Key characteristics of cloud applications
Although many legacy and enterprise applications can run in the cloud, only applications that are designed specifically for the cloud can truly capitalise on the benefits offered by cloud platforms. These include accelerated time-to-value, unparalleled elasticity and reduced costs.

This Blueprint explores the features of cloud applications that enable them to deliver these and other benefits, and explains why they’re rarely found in traditional application architectures.
Many applications work in the cloud, but only some are designed for it. This is an important distinction because many organisations are attracted to cloud for the unique benefits it offers compared to traditional managed hosting platforms, including:

- Accelerated time-to-value — resources can be provisioned on demand to remove delays
- Unparalleled elasticity — additional resources can be allocated and released as required
- Reduced costs — environments can be continuously right-sized so that you only pay for the resources you need, when you need them

These benefits are most likely to be realised when organisations run applications that dynamically and automatically control the underlying environment. Otherwise, the size of the cloud environment remains relatively static, which means organisations don’t benefit from cloud’s elasticity, and can’t realise the cost savings associated with releasing cloud resources when they’re not required.

At UKCloud, we tend to divide applications into three broad types:

- Legacy applications. Typically, bespoke applications, often large and monolithic, that have been developed by or for the organisation, and use legacy application architectures such as mainframe, client/server or similar.
- Enterprise applications. Commercial-off-the-shelf (COTS) applications such as SAP, Oracle e-Business Suite, Microsoft SharePoint. These applications are typically designed for traditional physical or virtual environments and, like legacy applications, rely on large servers (scale-up) and complex hardware clusters for high availability.
- Cloud applications. Designed to leverage the agility and elasticity inherent in cloud platforms. They are available both as commercial Software-as-a-Service (SaaS) and bespoke applications, and are commonly developed using modern application frameworks and data services. Unlike legacy and enterprise applications, cloud applications are designed to scale out horizontally and to expect and tolerate component failures.
### Table 1. Legacy, enterprise and cloud applications compared

<table>
<thead>
<tr>
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<th>Legacy applications</th>
<th>Enterprise applications</th>
<th>Cloud applications</th>
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<tbody>
<tr>
<td><strong>Type</strong></td>
<td>Bespoke</td>
<td>Commercial-off-the-shelf (COTS)</td>
<td>Bespoke or Software-as-a-Service (SaaS)</td>
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<tr>
<td><strong>Infrastructure</strong></td>
<td>Mainframe</td>
<td>Intel x86/x64 — virtual and physical</td>
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<td><strong>Scale</strong></td>
<td>Vertical — fewer, larger servers</td>
<td>Vertical — fewer larger servers</td>
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<td><strong>High availability</strong></td>
<td>Specialist fault-tolerant reliable hardware</td>
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<tr>
<td><strong>Disaster recovery</strong></td>
<td>Active/passive — single site which fails over to recovery site</td>
<td>Active/passive — single site which fails over to recovery site</td>
<td>Active/active — multiple sites in use at all times</td>
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<tr>
<td><strong>Security</strong></td>
<td>Secure physical environments and restricted mobility</td>
<td>Secure physical environments and restricted mobility</td>
<td>Secure data assets embracing mobile end-user devices</td>
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</tbody>
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So it is easy to see that although legacy and enterprise applications can run in the cloud, only cloud applications can capitalise on the unique benefits of cloud platforms.

This Blueprint explores the features of cloud applications that provide the levels of availability, security and elasticity that are rarely found in traditional application architectures.
Cloud platforms offer real benefits in terms of improved agility and reduced costs, as long as applications can take advantage of the elastic capabilities provided by the platform. To enable cloud applications to operate securely, resiliently and elastically in the cloud, they need specific architecture characteristics.

**Automated provisioning**

A key characteristic of cloud is the ability for the entire cloud-based solution — including the infrastructure — to be represented as code, so that the process of deploying, testing and releasing software can be fully integrated.

Cloud applications should therefore be developed using tools such as continuous integration and continuous deployment (eg Jenkins, Chef, Ansible), and automated testing (eg Cucumber). These tools commonly provide native support for the UKCloud API (based on VMware vCloud Director) and so make it easy to implement an end-to-end continuous integration solution. UKCloud Compute-as-a-Service also supports features such as server templates and fenced clones, which further facilitate the provisioning and testing of cloud applications.

Ideally it should be possible to automatically provision the entire application architecture as required. Because many legacy and enterprise applications require manual provisioning and customisation, it’s very difficult to re-provision them, which places more emphasis on backup and recovery as the applications will need to be restored from backup if problems occur.

Cloud applications, on the other hand, are designed so that they can be quickly and easily re-provisioned to a ‘known good’ state. This is most easily achieved if the entire application stack (application, middleware, operating systems, virtual machines, networks etc) can be automatically provisioned. This is sometimes referred to as ‘infrastructure-as-code’ — meaning that the infrastructure components such as firewalls, networks and virtual machines can be dynamically provisioned and reconfigured via code rather than manually via a GUI or portal.


**USING A CONTINUOUS INTEGRATION TOOL**

A continuous integration tool such as Chef can be used to automatically:

- Pull source code from a central repository such as Git
- Provision virtual machines on the UKCloud Compute-as-a-Service environment
- Deploy the application
- Perform automated integration testing
- Promote the release into production
- Tear down the non-production environment when finished
Resilience and redundancy

When designing a cloud application, it's important to consider how it will handle error conditions. Error conditions can occur for a number of reasons, including:

- Human action — operators might make an error (misconfiguration) or cause a component to become unavailable, eg by taking it offline for maintenance.

- Infrastructure issues — hardware devices, networks and entire sites can fail. Most infrastructure components are deployed in a resilient configuration and recovery times can range from near instantaneous to a number of hours.

- Software issues — software and web services can fail for a variety of reasons ranging from memory leaks and thread-safe issues through to poorly tested changes. As applications increasingly rely on third-party-controlled web services controlled (eg postcode lookups, payment authorisation), organisations cannot assume they will have visibility of all changes and issues which might have a direct or indirect impact on their application.

Organisations should therefore expect failures to occur, and develop their applications to respond gracefully to failure conditions. For example, customers should consider how their application will handle:

- Transient network failures — what if the application client can’t connect to the application server?

- Component unavailability — what if an application component is unavailable? What if the application can’t connect to its database?

- Unexpected configurations — what if the response generated by a component is not as expected? For example, a postcode lookup request to a web service that returns an unexpected value (such as an error code).

Traditionally, legacy applications and enterprise applications differentiate between high availability (keeping the system running when business-as-usual failures occur) and disaster recovery (restoring application service in the event of a catastrophic failure). In the cloud, these two failure conditions can be treated as one, because applications can be designed to expect and tolerate catastrophic failures, such as the loss of a data centre. However, for clarity, the following section describes how organisations can address high availability and disaster recovery concerns with their cloud applications.
**High availability**

When designing a cloud application, organisations need to consider how high availability will be achieved. In traditional infrastructures, specialist hardware is commonly used to provide high degrees of fault tolerance and reliability. As described above, it should be expected that individual components will fail (for example, system failure, misconfiguration, maintenance activity). UKCloud therefore focuses more on resilience than reliability to ensure that the cloud service continues to operate regardless of individual component failures. Cloud applications should be architected to expect failures to occur, including the implementation of sufficient error checking and redundancy to ensure that requests can be serviced by alternative means when required.

For example, when an application accesses a database service, it should:

1. Check that the database service is running
2. Respond gracefully if the primary database service isn't running by, for example:
   - Queuing the request so that it is processed when the database service becomes available again; or
   - Routing the request to a secondary database service, one that is perhaps running on another node, at another site or in another zone, or even on another cloud platform

Whereas legacy and enterprise applications would simply fail if the database service was unavailable, cloud applications can be designed to expect the failure and continue running in one way or another.

**Disaster recovery**

Legacy and enterprise applications typically implement an active/passive solution for disaster recovery: the application runs actively in one data centre and operates in standby in another data centre. The standby service could be anything from a real-time replica of the production service (for example, using synchronous replication) to a cold standby that involves restoring the application from a backup. In the event of a disaster at the primary data centre, the time taken to restore the application service (RTO) could range from seconds to days, and the amount of data potentially lost (RPO) could range from none to several days’ worth.

In the cloud, all sites (or zones) are active and capable of running active workloads: applications use this capability to offer zero downtime and zero data loss. To this end, applications should be designed to expect an entire site to become unavailable, and to gracefully resume operations within the remaining site until the other site becomes available again. This can be achieved using principles such as micro-services and loose coupling (both explained below) to enable the techniques for delivering high availability to be extended to cater for more catastrophic failures.
There are two primary challenges when running an application actively across two sites:

- How users are directed to each of the two sites. This can be solved by using solutions such as global load balancers (such as F5 Networks' Global Traffic Manager), content delivery networks (Akamai) or DNS-based solutions (for example Neustar UltraDNS).

- How data consistency is handled so that transactions can occur at either site. This is often achieved using application-layer replication technologies (for example Replicas, Availability Groups, Dataguard) or application-layer intelligence (for example two-phase commit).

**Micro-services**

Another characteristic of cloud applications is the use of a modular ‘micro-services’ architecture in place of large, complex application systems. The benefits of micro-services revolve around simplicity — each module is simple to develop, deploy, test and consume — and scalability.

Although micro-services are simple to develop, they are often harder to orchestrate than a large, complex application. But although a traditional, monolithic application can initially be easier to orchestrate, it becomes more difficult and inflexible over time owing to the levels of integration and regression testing associated with even minor changes.

The use of micro-services also supports other characteristics of cloud applications such as loose coupling and horizontal scaling.
Loose coupling

Legacy and enterprise applications are typically tightly coupled. This means that if an individual layer of the application stack fails, so does the entire application. For example, an application with a tightly coupled database cannot continue to service requests if the database becomes unavailable; and an application using a thick client cannot operate if connectivity between the client and the server is lost.

Cloud applications should be designed to be loosely coupled so that, wherever possible, application components can continue to operate even if other application components fail or are unavailable. For example, a loosely coupled mobile app will allow the user to benefit from at least some functionality even if there is no network connectivity to the server.

Loose coupling can be achieved using a service-oriented architecture (SOA) in which each component interacts with other components via published interfaces (for example, REST API). Another approach is to implement message queuing. This lets components interact with each other by submitting messages via a message queue which is processed by the first available worker.

Figure 2. Traditional tight coupling

Figure 3. Approaches to loose coupling for cloud applications

Web Services / API architecture

Service Bus / Message Queue architecture
**Horizontal scale**

Unlike legacy and enterprise applications, cloud applications are designed to scale horizontally — or scale out. The architecture calls for many small servers to work in parallel to service the requests — similar to grid computing. This contrasts with vertical scaling where workloads are restricted to a single server which is scaled up by adding resources such as CPU and memory. Horizontal scale provides the benefits of high performance and high availability at an affordable price point thanks to the elastic nature of cloud services. This is what enables customers to pay for large-scale solutions only during peak demand, scaling back when demand subsides to reduce on-going costs.

For cloud applications to dynamically benefit from horizontal scalability, they must be self-aware. They must be able to monitor the health and utilisation of the nodes so that they can orchestrate the underlying platform to add or remove nodes as appropriate — this is commonly referred to as auto-scaling. This feature is relatively easy to implement in the UKCloud Compute-as-a-Service environment, as an application can programmatically provision new virtual machines, reconfigure the virtual load balancer and shut down virtual machines via the UKCloud API.

**Cloud agnosticism**

Whereas legacy and enterprise applications are heavily dependent on the underlying infrastructure (for example, mainframe applications only work on certain mainframe hardware), cloud applications are much more portable across cloud platforms thanks to the inherent abstraction provided by the cloud. This enables applications to exist in virtual containers which are intentionally generic, so that workloads can run on a variety of hardware platforms and cloud service providers.

To prevent lock-in, cloud applications should use standards-based solutions wherever possible. For example, a number of UKCloud customers programmatically control the UKCloud environment via an open source abstraction technology called Fog — [http://fog.io/](http://fog.io/)

Although this Blueprint focuses on Infrastructure-as-a-Service cloud platforms, organisations can achieve significant benefits by designing applications to leverage Platform-as-a-Service (PaaS), such as Cloud Foundry, the most popular Open Source PaaS offering. Cloud Foundry and others can run on a variety of infrastructure solutions including vCloud Director–based IaaS, OpenStack platforms, VMware ESX platforms and Amazon Web Services. Indeed, PaaS makes it easier to run applications across multiple cloud service providers at the same time.
Stateless, shared-nothing architectures

Cloud applications are designed to expect occasional failures, and use a principle of redundancy to ensure multiple nodes can continue processing even if an individual node or an entire site becomes temporarily unavailable. This requires individual nodes to be designed to be stateless, which means that no persistent data is stored within the node. That way, if a node becomes unavailable, it has nothing specific to it which prevents other nodes from continuing processing.

Legacy and enterprise applications might achieve this by using shared storage solutions, in which a single data volume is connected to multiple nodes, so that all nodes have access to the data even if a single node fails. However, this approach brings a number of challenges:

- The shared storage represents a single point of failure — if the data volume should fail or become corrupted, all nodes would fail, too.
- This type of architecture typically requires expensive hardware components and additional software licensing.

It is well documented that shared-nothing architectures deliver superior performance and availability at scale. Many organisations are replacing traditional relational data stores (for example, Microsoft SQL Server, Oracle Database) with NoSQL (Not Only SQL) data stores (for example, MongoDB, Cassandra, Hadoop) as they look to take advantage of the power of cloud platforms.
Scalable object storage

Traditional storage models such as SAN (block storage) and NAS (file storage) aren’t well suited to the scalability, security and availability requirements of cloud applications. That’s why a new storage model — object storage — has emerged which is optimised for cloud applications. It provides a much higher level of autonomy relative to traditional storage models because capacity, security and availability are defined and provided on a per-object, rather than a per-volume, basis.

Most importantly, object storage is inherently loosely coupled as it is controlled and accessed over a REST API. This makes it an ideal target for data such as web assets (including PDFs and videos) and large datasets such as archives and backups.

UKCloud API accessible storage is an object storage solution optimised to work with cloud applications. The solution is secure (suitable for all OFFICIAL data as it is CESG Pan Government Accredited at IL2 and IL3), scalable, and available in both of UKCloud’s UK data centres. The API is well documented, has a number of open source SDKs for most popular languages, and is compatible with the Amazon S3 API, which means it works with existing code, tools and applications that use Amazon S3.

Licensing and open source

When designing applications for the cloud it is important to consider the implications of using commercial software. Most commercial software runs well in the cloud, is supported by the software vendor, and benefits from cloud-friendly licensing schemes. However, some commercial software can’t run in the cloud for one or more of the following reasons:

- Technology issues. Most software runs on standard Intel-compatible x86/x64 systems, as used in the cloud. However, some software requires specific technology such as mainframe, AIX or Solaris SPARC.

- Support issues. Most software vendors are comfortable supporting their software in virtualised and cloud environments, including complex enterprise applications such as SAP and Microsoft. However, some vendors provide limited support in the cloud which could be an important consideration for critical production services.

- Licensing issues. Some software is based on legacy licensing models which are not compatible with the cloud. For example, Oracle typically requires customers to license all physical processors that the application could potentially be run on, which could clearly be an issue in cloud-scale deployments. Other software, for example Microsoft Windows desktop operating systems, may be licensed only to run on physical hardware dedicated to the customer. And some vendors, such as Apple, only license their software to run on their own branded hardware.

Awareness about these restrictions and limitations is driving many organisations to consider open source solutions in preference to commercial solutions. Open source software is typically more flexible in terms of licensing and compatibility. In addition, support is provided within the customer organisation or the wider open source community, rather than by a single commercial organisation. It’s rare to find an open source solution that isn’t supported in cloud and virtualised environments.
Cloud security: defence-in-depth, CESG

Cloud Security Principles

A common argument against cloud applications is the perception that legacy and enterprise applications are more secure. This perception stems from the fact that most legacy and enterprise applications are deployed in private environments inside the customer organisation. The concern is that if applications are hosted externally, the data held in those applications may become less secure.

It’s a perception that has widely been challenged in recent times. The data centres and physical devices used within cloud servers are generally managed with a higher degree of security than organisations can implement internally.

For example, UKCloud’s cloud platform operates from data centre facilities that can achieve both accreditation to host IL5 workloads and List X status. The security of cloud services is further validated through the CESG G-Cloud Pan Government Accreditation Scheme. Under this scheme, UKCloud has achieved accreditation to host both IL2 and IL3 workloads (and IL4 by aggregation).

Additionally, UKCloud has achieved PSN Accreditation to provide services at both ‘PSN Assured service’ (IL2) and ‘PSN Protected service’ (IL3), demonstrating the depth of security implemented within our cloud platform.

CESG has published Cloud Security Principles which provide guidance on to implement security within the cloud. UKCloud has implemented all 14 Cloud Security Principles and can advise its customers on how to operate securely within our assured cloud platforms.
AN EXAMPLE CLOUD APPLICATION ARCHITECTURE

This example involves a citizen-facing application that needs to deliver a highly available and scalable service. Typically, the application will be designed as a three-tier application:

- **Presentation layer** — responsible for handling web requests
- **Application layer** — responsible for processing the web requests and delivering application functionality
- **Data layer** — responsible for storing persistent data assets

Figure 6 shows the example architecture featuring:
- an application running across two independent sites,
- an elastic presentation layer with auto-scaling web servers,
- a loosely coupled application layer,
- and a data layer with a distributed data architecture. Each layer is described in more detail below.

![Figure 6. Schematic of example cloud application architecture](image-url)
**Presentation layer**

The presentation layer is likely to have the largest demand for scalability and elasticity. When idle, the solution can probably run on just one or two web servers. But at peak times the application may need to support millions of users, so the presentation layer will need to scale out to dozens or hundreds of servers.

UKCloud recommends that its customers use relatively small virtual machines for this purpose as it makes more sense to run many, smaller servers rather than fewer, larger ones. VMs without automatic back-ups are easily re-provisioned, rather than recovered from backup.

A load balancer is required to distribute requests across the servers. The one included in the vShield Edge virtual firewall could be used, but there may be more benefit in using a virtual appliance from a specialist such as F5 Networks. That’s because these virtual appliances typically provide additional functionality such as more intelligent load-balancing algorithms, health and utilisation monitoring (to identify when to scale out and scale back), and workflows (to easily add and remove servers from the load-balancing farm).

**Application layer**

This layer provides the functionality of the application. It’s likely there will be various types of application server at this layer. For example, some might provide searching and indexing function, some might provide reporting and analytics function, and others the content management function.

For bespoke application components, it’s worth taking a similar approach to the presentation layer, using smaller servers. For pre-built application components, like Alfresco and Lucene, the applications’ requirements should be followed. Some components may need to scale up — in which case larger servers can be used; while others might need the Automated VM Backup and data replication as required.

If possible the application component should use loose coupling when interfacing with other components, including the data layer. Implementing message queuing, service bus or web services enables this to be achieved in a scalable, highly available and secure manner.
**Data layer**

This is the layer at which the data which drives the application is persistently stored. Traditionally, this is the most secure layer of the application, to maintain the confidentiality, integrity and availability of sensitive data.

The most common traditional data store is a relational database management system (DBMS) such as Microsoft SQL Server, Oracle or DB2. All of them need very powerful, reliable server hardware, and often require expensive licenses to achieve high availability through clustering technology.

UKCloud recommends that its customers consider alternative data stores which are much better suited to modern platforms such as cloud. SQL data stores such as MySQL and PostgreSQL work effectively in the cloud — especially using techniques such as data sharding. However, the real benefit comes from scale-out, shared-nothing data architectures such as NoSQL solutions like MongoDB, Riak, Cassandra, or a distributed data fabric such as Hadoop.

With NoSQL solutions, the servers required to support the application will be similar to the application and presentation layers. The servers are likely to be small-to-medium sized and able to run at the STANDARD service level, as the data stored on them will probably benefit from automated VM backup. Alternatively, customers can use servers running at the BASIC service level, complemented by UKCloud's Storage-as-a-Service environment to store backups of important data.
In this Blueprint we have described the key characteristics of applications which are designed to take advantage of the benefits of cloud. Unlike traditional legacy and enterprise applications, cloud applications are inherently more scalable and highly available; and deliver exceptional agility and cost effectiveness as they respond dynamically to the changing demands placed on them.

UKCloud provides native support for cloud applications as our services include:

- Well documented APIs that enable cloud applications to dynamically provision and reconfigure the cloud platform.
- Multiple sites over 100km apart, connected by secure, low-latency fibre circuits, enabling cloud applications to deliver 100% uptime and zero data loss.
- Choice of security levels — most cloud platforms are available only at lower security levels as they are natively connected to the internet. UKCloud also provides a higher security cloud which is natively connected to government community networks such as PSN.

In addition to our own expertise as a leading G-Cloud provider, UKCloud has over 100 partners who can deliver commercial cloud applications (SaaS) and help you design and develop bespoke cloud applications, such as digital applications.
UKCloud has developed a range of cloud services designed specifically for the UK public sector, to help increase efficiencies, reduce costs, significantly improve procurement times and increase transparency. Our services are easy to adopt, easy to use and easy to leave to ensure that our customers remain in complete control with minimum risk. We were one of the first G-Cloud providers to achieve Pan Government Accreditation (PGA) up to Elevated OFFICIAL, and our services continue to achieve formal UK Government accreditations which make them suitable for all data at OFFICIAL (including OFFICIAL-SENSITIVE).

UKCloud’s full offering consists of:

1. Infrastructure as a Service (IaaS) – seven offerings around Compute and Storage on demand
2. Software as a Service (SaaS) – offerings for email and collaboration as well as secure sync-and-share of files to help teams work effectively in groups, using a variety of devices
3. Platform as a Service (PaaS) – based upon Open Source Digital Application Platform and Hadoop which provides organisations the benefits of using a commodity cloud platform without the added management overheads

All of UKCloud’s UK sovereign cloud computing services are hosted in one (or both) of our highly resilient tier 3 UK data centres in Farnborough and Corsham. UKCloud services are delivered with leading technologies from UKCloud Alliance Partners: QinetiQ, VMware, Cisco, EMC and Ark Data Centres. The Cloud Alliance also provides a collaborative resource which drives innovation and technical product development, helping to continually improve UKCloud’s offering to meet the needs of the UK public sector.

UKCloud is focused on providing cloud services in a more agile, secure and cost effective manner. We strive to deliver solutions that harness technology as a way to facilitate the changes that are needed to streamline processes and reduce costs to support the UK public sector and, ultimately, UK citizens and taxpayers.

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