust. With Aneka and Cloud computing, telecom providers such as Telstra, Verizon Wireless, AT&T, China mobile, etc. can realize these strategies in a cost effective, reliable and scalable manner. With the help of MapReduce leveraging the Aneka technology mission critical applications can be delivered in with the desired performance and within the required timeline. This is done by automating their initiation across a shared pool of computational resources, by breaking the executions into many parallel workloads that produce results faster in accordance with the agreed upon SLA and policies. In brief organizations can utilize their computational resources effectively and reduce their technology cost, which means more analysis.

**Manufacturing and Engineering.** The Manufacturing and Engineering sectors include a wide range of market segments, from aerospace to automotive. Manufacturing organizations are faced with a number of computing challenges as they seek to optimize their IT environments, including high infrastructure costs and complexity to poor visibility in capacity and utilization. Today's design engineers need access to unrestrained, flexible computing capacity on demand, so that design cycles can be as fast, cheap, and productive as possible. With Aneka and Cloud computing, engineers, designers and testers can operate unhindered by capacity and technology constraints and can focus where they should: on the design process. Aneka enables organizations to perform process simulation, modeling, and optimization at a highly increased rate so key products get to market faster and effectively leverage Cloud technology. In a real time scenario, GoFront Group, a division of Southern China Railway, is the one-stop-shop for locomotive design in China and leverages the Aneka technology for their design process. Their primary objective was to develop futuristic designs of locomotives to aid the advancement of public transport in China using Autodesk Maya. By using Manjrasoft's Aneka the local IT infrastructure has been turned into a powerful and scalable private Cloud allowing GoFront to significantly speed up their design process and to be more timely and productive.

**Health and Life Science.** With the high volume and density of data required for processing in most R&D environments, along with the growing complexity of IT ecosystem and the pressures of competition and regulatory groups, life sciences organizations need IT infrastructure and management tools that can respond quickly to changing needs and, more importantly, enable rather than hamper the ability to innovate. Aneka enables faster execution and massive data computation in life science R&D, clinical simulation, and business intelligence tools. It helps organizations to achieve greater levels of innovation in shorter timeframes while maximizing license utilization, increasing ROI, and realizing significant savings over cloud based technology. For its application in real time scenario, Jeeva a Enterprise Cloud enabled portal for protein secondary structure prediction was developed by leveraging Aneka. Research scientists use the portal to discover new prediction structures using parallel execution method. The prediction took 20 minutes to complete when compared with the previous computational time of 8 hours. Also, Aneka has powered the implementation of personal health monitoring systems aiding rehabilitation of stroke patients on public Cloud platform such as Amazon EC2.

## 4. Summary and Conclusions

Cloud computing offers interesting opportunities for a huge cost savings in IT infrastructure, applications, and service delivery. Profitably integrating these resources into an existing IT is challenging. Market-Oriented Cloud Computing (MOCC) provides the reference framework where Cloud services can be offered, traded, and exchanged

in a competitive basis. Despite the popularity and maturity of the Infrastructure-as-a-Service (IaaS) market segment, which lays the foundations of every Cloud computing based solution, the Platform-as-a-Service (PaaS) market is the most reasonable venue where MOCC can be profitably implemented and explored. Platform-as-a-Service solutions provide environment and applications development platforms for seamlessly integrating Cloud computing into existing application, services, and infrastructure with a market-oriented approach. This is the most common case indeed, because most enterprises already feature a corporate IT and develop application in house. Thus hybrid Clouds are most convenient way to go to comfortably adopt this new technology trend.

Manjrasoft Aneka is a PaaS solution strongly leveraging market-oriented concepts for Cloud application delivery. The framework is built on a solid .NET service oriented architecture allowing seamless integration between public Clouds and enterprise mainstream applications. The core capabilities of the framework are expressed through its extensible and flexible architecture as well as its powerful application model featuring support for several distributed and parallel programming paradigms. These features enhance the development experience of software engineers allowing them to rapidly prototype elastically scalable application, thus maximizing the return on investment of the enterprise. All these features are delivered with a high application service profile and a complete ease of management that makes both IT administrators and CIOs comfortable in investing their resources on the Cloud. Aneka has already proven to be a successful technology in many sectors ranging from the media and entertainment industry, to engineering, education, health and life sciences and several others. It is possible to explore the opportunities that Aneka offers to improve and empower your enterprise with Cloud computing by downloading an evaluation version of the platform from the Manjrasoft website (<http://www.manjrasoft.com/>).

## Acknowledgements

We thank all members of CLOUDS Lab at the University of Melbourne and Manjrasoft for their contributions to the development of concepts and technologies presented in this article. In particular, we like thank to Xingchen Chu and Dileban Karunamoorthy for their contribution towards the development of Aneka software. We also like to thank our collaborators, application scientists, and partners for developing interesting application case studies reported in this article. We like to offer our special appreciation to Spencer Denyer, editor-in-chief of the Strategic Facilities Magazine, for encouraging and guiding us to write a series of articles in cloud computing space.

## Web Pointers

[Aneka] <http://www.manjrasoft.com>

[Windows Azure] <http://www.microsoft.com/windowsazure>

[Google AppEngine] <http://code.google.com/appengine>

[Amazon EC2] <http://aws.amazon.com/ec2>

[GoGrid] <http://www.gogrid.com>

## References

1. D. Duncan, X. Chu, C. Vecchiola, and R. Buyya, *The Structure of the New IT Frontier: Cloud Computing*, Strategic Facilities Magazine, Issue 9, Pages: 67-72, Pacific & Strategic Holdings Pte Ltd, Singapore, August/September 2009.
2. C. Vecchiola, D. Duncan, and R. Buyya, *The Structure of the New IT Frontier: Market Oriented Computing*, Strategic Facilities Magazine, Issue 10, Pages: 59-66, Pacific & Strategic Holdings Pte Ltd, Singapore, 2010.
3. C. Vecchiola, X. Chu, and R. Buyya, *Aneka: A Software Platform for .NET-based Cloud Computing*, High Speed and Large Scale Scientific Computing, 267-295 pp., IOS Press, Amsterdam, Netherlands, 2009.
4. C. Vecchiola, X. Chu, M. Mattess, and R. Buyya, *Aneka - Integration of Private and Public Clouds*, Cloud Computing: Principles and Paradigms, ISBN-13: 978-0470887998, Wiley Press, New York, USA, 2010.
5. K. Raghavendra, A. Akilan, N. Ravi, K. Pramod, and G. Varadan, *Satellite Data Product Generation Using Aneka Cloud*, CCGrid 2010 Research Demo, available at: [www.ieeetcsc.org/tcsc\\_files/aneke-vaps-TCSC-1.pdf](http://www.ieeetcsc.org/tcsc_files/aneke-vaps-TCSC-1.pdf).