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White Paper

Windows Azure – The Cloud Computing Platform

TCS Perspectives

The whitepaper delves into the evolving cloud computing model and provides an overview of Windows Azure as a cloud platform. It also describes the various tools that are supported by the platform and compares Windows Azure with other cloud platforms such as Amazon and Google. Finally the paper details TCS's perspective on Windows Azure and the future roadmap of the platform.

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Evolution of Cloud Computing Model

To obtain better returns on their investments in Information Technology (IT), enterprises typically adopt several technology transformation programs. These technology transformation programs are heavily influenced by the evolving computing paradigm, from the mainframes to client server (distributed and web), SOA and web 2.0. To realize cost effective, high performance and scalable IT investments, enterprises have experimented with various new computing models such as grid computing, utility computing and now **Cloud Computing**. Cloud computing is a disruptive force that will significantly impact the existing business models of technology vendors, systems integrators and ISVs in the future. As per Gartner's estimate, the cloud computing model will command a compound annual growth rate of more than 22% by 2011 of the enterprise application development market.

Cloud computing is an internet based services delivery model where services are hosted over the internet by a service provider. Cloud service providers have infrastructure, such as, servers, hardware and software and offers this as a service to enterprises.

The cloud services can be consumed by the enterprises through various channels, like mash-ups, browser based user interface, mobile applications, smart client applications deployed in on-premises and other open channels as well, such as, Windows Azure Marketplace – data market and application market.

Further, cloud services can interoperate with other programming platforms such as Java and Flash. Enterprises can significantly lower the total cost of ownership of applications in a cloud computing model as against the on-premise deployment model. The cloud computing model allows a service provider to leverage a common shared infrastructure across a number of enterprises. Typical billing models that are employed in the cloud paradigm are either subscription based or usage based or a combination of both. The billing models are also tied to strict SLA compliance by the service provider.

It is more important to classify cloud deployment models, which are typically organized as Public Cloud, Hybrid Cloud, Private Cloud, and Community Cloud

Public Cloud: Public cloud (external cloud) deployment model describes cloud computing in the traditional mainstream sense, whereby resources are dynamically provisioned on a fine-grained, self-service basis over the Internet, via web applications/web services, from an off-site third-party provider using a fine-grained utility computing basis Ex: Amazon EC2, Windows Azure.

Private Cloud: Private cloud (internal cloud) deployment model details how cloud capabilities are built into the internal IT infrastructure to manage and monitor mission critical applications of enterprises. This model is the perfect choice when enterprises require cloud computing benefits without compromising on data security.

Hybrid Cloud: Hybrid cloud is also called hybrid delivery by major vendors including HP, IBM, Oracle and VMware who offer technology to manage the complex issues concerning performance, security and privacy that results from the mixed delivery methods of IT services. A hybrid storage cloud uses a combination of public and private storage clouds. Hybrid storage clouds are often useful for archiving and backup functions, allowing local data to be replicated to a public cloud.

Community Cloud: A community cloud involves the participation of multiple tenants to share the same infrastructure and realize benefits of cloud computing. This option may offer a higher level of privacy, security and/or policy compliance. In addition it is also economically attractive as the resources (storage, workstations) utilized and shared in the community have already been used to the maximum delivering an attractive return of investment. Ex: Google's "Gov Cloud".

This cloud deployment models will influence the overall cloud platform architecture in various dimensions.

Cloud Platform Architecture

A cloud platform typically consists of a core virtualized infrastructure that provides computing and storage services. It also hosts common services such as provisioning, security, metering, billing and monitoring services. Services for user interface, workflow and multi-tenet database are exposed to the application layer. The cloud platform should also provide an application development platform that allows developers to create, test and deploy applications. Typical cloud platform architecture is depicted in the diagram below:

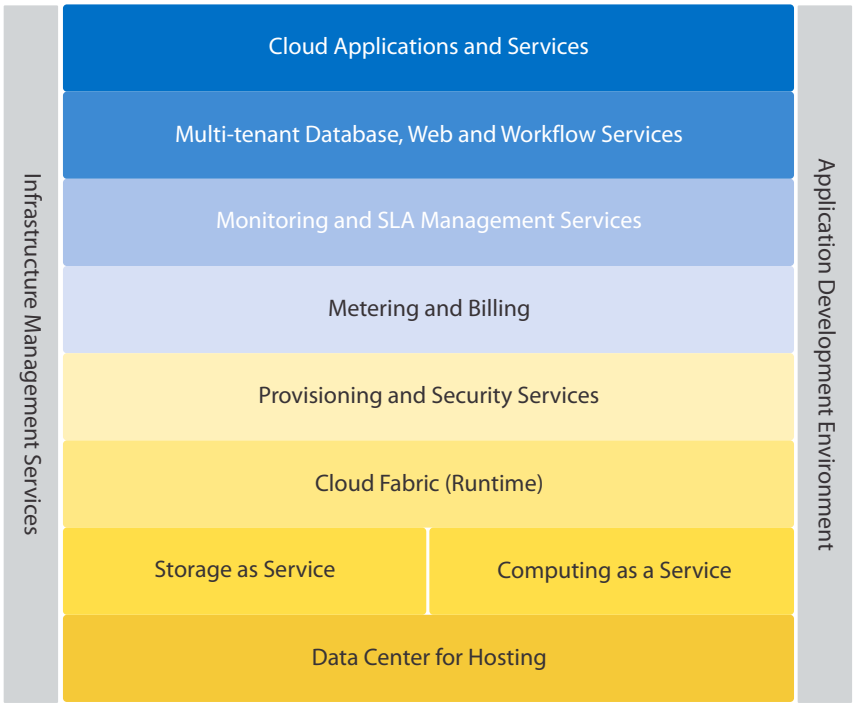

Figure 1: Typical Cloud Platform Architecture

Key attributes that should be supported by a good cloud platform include:

- Identity Federation
- Multi-tenant Data Architecture
- Dynamic UI Branding based on Request Context (relevant to SaaS)
- Customization of Business Rules and Workflow based on Metadata
- Shared Billing Service
- Service Management and monitoring

Cloud Computing Service Delivery Models

Cloud computing service delivery models can be further divided into the following categories:

Software as a Service: Software as a Service (SaaS) vendors help in building custom applications to provide solutions tailored to specific needs by developing services that are hosted in the cloud and can be consumed by the end users. SaaS vendors include Salesforce.com, Zoho, Exchange Server, Microsoft Dynamics CRM Online etc.

Platform as a Service: Platform as a Service (PaaS) vendors provide end-to-end cloud computing platform with capabilities for application design, development, testing, deployment and hosting. Key vendors in the PaaS category include Microsoft (Windows Azure), Google (App Engine) and Salesforce's (Force.com platform).

Infrastructure as a Service: Infrastructure as a Service (IaaS) vendors provide virtualized computing and storage resources in the cloud as a service. Key vendors in IaaS category include Amazon (Elastic Cloud Computing Platform), 3tera (AppLogic Platform), VMWare (vSphere Cloud OS) and Citrix (Cloud Center – C3).

The following figure demonstrates each of the service delivery models and the key players offering these cloud services:

Figure 2: Cloud Computing – Service Delivery Models

The figure below illustrates the relationship between IaaS, Paas and Saas and the associated risks and disadvantages. Ex: Data Security, Network Delays, among others.

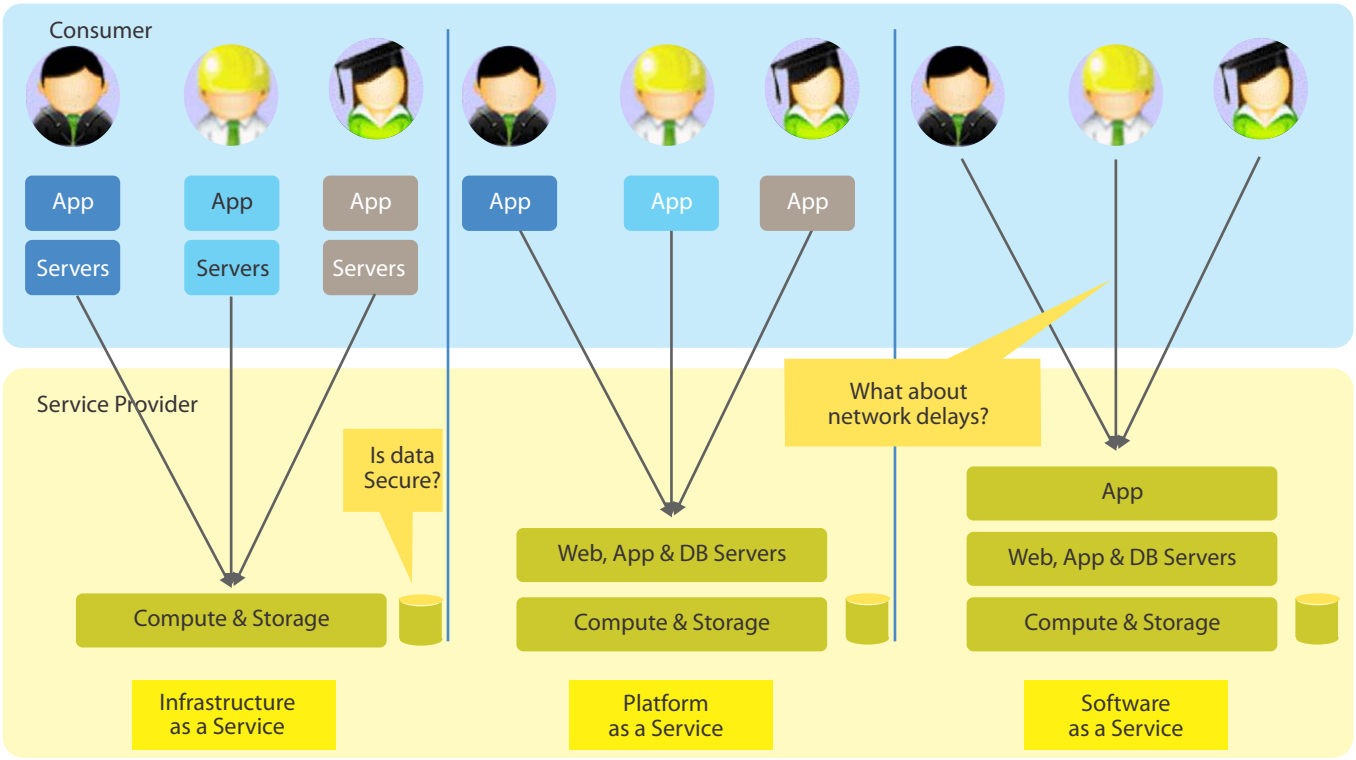

Figure 3: Relationship of IaaS, Paas and SaaS

The key benefits that enterprises can leverage as a result of migrating some of their applications to the cloud:

- Ability to leverage the Opex model as opposed to the Capex model for IT investments.
- Optimized investments in core IT Infrastructure by moving to the private cloud model.
- Ability to achieve higher scalability, availability and performance without upfront infrastructure investments.
- Flexibility to pay as per service usage or subscription based and SLA driven payment models.
- Ability to focus on core business instead of managing large IT infrastructures.

The subsequent sections will focus on Microsoft Windows Azure platform and its components, our experiences and perspectives on Windows Azure and its future roadmap.

Windows Azure Platform Overview

With the advent of the cloud computing platform, we are experiencing a paradigm shift in the development spectrum, where cloud capabilities are also considered when designing and building new applications. The key levers influencing this shift in hosting applications from on-premise to cloud are flexibility, scalability, reduced capital expenses, 24 x 7 availability, geographical access and lower total cost of ownership. However, it is evident that not all applications are ready to be placed in the cloud. Instead seasonal, non-mission critical applications that are not driven by strict compliance or regulatory needs are the most immediate set of applications that can be moved to the cloud.

Microsoft's Windows Azure Platform provides a familiar and flexible environment to drive and support specific needs and services of the development team, customers and users. The Windows Azure platform provides a uniform experience as it enables developers and users to use existing Microsoft technologies to develop or use applications on-premise or in the cloud.

Windows Azure platform comprises the following:

- Windows Azure
- Microsoft SQL Azure
- Windows Azure Platform AppFabric

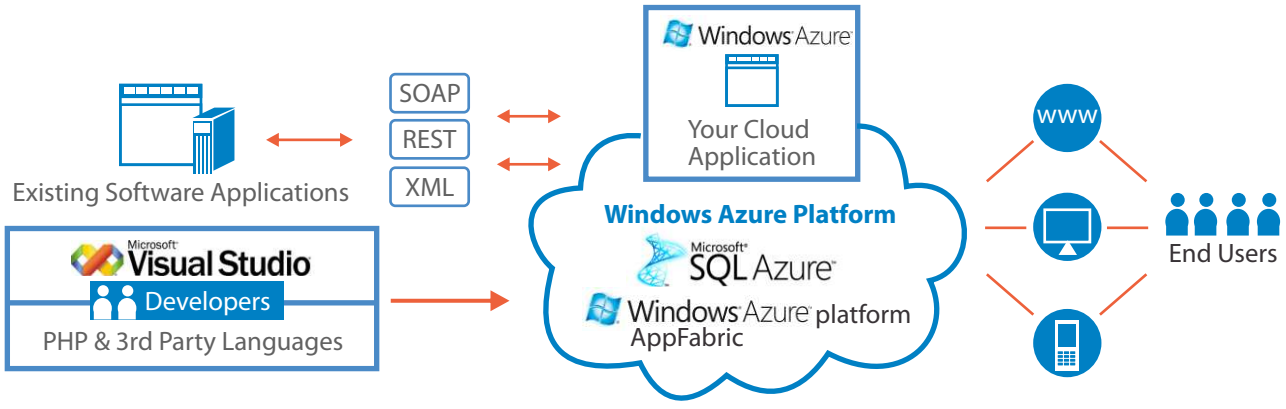

Figure 4: Windows Azure Platform Footprint

In a nutshell, Windows Azure can be defined as a cloud operating system with the ability to host services and manage them centrally. This provides a wide range of capabilities in the form of computing service to run applications, storage services and creating a framework that supports several applications. Windows Azure Platform lays the foundation for running applications and storing data on the cloud. Windows Azure Platform contains computer service, storage service and fabric. Computer service enables applications to run in the cloud; storage service provides storage for content types and the fabric provides a framework to manage and monitor the applications running in cloud.

SQL Azure is a fully relational database support on Windows Azure. Windows Server AppFabric and Windows Azure Platform AppFabric enable the building and management of on-premise applications in the cloud. Windows Server AppFabric incorporates capabilities in the form of caching, workflow and service hosting while Windows Azure Platform AppFabric Services constitutes services bus for connectivity across the network and access control services for federated authorization.

Windows Azure Compute

Windows Azure platform offers runtime execution environment for managed code to host and run scalable solutions. Each Windows Azure Compute instance is also a Virtual Machine (VM) instance created by the platform and only the number of instances is configured by the team hosting the application. Every VM instance runs an Azure agent to connect and interact with the Windows Azure fabric. Every VM has a local file system which can be utilized by the web/worker role instance during their life-time, but once the VM instance is shut down, VM and local storage will go away. Azure maintains 3 different instances of every application on the cloud and the end-user will not be aware of which instance is serving the specific request. Hence persistent storage is required to support the application data and this can be met using the Windows Azure Storage Service. With geographically distributed centers, Windows Azure Compute provides developers with the functionality to build, host and manage applications on the cloud.

Application developers can connect to Windows Azure portal using Windows Live ID and choose a hosting account to host applications on the cloud and a storage account to store data or any relevant content on the cloud. Certain applications can use either the hosting or storage accounts or both. The accounts enable developers to host and deploy applications on the Windows Azure platform. Windows Azure presently supports three roles; web role instance, worker role and VM role.

1. **Web Role** is customized for web application programming and supported by IIS 7.
2. **Worker Role** is used for performing the background process for the web role. Message queue endpoints are, in general, configured in the worker role to generate programs in an asynchronous mode.
3. **VM Role** runs an image (a VHD) of a Windows Server 2008 R2 virtual machine. This VHD is created using on-premises Windows Server machine, then uploaded to Windows Azure. Customers can configure and maintain the OS and use Windows Services, scheduled tasks etc. in the VM role. Once it's stored in the cloud, the VHD can be loaded on-demand into a VM role and executed. The VHD can be used as the base image for all instances of a VM Role.

Windows Azure compute instances have four unique sizes to enable complex applications and workloads as described in the following table. This enables enterprises/users to choose the appropriate Virtual Machine size to run their applications based on the application complexity and resource requirements.

Compute Instance Size	CPU	Memory	Instance Storage	I/O Performance
Extra Small	1.0 GHz	768 MB	20 GB	Low
Small	1.6 GHz	1.75 GB	225 GB	Moderate
Medium	2x1.6 GHz	3.5 GB	490 GB	High
Large	4x1.6 GHz	7 GB	1,000 GB	High
Extra Large	8.1.6 GHz	14 GB	2,040 GB	High

Windows Azure Compute Instances can support native code execution and applications running on the .NET framework, PHP, Java, Apache TOMCAT, MySQL. However, future expansion of Windows Azure will enable support of multiple languages and frameworks, such as, Ruby on Rails, Python and so on. Further, applications deployed can use Web and Worker Role instances together for the user load. Multiple Web and Worker role instances can be configured using the service configuration file.

One point to remember is that Windows Azure further provides a capability to retain the VMs where any crash leads to debugging and reusing the storage state to investigate the causes of the crash.

Windows Azure Storage

Windows Azure provides three types of storage in the cloud as defined in figure 5 above:

- **Azure Blob** provides storage for large binary objects such as video and images.
- **Azure Table** provides structured storage for maintaining service state.
- **Azure Queue** helps in sending asynchronous work request dispatch to enable communication.
- **Azure XDrive** helps in storing the data in a durable drive in the cloud.

Blob: Blob is a set of blocks which can store text or binary data. A block blob is optimized for streaming workloads up to 200GB in size and page blobs are used for random read/write access of 1TB.

Table: Tables are another storage representation on cloud where data is stored in the form of entities and properties. Tables enable data storage across machines and enables scale-out storage. Tables can be consumed using REST APIs. This provides the ability to store huge volume of entities in tables that scale into terabytes.

Queues: Queue helps in storing messages that may be accessed by a client. A queue's prime function is to enable communication between Web and Worker Role instances. Web Role instances can place user requests which need to be processed in the background while the Worker Role monitors the queue to process the request and respond back via the same queue or any other queue to the Web Role instance.

Windows Azure XDrive: XDrive allows Windows Azure to compute applications running in the cloud and use the NTFS APIs to store data in a durable drive. This drive allows Windows Azure applications to mount a

page blob, which is a single volume NTFS VHD. All areas in the application can be integrated with the blob, and reads come out of the local VM cache or the page blob if there is a cache miss. This allows applications to upload/download VHDs via blobs, and the VHD remains durable and able to survive the failure of the VM, since it is backed by a paged blob.

The entire storage areas can be accessed using REST APIs or HTTP standard calls as blobs, tables and queues are represented using URIs. Irrespective of the storage types – data in blobs, tables and queue get replicated a minimum of 3 times within the Windows Azure storage across the virtual machines to ensure there is NO data loss. This also equips the self-heal capacity to recover the data and handle fault-tolerant situations and increase availability under extreme conditions as well. This data replication is possible via the association of VM agents with the Windows Azure fabric, which manages and monitors the applications on Windows Azure platform.

Windows Azure Fabric

One of the key features of the Windows Azure is to provide highly scalable solutions to support large volumes of simultaneous users accessing many different applications hosted on the platform. This capability is handled by providing a scale-out feature within the platform to manage a sudden increase in the volume of users accessing the system. The fabric controller manages and controls the Windows Azure Fabric and is responsible for automating the load balancing to ensure the required scalability is achieved. Windows Azure Fabric has parallel virtual machines running the image of the applications utilizing a Hyper-V, which is a fine-tuned version specific to Windows Azure. The following figure displays the Windows Azure Fabric.

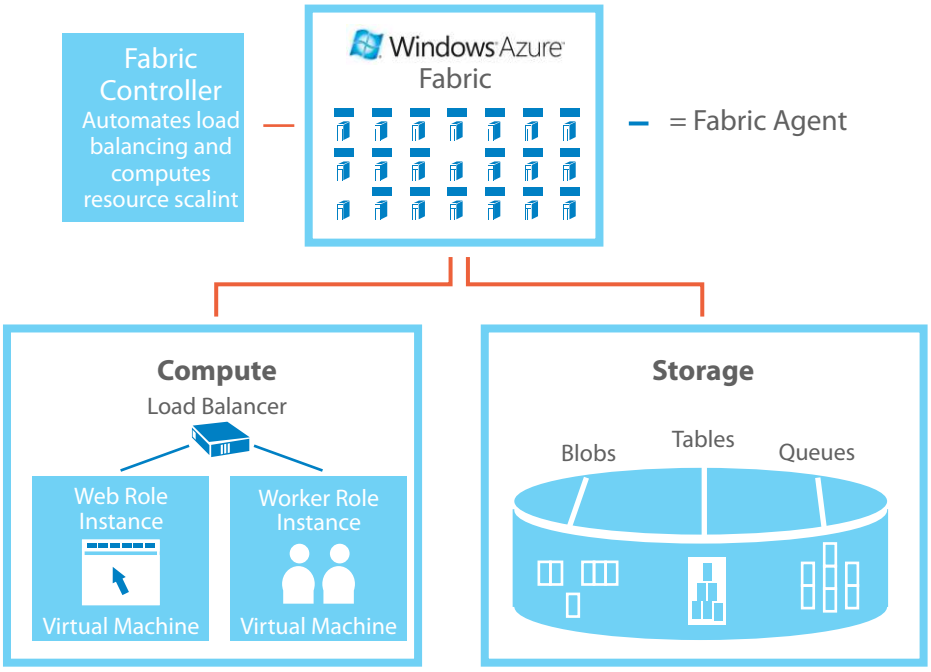

Figure 5: Windows Azure Fabric

Fabric controller utilizes the visibility of the configuration file indicating deployment requirements, such as, storage issues, number of Web and Worker Role instances and so on. The fabric controller is notified if a machine fails and configures a new virtual machine with the same configuration and adds it to the Windows Azure Fabric to serve the needs immediately. This ensures service availability without seriously impacting the end-user.

Multiple deployment topology configurations can be customized using the inter-role communication feature of Windows Azure which has the capability to communicate between individual role instances in the user application. This supports complex topology configuration within Windows Azure as it is better supports message infrastructure and mapping.

So far we have covered the core services of Windows Azure platform dealing mainly with structured and relational data. Windows Azure provides the same through SQL Azure – which will be highlighted subsequently.

SQL Azure

One of the key attributes of any application within the enterprise, over web, is data. As time passes, data grows immensely attributed to different sources, different devices and different systems. To address the growing size and scale of the data – we need a solution which can address the primary data challenges associated to manageability, scalability and availability.

SQL Azure is the cloud-based technology solution to deal with relational and other types of data as part of Windows Azure platform. It contains two primary parts i. SQL Azure Database and ii. SQL Azure Data Sync.

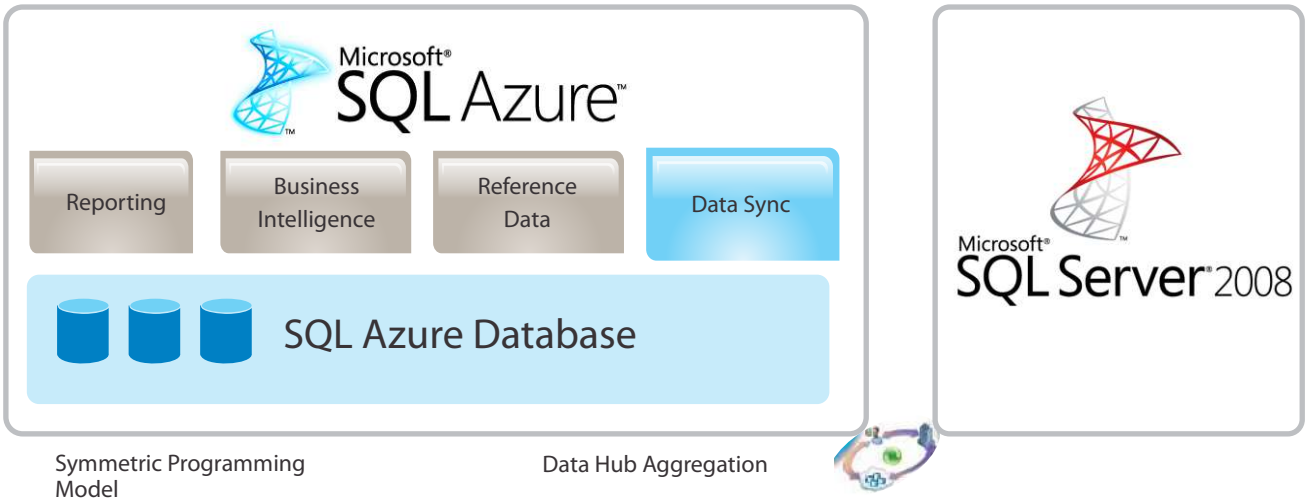

Figure 6: SQL Azure Snapshot

SQL Azure database addresses few key areas of concern in terms of database administration functions, such as, disaster recovery, replication, backup and others. The data in the SQL Azure database can be accessed by the Tabular Data Stream (TDS) protocol.

The top features of SQL Azure include:

1. Relational Database Management Services

a. Create, access, manipulate tables, indexes, views, roles, stored procedures, triggers and functions.

b. Execution of complex queries and joins across multiple tables

c. Constraints

d. Transactions

e. Temp tables

f. Basic aggregation functions Ex: String aggregations, math, date/ time

g. Support for tracking billable metrics in real-time and for historical analysis

2. Programmability

a. Managed ADO.Net data access

b. Native ODBC

c. Support for PHP

3. Tools

a. SQL Azure Account portal – to provision logical servers and databases

b. SQL Server Management studio – an integrated environment to configure and access the databases on cloud

c. Visual Studio 2010 – Supports building applications with data connections to SQL Azure to design queries and perform data binding operations in their applications.

SQL Azure Data Sync

SQL Azure Data Sync is another important feature of SQL Azure which aims to provide bidirectional data synchronization functionality based on the Microsoft Sync Framework enabling symmetry between SQL Azure and on-premise SQL Server. SQL Azure Data Sync allows linking on-premise database to SQL Azure Database, seamlessly moving or synchronizing the applications from on-premise to cloud and ability to provide the offline capabilities on the database where SQL Azure data sync can synchronize the data from on-premise and remote sources.

The goal of SQL Azure is to provide anytime and anywhere access of data by means of SOAP and REST interfaces – so data can be accessed in multiple ways. You can use the SQL Azure by creating a storage account in the Windows Azure platform account. Each Windows Azure platform account can host multiple SQL Azure storage servers and each storage server can include multiple databases. By default each database server uses the Master database.

SQL Azure has the following features:

1. No code sync configuration: Can be easily configured
2. Schedule Sync : Ability to configure the interval for synchronization
3. Conflict Handling: Ability to handle the same data changed in multiple locations
4. Logging and Monitoring: Administration capabilities to monitor and track the potential issues associated with the data
5. Data sub-setting: Provides controllable levers to synchronize data at table level.
6. Elastic-Scale: Service scales as resource requirements grow.
7. SQL Azure has programming ability using the WCF Data services, ODBC and PHP data connectivity channels.
8. SQL Azure supports overall development, deployment and provisioning of databases on the cloud.
9. SQL Azure provides similar authentication and authorization framework as that of SQL Server databases in on-premise systems and using firewall security, which can be configured through Azure Management Portal.
10. WCF Data Services can be exposed as a REST interface for connecting with SQL Azure database in the back end

Another important goal is to improve reuse of the data and share the data across disparate systems. Keeping the purpose in mind, The Open Data Protocol, referred to as OData[7], is a new data-sharing standard that has been introduced to break down silos and foster an interoperate ecosystem for data consumers (clients) and producers (services) that is far more powerful than currently possible. It enables applications to access a broader set of data, and helps every data service and client add value to the whole ecosystem. WCF Data Services was the first Microsoft technology to support the Open Data Protocol in Visual Studio 2008 SP1. It provides developers with client libraries for .NET, Silverlight, AJAX, PHP and Java. Microsoft now also supports OData in SQL Server 2008 R2, Windows Azure Storage, Excel 2010 (through PowerPivot), and SharePoint 2010.

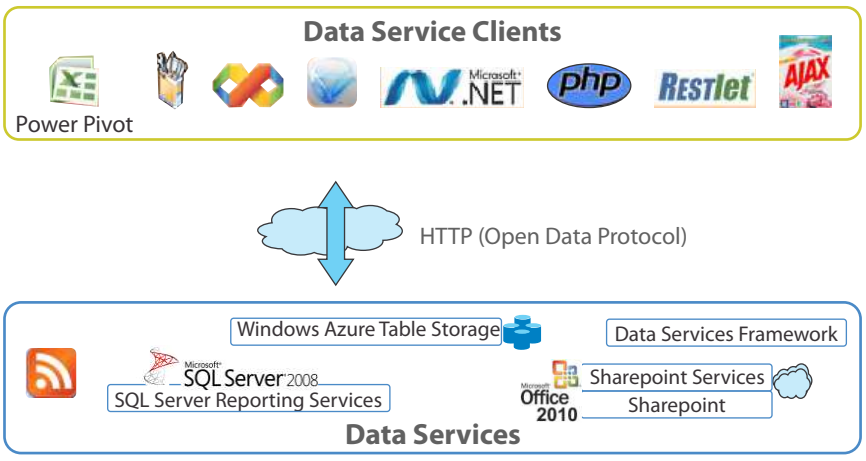

Figure 7: WCF Data Services - Glance

Figure 8 provides the data access architecture of SQL Azure database from applications both within and outside the cloud. To reduce the latency, we can ensure that the applications and SQL Azure database are hosted in the same cloud platform. As a result, the time lag can be significantly reduced between application and data in the database.

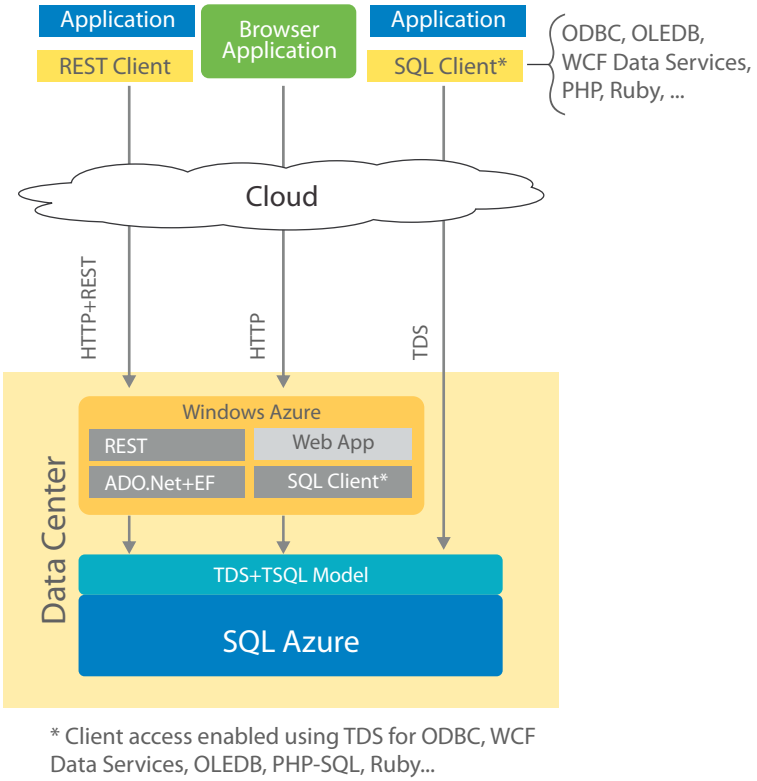

Figure 8: SQL Azure Data Access Architecture

To query this data from the applications hosted outside the cloud can be done through TDS, HTTP or HTTP+REST protocols. Applications hosted in the Windows Azure platform use TDS protocol and the TSQL model to access the data from SQL Azure.

The key benefits with SQL Azure are:

1. Supports multi-tenant.
2. Ease of use – simple provisioning and deployment of multiple databases
3. Built-in high availability and multi-tolerance
4. No physical administration is required
5. Ability to scale up or down based on business needs.
6. Support T-SQL based relational data model
7. Integration with SQL Server and Visual Studio tools for designing and building

Windows Azure Platform AppFabric Services

To build applications on Windows Azure, the Windows Azure platform AppFabric services can be leveraged including the Service Bus and Access Control Services – this helps in connecting applications residing on-premises to the cloud. The AppFabric includes the following:

- Service Bus - Service Bus is used to enable applications and services to communicate across the network and organizational boundaries for both on-premise and cloud applications.
- Access Control - Access Control helps to create highly secure authorization for applications, services and users using an organization's existing infrastructure.

Access Control Services [8] provides a claims-based identity model to support single-sign-on, federated identity and role-based access. This service orchestrates the authentication and authorization of users using Windows Live ID, active directory or any other user identity store to support standard identity federation protocols. Access control services comprise three entities: a Security Token Service (STS), administration portal and administration API. STS issues security tokens, administration portal helps use tokens and defines claim types, rules and authorized STS providers. Administration API is used to program and construct configuration settings. Claim based identity management is the future for managing identities and this is enabled by the access control service of AppFabric. So designing applications to accept identity and perform authorization based on claims will enable the integration of applications deployed in the private cloud with those in the public cloud.

Service Bus represents an enterprise service bus pattern designed to operate on highly scalable data centers working within the scope of the internet. Microsoft service bus provides federated identity and access control mechanisms, a dynamic service registry and a robust messaging fabric capable of overcoming the connectivity challenges. An important component of service bus messaging fabric is a centralized relay service supporting many transport protocols and web service standards (such as. REST, SOAP). The relay service provides different relay connectivity options and helps in negotiating peer to peer connections. Service bus functionality is built on top of the Windows Communication Foundation.

The Service Bus provides a secure, standards-based messaging fabric for connecting applications across the Internet, making it possible to pass through difficult firewall and NAT obstacles when necessary. It offers a new set of WCF bindings without significantly altering the rest of the WCF programming model. A few such bindings include Net Tcp Relay Binding, Net One Way Relay Binding, Net Event Relay Binding and so on. In short, the service bus enables Windows Azure applications with existing applications and databases; it acts like a bridge for on and off-premise applications and also constructs composite applications.

Implementing Windows Azure Applications

Building applications using the Windows Azure platform is not very complicated as developers can write familiar .NET code using Visual studio to build applications, which have the capability to run in the cloud. Developers can completely leverage their existing knowledge of .NET, Workflow Foundation, Windows Communication foundation, SharePoint, Windows Live and SQL Server to build cloud applications. The only difference will be the way applications need to be deployed and hosted (in the cloud) and the execution environment of the applications (on the development fabric or in the cloud fabric).

For building large-scale cloud-based applications on Azure platform, many tools and service offerings can be used and leveraged. For instance, Windows Azure AppFabric services can be used for security and connectivity, SQL Azure for data storage and retrieval from cloud relational data store and other mash-up services can be exploited for enabling data synchronization from services, applications and devices.

The implementation methodology follows the simple practice of modeling the services and decides if either a completely new application needs to be developed or if the application can be composed through other mash-up services or channels. This is to build a new service to support market needs or consume the services which are already available in the marketplace. For a quicker method, the consumption of services can be leveraged through the Windows Azure Marketplace.

Windows Azure Marketplace

Windows Azure Marketplace [9] is an online marketplace for evangelists to contribute, search, purchase and exchange building block components, training, service templates, premium data sets plus finished services and applications needed to build Windows Azure platform applications.

The marketplace contains data and application market sections that include data, imagery, and real-time web services from leading commercial data providers and authoritative public data sources. Customers will have access to datasets such as demographic, environmental, financial, retail, weather and sports. Data market also includes visualizations and analytics to enable insights into data. The application market section of the Windows Azure Marketplace includes listings of building block components, training, services, and finished services/applications. These building blocks are designed to be incorporated by other developers into their Windows Azure platform applications. Other examples include developer tools, administrative tools, components and plugins, and service templates.

Azure Tools

The following table highlights the Windows Azure tools that help develop, test and deploy Azure applications.

Phase	Tools	Description
Development Tools	Visual Studio IDE	Integrated development environment to enable the creation, building, debugging, running and packaging of scalable web applications and services for Windows Azure.
	Development Fabric	Simulates the Windows Azure fabric on your local machine so that you may run and test your service locally before deploying it.
	Development Storage	Utility that simulates the Blob, Queue, and Table Storage services available in the cloud.
Development Project Elements	Cloud Service	The project specifies the Web Role and Worker Role projects and contains the configuration information for the service. It also provides run/debug and the publish functionality.
	Web Role	Web Role produces a web site for Windows Azure, and is the entry point for users to your application. Each cloud service can have zero or one Web Role.
	Worker Role	Worker Role is a background processing component. It does not accept inbound network connections. Each cloud service can have zero or one Worker Role.
	Service Package	Service Package contains your Web Role and/or Worker Role. You can upload this package along with the Service Configuration file to Windows Azure via the Windows Azure Developer Portal.
Management Console	Windows Azure Management Console (Windows Azure AppFabric Services)	The Windows Azure Management Console enables you to construct the claims associated to AppFabric access control service using a user interface.
	Windows Azure Management Console (SQL Services)	To manage storage accounts in Windows Azure and makes it simpler to create, debug and explore the s torage solutions.
Environments	Development Environment	Available in the developer's local machine to build and test the solutions.
	Staging Environment	Windows Azure developer platform provides a GUI to move the application into the cloud from the development environment either by using the hosting account or storage account or both. The URL used to access the application will be based on GUID.
	Production Environment	After completing the application testing on cloud, the application can be moved to the production environment using the same GUI in Windows Azure developer platform. Here the URL is user-friendly and can be mapped to any unique domain specific name.

Table 1: Windows Azure Tools

Key Implementation Challenges

The key challenges encountered in Windows Azure implementation are as follows:

- Identity challenges.
- Storage challenges.
- Communication challenges.

The key aspect associated with the identity challenge is to address the issue of identity federation when on-premise identity providers and applications need to interact with identity providers and applications in the cloud. Windows Azure AppFabric access control service and Geneva framework enables to build claims-based identity management solutions for the applications – this can help build applications that support identity federation.

The storage challenge is to provide scalable data storage for similar applications used by multiple customers/tenants; another challenge is to offer data security measures, to ensure security. This challenge is addressed by the SQL Azure relational database storage using the multiple storage tokens whereby each token can be used by each tenant to store and access their data securely.

Communication challenges revolve around employing an efficient mechanism to transmit and communicate while enabling bulk processing and computing activities. The Azure queue aids asynchronous communication between the Web and Worker Roles necessary to perform certain tasks, with a careful adoption of appropriate relay bindings to achieve optimum performance levels.

Real world Implementation Scenarios

Here are few real world scenarios that can be implemented using Windows Azure:

Scenario 1: An existing .NET based payroll system of ABC Corporation is already deployed in an on-premise private cloud environment that needed to be moved to the public cloud platform. As a result, the application would have to be re-factored for the cloud environment. The design would be based on access control services and claims-based identities. The pay slip generation, which happens once in a month, can be handled by Worker Role based on a trigger controlled by the Web Role instance of the application. These pay-slip formats can be stored in blobs while the metadata associated with it can be stored in the Azure Tables.

Scenario 2: An Education Board in a country conducts different exams for the students. The exams are conducted once in a year and the results are announced after evaluation. The board required that results are made visible to students the very day it is announced. This is a highly seasonal application that could leverage the scale-up and scale-down capabilities to avoid the huge capital expenditure that would be involved considering the limited time frame.

Scenario 3: A retail store chain wants to manage its workforce optimally by scheduling work across all the stores based on region, location and work functions. This solution can be developed using the cloud platform. The entire scheduling activity can be managed by the background Worker Role by applying the relevant store and work function rules. The workforce is thus able to access their schedule and management can alter the rules based on the store demand.

Cloud Adoption Model

An enterprise planning to take the first step towards cloud computing using Windows Azure platform should, in our view, follow a sequential adoption model over time to realize the maximum benefits. The figure below highlights the cloud computing adoption model in an enterprise:

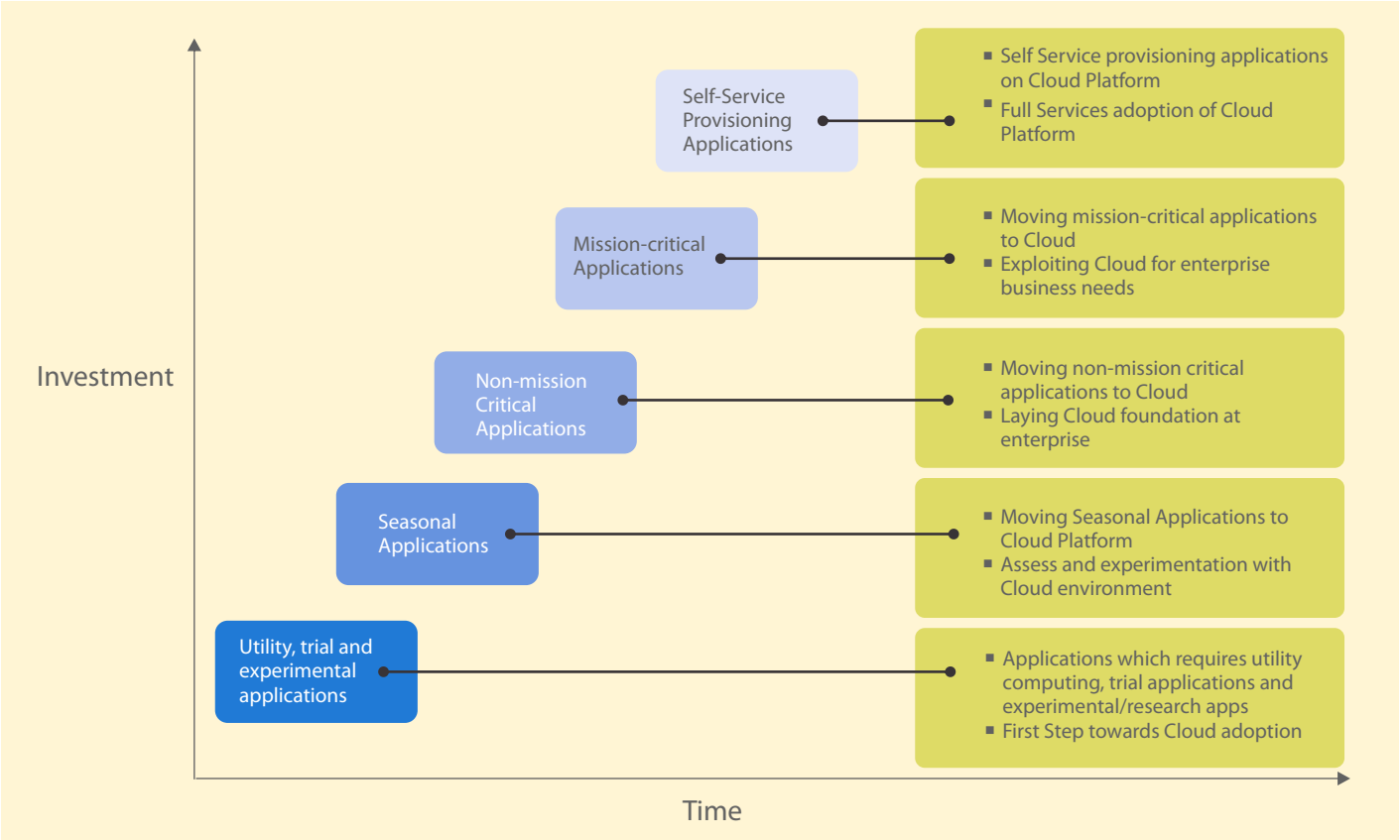

Figure 9: Windows Azure Adoption Model

The first step towards adoption of Windows Azure is to test applications which require utility computing and new applications for the startup and research applications with greater leverage on processing, storage and infrastructure. To reduce the infrastructure cost further – the Windows Azure platform can be utilized for seasonal applications because of the periodic need for computing resources and lack of significant business imperatives to host them on-premise.

Utilizing the Windows Azure platform, enterprises can opt for a pay per use model to optimize capital expenses. The next step is to identify the non-mission critical applications which do not warrant strict SLAs – these applications help in understanding the Windows Azure performance levels, its fault-tolerant and self-healing capabilities and provide the foundation for a future strategy. Once the enterprise feels comfortable taking this approach, mission-critical applications can be moved to the cloud to completely exploit the Windows Azure platform and serve overall enterprise needs and objectives. The final step is to host all future applications with self-service provisioning capabilities in the cloud and build a federated interoperability model with the on-premise applications. This phased adoption model will help enterprises in taking informed decisions and gain a growing confidence and trust in the Windows Azure Platform.

Windows Azure Perspectives and Future Roadmap

This section highlights different Windows Azure perspectives, comparisons and highlights the future roadmap from the customer, organization, management, and architect's perspective. It brings out current concerns and provides the necessary clarifications on the Windows Azure platform, which would enable the key stakeholders to make the right decisions.

Stakeholder	Perspective Areas	Challenge	TCS Viewpoint
Customer/ User	SLA and Speed	How do you guarantee existing performance metrics will be met on cloud when data is moved from on-premise?	SLA's and benchmarks need to be determined and published by the ISV vendors.
Organization	Private Cloud	Is there any support for private instance of Azure cloud for large enterprises?	Next phase of Windows Azure will enable enterprises to build private and hybrid cloud solutions.
Management	Data Compliance	How does Azure support data and regulatory compliance? Any process to certify the platform?	Certain compliance requirements are still not supported, for example, HIPAA.
	Cost	What are the pricing model options provided by Azure?	Pricing model is based on computing power, used storage and consumed bandwidth.
	Tools	What kinds of tools are a vailable to manage VM instances on azure?	System Center Online and Powershell can be leveraged to manage the VM instances.

Stakeholder	Perspective Areas	Challenge	TCS Viewpoint
	Investment Protection	What are the capabilities Azure provides when customer opts out of cloud service? Any data migration support?	Not planned
Architect / Designer	Security	How is data secured in a multi-tenant model?	Claims-based access; data encryption; support for federated identities. Microsoft announced Project Sydney so that Windows Azure can access an on-premise SQL Server location for locating corporate data sources in a secure manner to address security and data regulation issues.
	Design	What are the best practices associated with Azure?	Patterns and practices team is working on it.
	Self-Healing and Backup	How does Azure deal with auto recovery and self-healing?	Data replicated at 3 places – however backup strategies are not disclosed.
	Scalability	What is the model of scalability supported by Azure?	Azure supports scale-out strategy for creating multiple instances of web/worker role.
	Reliability	What is the reliability guaranteed by Azure?	High reliability because of service instance replication.
	Debugging and Diagnostics	What kind of frameworks is available to debug and diagnose issues?	Windows Azure provides extensive logging framework and Event Tracing for Windows (ETW) to diagnose the Windows Azure application deployment and runtime issues.

Table 2: Perspectives on Azure

The following table provides a comparison chart of Azure with other cloud computing platforms [4] and on-premise hosting versus cloud hosting.

Feature	Amazon EC2	Google AppEngine	Microsoft Azure
Cloud Service Areas	Infrastructure as a service	Platform as a service	Platform as a service
Compute Capability	64-bit platform, with four virtual core 2 EC2 compute units – supports multiple operating systems	Not disclosed	Comes with multiple configurations with different VM instances capacity.
Storage Engine	Supports SimpleDB and a simple storage service	No storage – as Google APIs can connect with any open store	SQL Azure Storage: Table, Blobs and Queues SQL Azure Database SQL Azure Data Sync
Platform Services	Not available	Google Services	Windows Azure AppFabric Services Ex: Service Bus and Access Control
Programming Language Support	Supports multiple open source languages and Java, Oracle and .Net	Python and Django	.Net Languages, Java, Apache Tomcat, Ruby, PHP, C, C++, MySQL Support for native languages and full-trust execution
Asynchronous Communication	Simple Queue Service	Not supported	Queues in Windows Azure Storage
Development Tools	Not applicable – only provides virtual machines to create images of the server platform	Does provide editing, simulation and deployment tools.	Visual Studio is one of the IDE used for developing cloud-based projects using Microsoft technologies and other supporting languages.

Table 3: Azure Comparison Chart

All the three platforms have datacenter hosting capabilities and can manage the spikes in load with pre-defined load-balancing capabilities. An overall perspective reveals that Windows Azure offers the platform support to develop cloud applications in a simplified manner. However it needs to address security, hybrid cloud support, private cloud support, on-premise transfer, legal obligations, socio-economic policies, governing policies from different stakeholders' perspective before it is globally accepted. Productivity gains can be realized by leveraging the existing development capabilities on .NET platform and expanding it.

Conclusion

The cloud computing model is evolving fast as a technology wave that will unleash disruptive forces in the market place by providing alternate service delivery models to the enterprises. TCS is very much part of this wave, realizing the potential of this new trend by building significant competencies on the Windows Azure platform to help our customers realize the benefits of cloud computing. Microsoft's Windows Azure platform with its infrastructure and platforms services will support and drive the development culture shift from on-premise application developers to cloud developers. The Windows Azure platform can gain maturity by addressing the concerns associated with each stakeholder and helping them realize its business value. We believe that Windows Azure platform has a bright future and will go a long way to help realize the power of cloud computing because ***Potential Lives Here.***

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