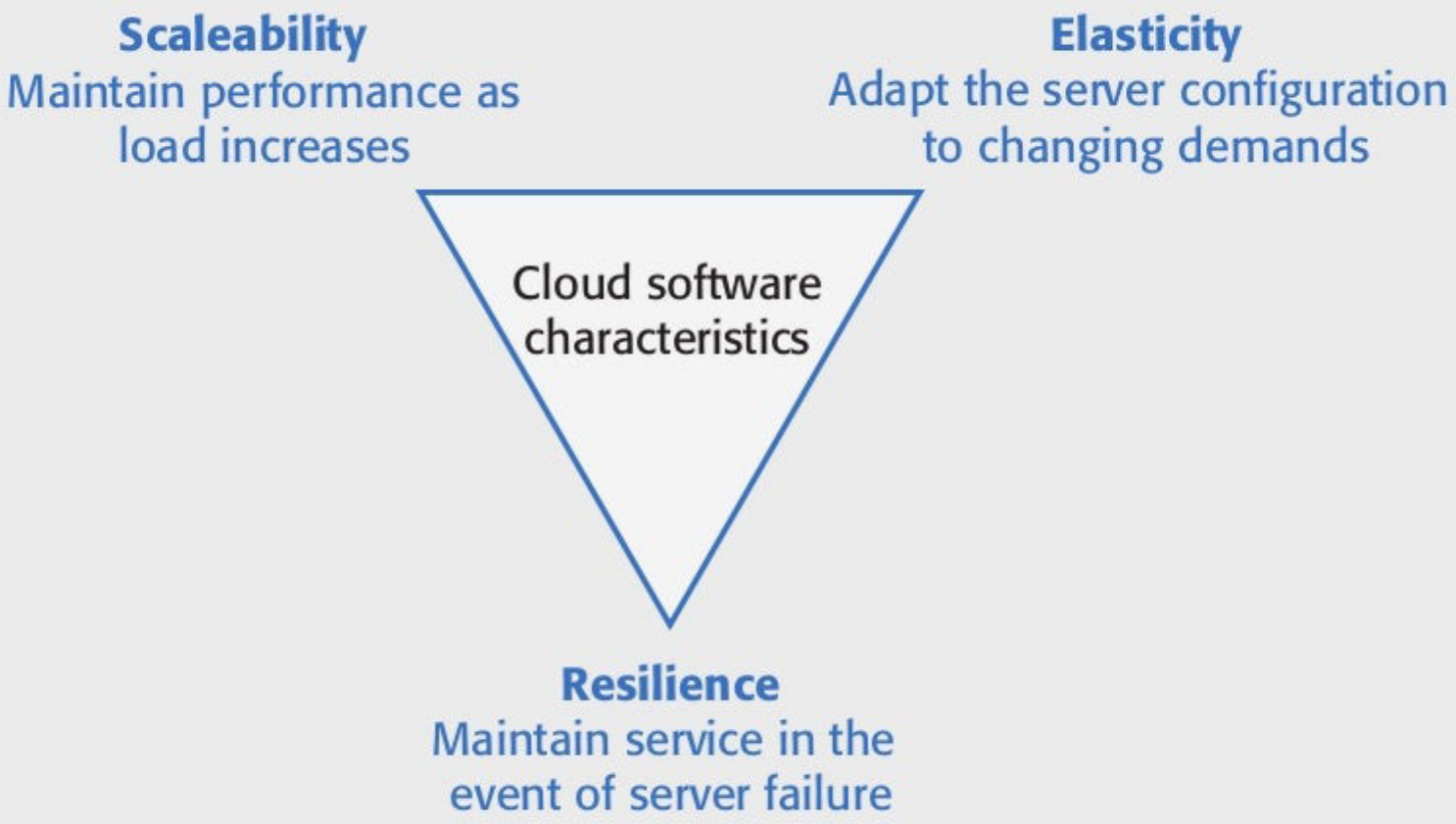
Cloud-based software

The cloud

- The cloud is made up of very large number of remote servers that are offered for rent by companies that own these servers.
  - Cloud-based servers are ‘virtual servers’, which means that they are implemented in software rather than hardware.
- You can rent as many servers as you need, run your software on these servers and make them available to your customers.
  - Your customers can access these servers from their own computers or other networked devices such as a tablet or a TV.
  - Cloud servers can be started up and shut down as demand changes.
- You may rent a server and install your own software, or you may pay for access to software products that are available on the cloud.

Figure 5.1 Scaleability, elasticity and resilience



Scaleability, elasticity and resilience

- Scaleability reflects the ability of your software to cope with increasing numbers of users.
  - As the load on your software increases, your software automatically adapts so that the system performance and response time is maintained.
- Elasticity is related to scaleability but also allows for scaling-down as well as scaling-up.
  - That is, you can monitor the demand on your application and add or remove servers dynamically as the number of users change.
- Resilience means that you can design your software architecture to tolerate server failures.
  - You can make several copies of your software concurrently available. If one of these fails, the others continue to provide a service.

Table 5.1 Benefits of using the cloud for software development

Cost
You avoid the initial capital costs of hardware procurement

Startup time
You don't have to wait for hardware to be delivered before you can start work. Using the cloud, you can have servers up and running in a few minutes.

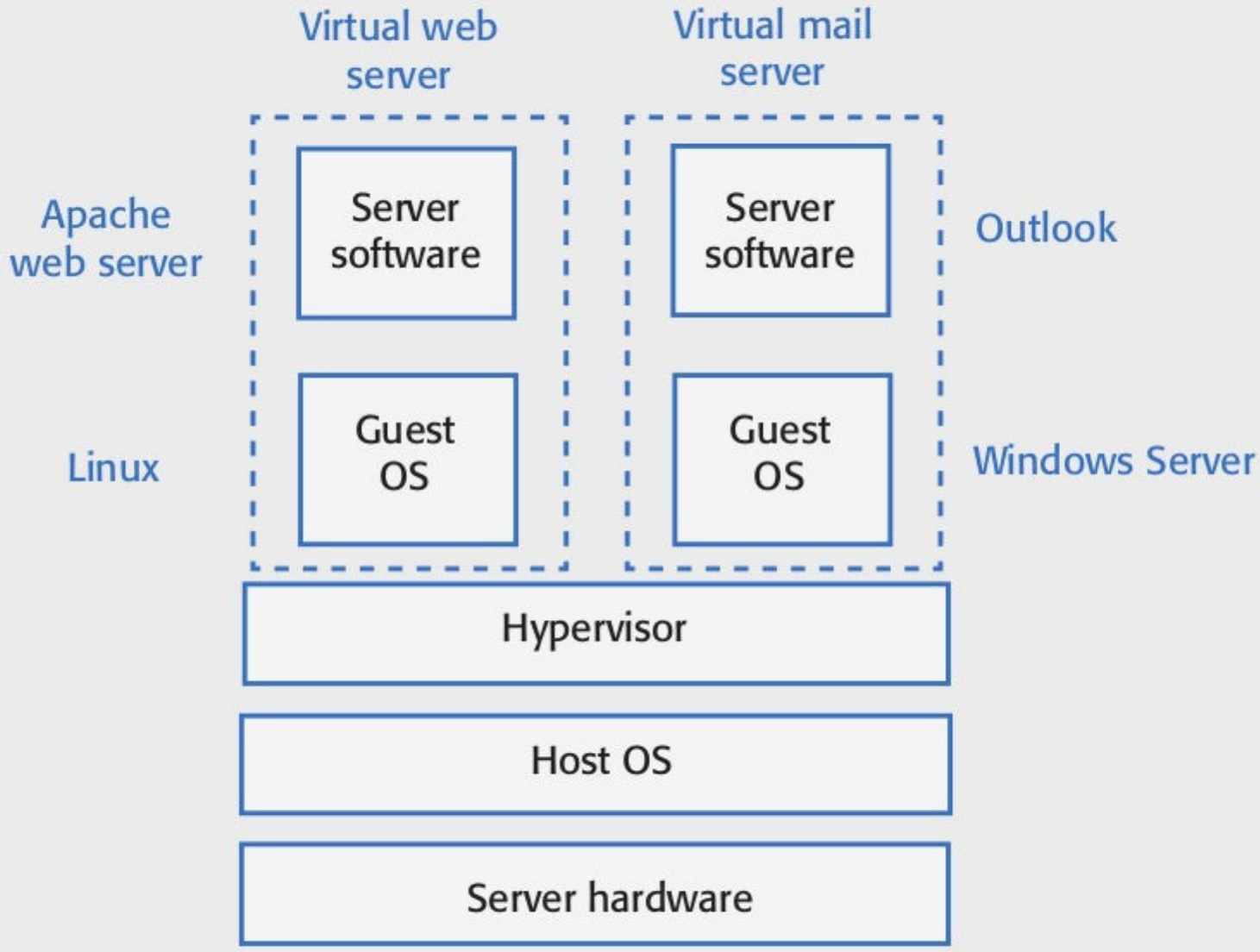
Server choice
If you find that the servers you are renting are not powerful enough, you can upgrade to more powerful systems. You can add servers for short-term requirements, such as load testing.

Distributed development
If you have a distributed development team, working from different locations, all team members have the same development environment and can seamlessly share all information.

Virtual cloud servers

- A virtual server runs on an underlying physical computer and is made up of an operating system plus a set of software packages that provide the server functionality required.
- A virtual server is a stand-alone system that can run on any hardware in the cloud.
  - This 'run anywhere' characteristic is possible because the virtual server has no external dependencies.
- Virtual machines (VMs), running on physical server hardware, can be used to implement virtual servers.
  - A hypervisor provides hardware emulation that simulates the operation of the underlying hardware.
- If you use a virtual machine to implement virtual servers, you have exactly the same hardware platform as a physical server.

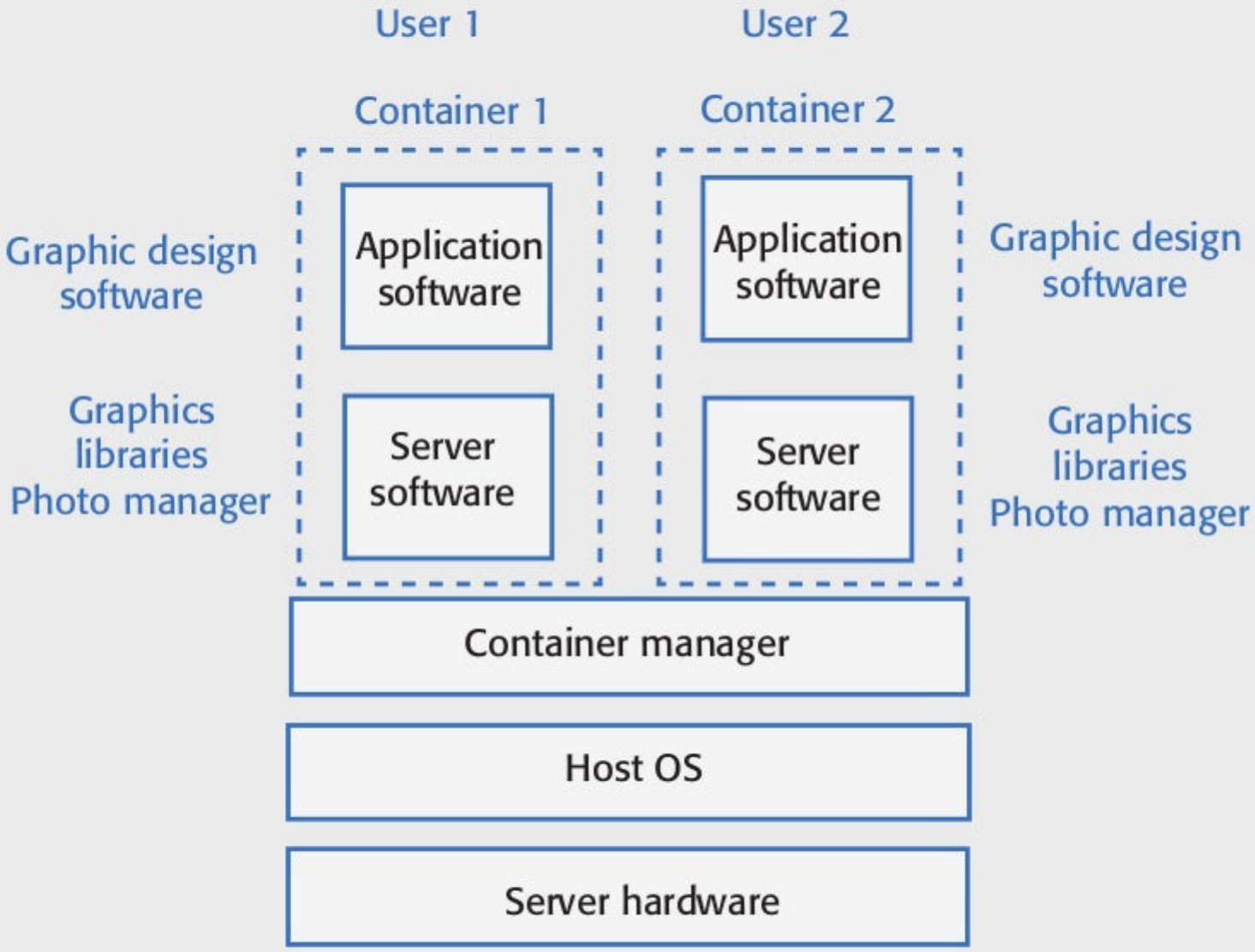
Figure 5.2 Implementing a virtual server as a virtual machine



Container-based virtualization

- If you are running a cloud-based system with many instances of applications or services, these all use the same operating system, you can use a simpler virtualization technology called ‘containers’.
- Using containers accelerates the process of deploying virtual servers on the cloud.
  - Containers are usually megabytes in size whereas VMs are gigabytes.
  - Containers can be started and shut down in a few seconds rather than the few minutes required for a VM.
- Containers are an operating system virtualization technology that allows independent servers to share a single operating system.
  - They are particularly useful for providing isolated application services where each user sees their own version of an application.

Figure 5.3 Using containers to provide isolated services



Docker

- Containers were developed by Google around 2007 but containers became a mainstream technology around 2015.
- An open-source project called Docker provided a standard means of container management that is fast and easy to use.
- Docker is a container management system that allows users to define the software to be included in a container as a Docker image.
- It also includes a run-time system that can create and manage containers using these Docker images.

Figure 5.4 The Docker container system

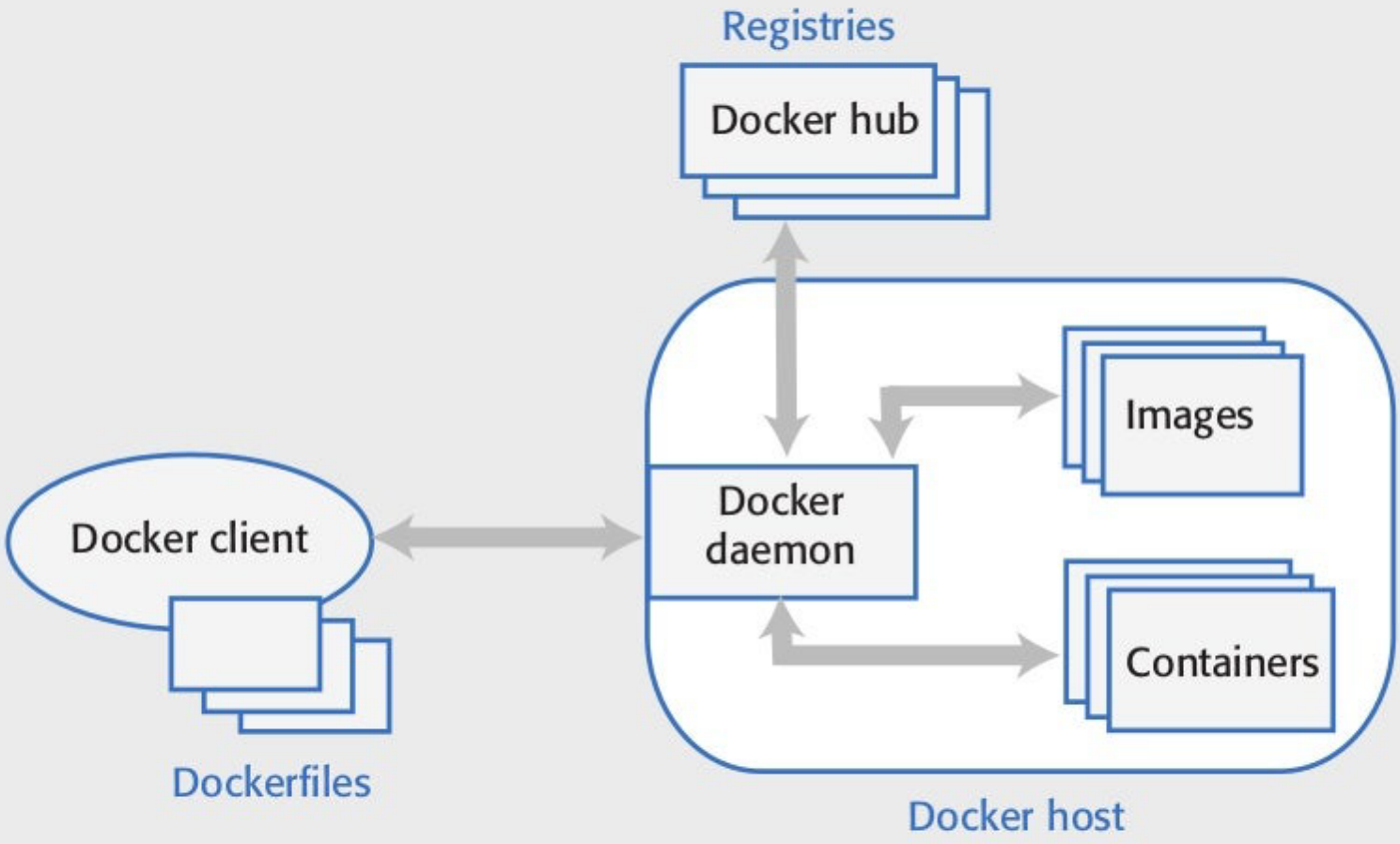


Table 5.2 The elements of the Docker container system

Docker daemon
This is a process that runs on a host server and is used to setup, start, stop, and monitor containers, as well as building and managing local images.

Docker client
This software is used by developers and system managers to define and control containers

Dockerfiles
Dockerfiles define runnable applications (images) as a series of setup commands that specify the software to be included in a container. Each container must be defined by an associated Dockerfile.

Image
A Dockerfile is interpreted to create a Docker image, which is a set of directories with the specified software and data installed in the right places. Images are set up to be runnable Docker applications.

Table 5.2 The elements of the Docker container system

Docker hub
This is a registry of images that has been created. These may be reused to setup containers or as a starting point for defining new images.

Containers
Containers are executing images. An image is loaded into a container and the application defined bby the image starts execution. Containers may be moved from server to server without modification and replicated across many servers. You can make changes to a Docker container (e.g. by modifying files) but you then must commit these changes to create a new image and restart the container.

Docker images

- Docker images are directories that can be archived, shared and run on different Docker hosts. Everything that's needed to run a software system - binaries, libraries, system tools, etc. is included in the directory.
- A Docker image is a base layer, usually taken from the Docker registry, with your own software and data added as a layer on top of this.
  - The layered model means that updating Docker applications is fast and efficient. Each update to the filesystem is a layer on top of the existing system.
  - To change an application, all you have to do is to ship the changes that you have made to its image, often just a small number of files.

Benefits of containers

- They solve the problem of software dependencies. You don't have to worry about the libraries and other software on the application server being different from those on your development server.
  - Instead of shipping your product as stand-alone software, you can ship a container that includes all of the support software that your product needs.
- They provide a mechanism for software portability across different clouds. Docker containers can run on any system or cloud provider where the Docker daemon is available.
- They provide an efficient mechanism for implementing software services and so support the development of service-oriented architectures.
- They simplify the adoption of DevOps. This is an approach to software support where the same team are responsible for both developing and supporting operational software.

Everything as a service

- The idea of a service that is rented rather than owned is fundamental to cloud computing.
- Infrastructure as a service (IaaS)
  - Cloud providers offer different kinds of infrastructure service such as a compute service, a network service and a storage service that you can use to implement virtual servers.
- Platform as a service (PaaS)
  - This is an intermediate level where you use libraries and frameworks provided by the cloud provider to implement your software. These provide access to a range of functions, including SQL and NoSQL databases.
- Software as a service (SaaS)
  - Your software product runs on the cloud and is accessed by users through a web browser or mobile app.

Figure 5.5 Everything as a service

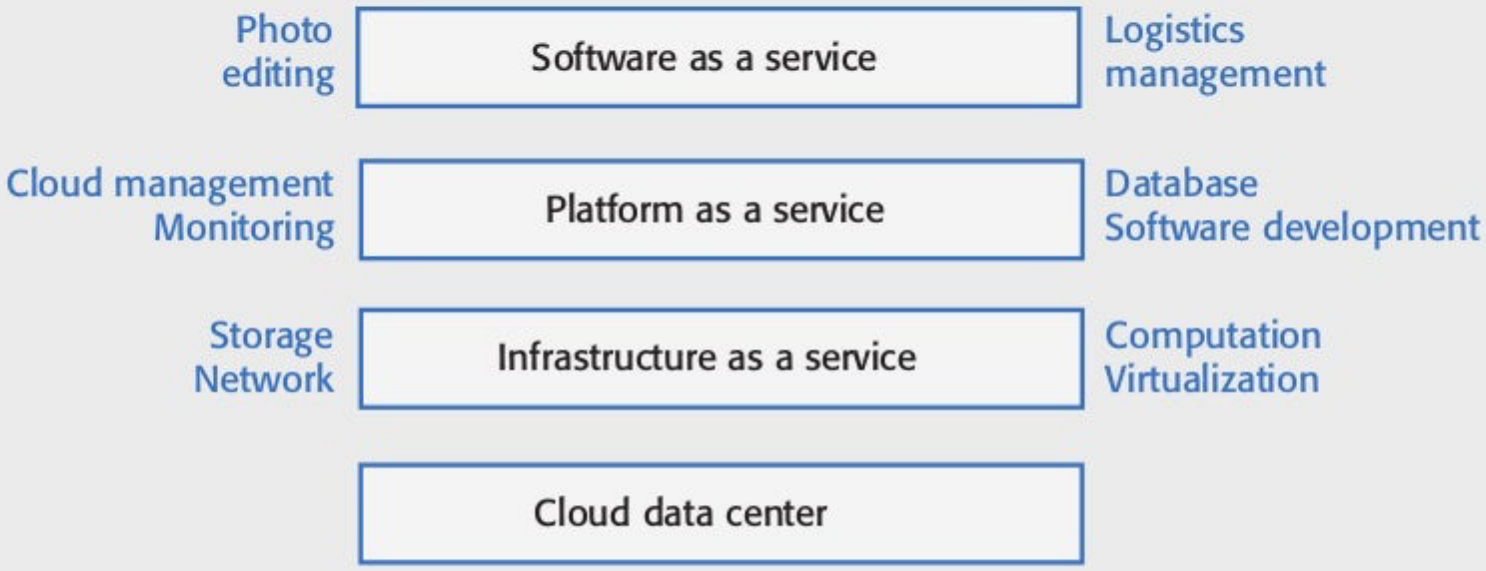
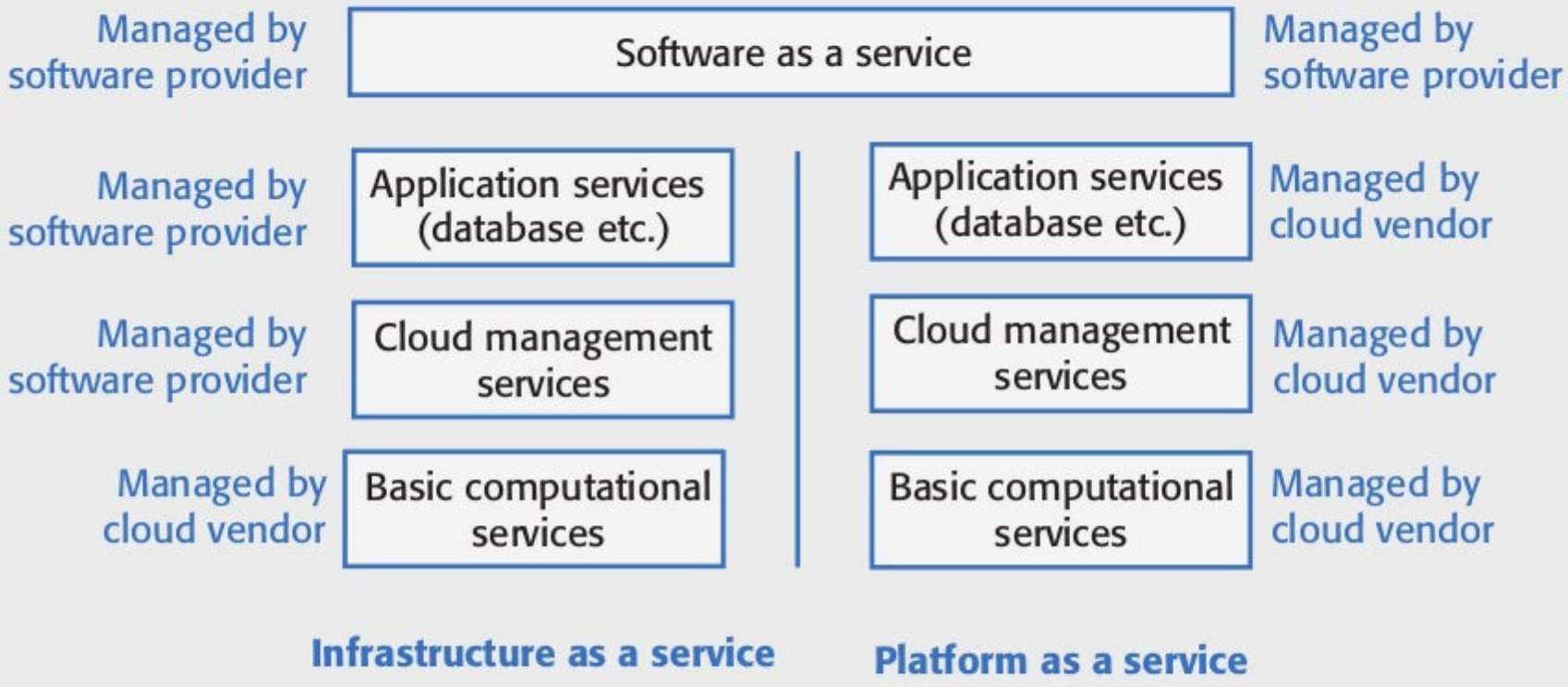


Figure 5.6 Management responsibilities for IaaS and PaaS



Software as a service

- Increasingly, software products are being delivered as a service, rather than installed on the buyer's computers.
- If you deliver your software product as a service, you run the software on your servers, which you may rent from a cloud provider.
- Customers don't have to install software and they access the remote system through a web browser or dedicated mobile app.
- The payment model for software as a service is usually a subscription model.
  - Users pay a monthly fee to use the software rather than buy it outright.

Figure 5.7 Software as a service

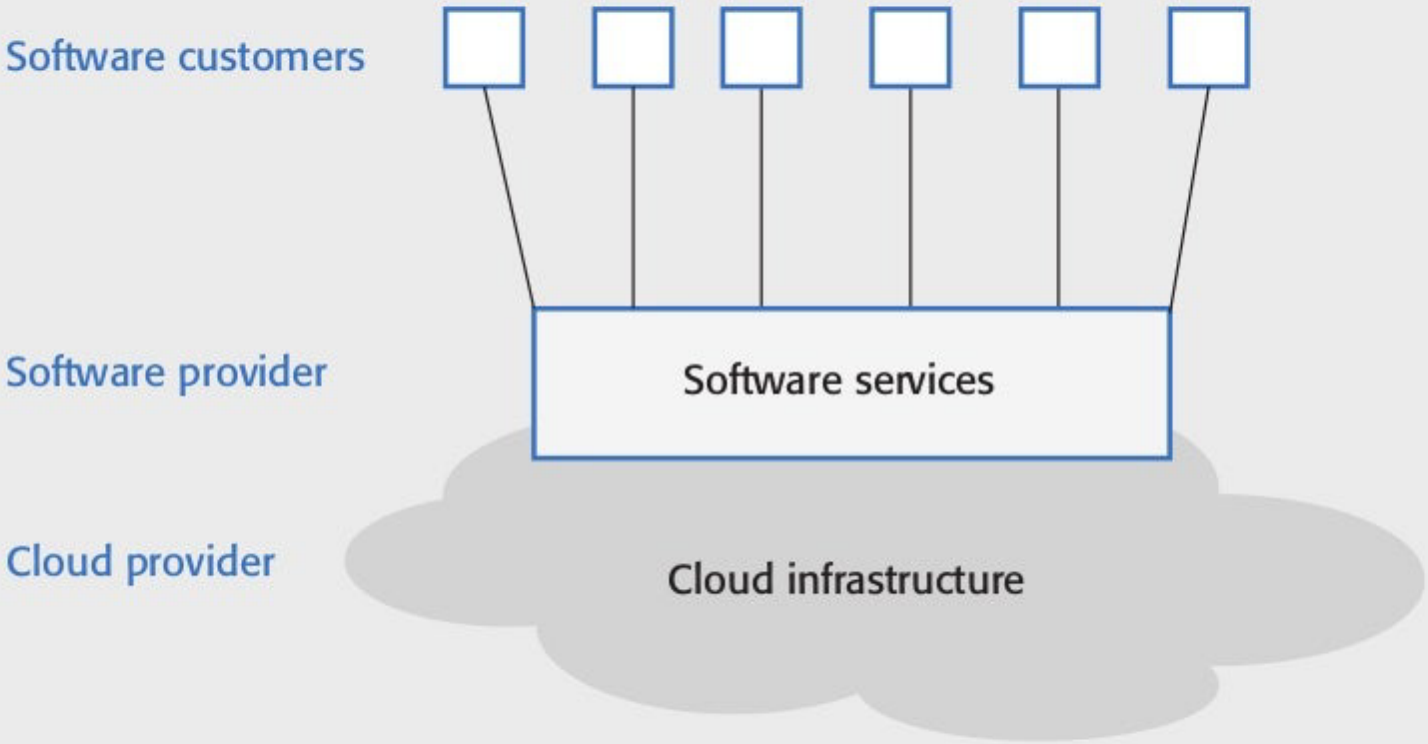


Table 5.3 Benefits of SaaS for software product providers

Cash flow
Customers either pay a regular subscription or pay as they use the software. This means you have a regular cash flow, with payments throughout the year. You don't have a situation where you have a large cash injection when products are purchased but very little income between product releases.

Update management
You are in control of updates to your product and all customers receive the update at the same time. You avoid the issue of several versions being simultaneously used and maintained. This reduces your costs and makes it easier to maintain a consistent software code base.

Continuous deployment
You can deploy new versions of your software as soon as changes have been made and tested. This means you can fix bugs quickly so that your software reliability can continuously improve.

Table 5.3 Benefits of SaaS for software product providers

Payment flexibility
You can have several different payment options so that you can attract a wider range of customers. Small companies or individuals need not be discouraged by having to pay large upfront software costs.

Try before you buy
You can make early free or low-cost versions of the software available quickly with the aim of getting customer feedback on bugs and how the product could be approved.

Data collection
You can easily collect data on how the product is used and so identify areas for improvement. You may also be able to collect customer data that allows you to market other products to these customers.

Figure 5.8 Advantages and disadvantages of SaaS for customers

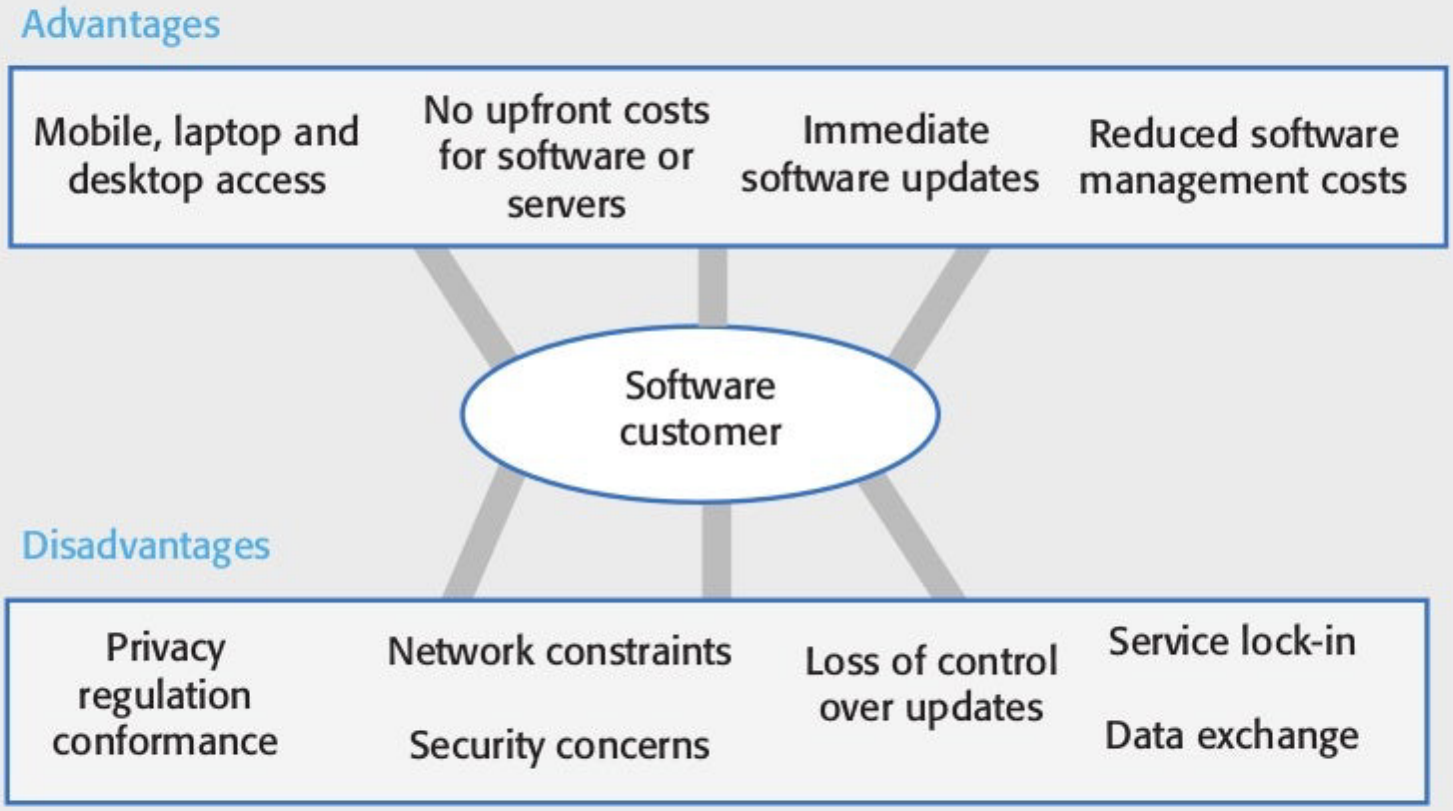


Table 5.4 Data storage and management issues for SaaS

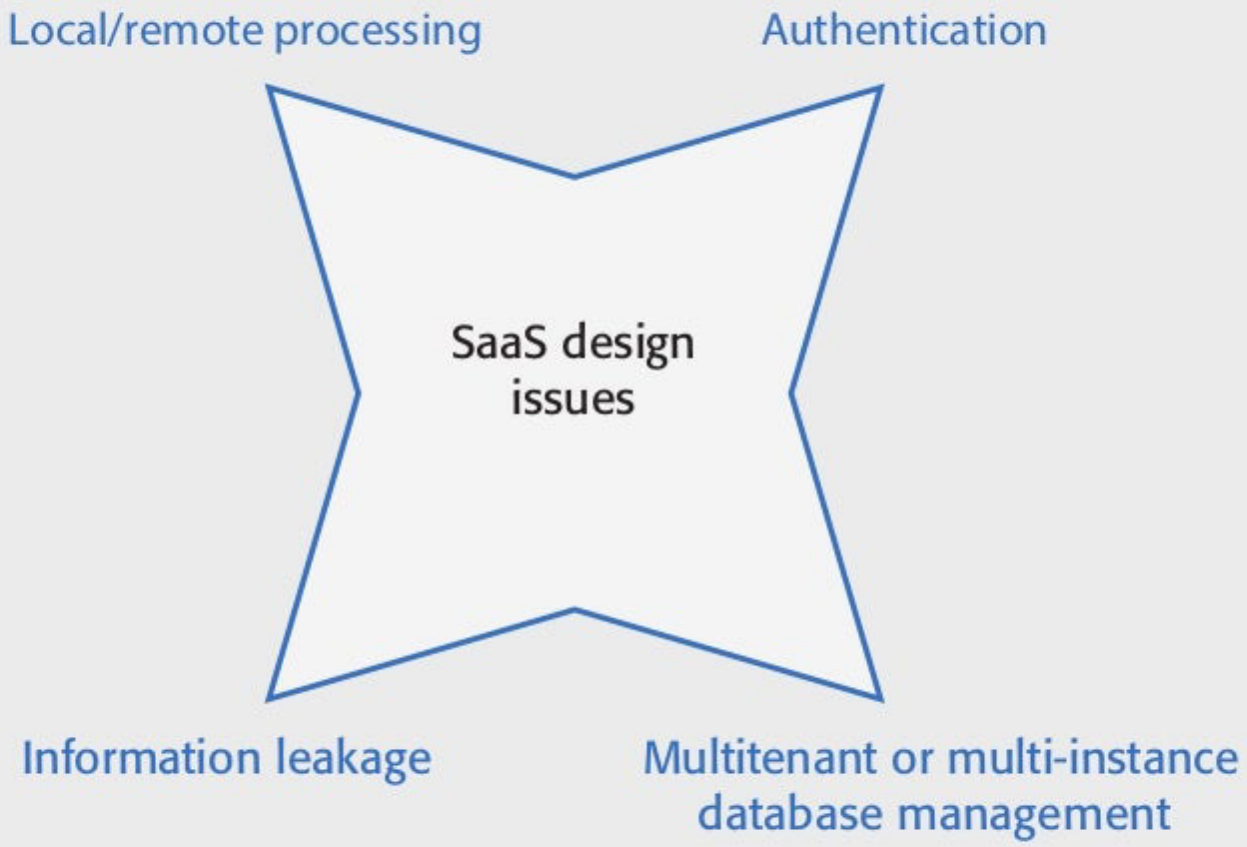
Regulation
Some countries, such as EU countries, have strict laws on the storage of personal information. These may be incompatible with the laws and regulations of the country where the SaaS provider is based. If a SaaS provider cannot guarantee that their storage locations conform to the laws of the customer's country, businesses may be reluctant to use their product.

Data transfer
If software use involves a lot of data transfer, the software response time may be limited by the network speed. This is a problem for individuals and smaller companies who can't afford to pay for very high speed network connections.

Data security
Companies dealing with sensitive information may be unwilling to hand over the control of their data to an external software provider. As we have seen from a number of high profile cases, even large cloud providers have had security breaches. You can't assume that they always provide better security than the customer's own servers.

Data exchange
If you need to exchange data between a cloud service and other services or local software applications, this can be difficult unless the cloud service provides an API that is accessible for external use.

Figure 5.9 Design issues for software delivered as a service



SaaS design issues (1)

- Local/remote processing
  - A software product may be designed so that some features are executed locally in the user's browser or mobile app and some on a remote server.
  - Local execution reduces network traffic and so increases user response speed. This is useful when users have a slow network connection.
  - Local processing increases the electrical power needed to run the system.
- Authentication
  - If you set up your own authentication system, users have to remember another set of authentication credentials.
  - Many systems allow authentication using the user's Google, Facebook or LinkedIn credentials.
  - For business products, you may need to set up a federated authentication system, which delegates authentication to the business where the user works.

SaaS design issues (2)

- Information leakage
  - If you have multiple users from multiple organizations, a security risk is that information leaks from one organization to another.
  - There are a number of different ways that this can happen, so you need to be very careful in designing your security system to avoid this.
- Multi-tenant and multi-instance systems
  - In a multi-tenant system, all customers are served by a single instance of the system and a multitenant database.
- In a multi-instance system, a separate copy of the system and database is made available for each user.

Multi-tenant systems

- A multi-tenant database is partitioned so that customer companies have their own space and can store and access their own data.
  - There is a single database schema, defined by the SaaS provider, that is shared by all of the system's users.
  - Items in the database are tagged with a tenant identifier, representing a company that has stored data in the system. The database access software uses this tenant identifier to provide 'logical isolation', which means that users seem to be working with their own database.

Figure 5.10 An example of a multi-tenant database

Stock management					
Tenant	Key	Item	Stock	Supplier	Ordered
T516	100	Widg 1	27	S13	2017/2/12
T632	100	Obj 1	5	S13	2017/1/11
T973	100	Thing 1	241	S13	2017/2/7
T516	110	Widg 2	14	S13	2017/2/2
T516	120	Widg 3	17	S13	2017/1/24
T973	100	Thing 2	132	S26	2017/2/12

Table 5.5 Advantages of multi-tenant databases

Resource utilization
The SaaS provider has control of all the resources used by the software and can optimize the software to make effective use of these resources.

Security
Multitenant databases have to be designed for security because the data for all customers is held in the same database. They are, therefore, likely to have fewer security vulnerabilities than standard database products. Security management is simplified as there is only a single copy of the database software to be patched if a security vulnerability is discovered.

Update management
It is easier to update a single instance of software rather than multiple instances. Updates are delivered to all customers at the same time so all use the latest version of the software.

Table 5.5 Disadvantages of multi-tenant databases

Inflexibility
Customers must all use the same database schema with limited scope for adapting this schema to individual needs. I explain possible database adaptations later in this section.

Security
As data for all customers is maintained in the same database, then there is a theoretical possibility that data will leak from one customer to another. In fact, there are very few instances of this happening. More seriously, perhaps, if there is a database security breach then it affects all customers.

Complexity
Multitenant systems are usually more complex than multi-instance systems because of the need to manage many users. There is, therefore, an increased likelihood of bugs in the database software.

Table 5.6 Possible customisations for SaaS

Authentication
Businesses may want users to authenticate using their business credentials rather than the account credentials set up by the software provider. I explain, in Chapter 7, how federated authentication makes this possible.

Branding
Businesses may want a user interface that is branded to reflect their own organisation.

Business rules
Businesses may want to be able to define their own business rules and workflows that apply to their own data.

Data schemas
Businesses may want to be able to extend the standard data model used in the system database to meet their own business needs.

Access control
Businesses may want to be able to define their own access control model that sets out the data that specific users or user groups can access and the allowed operations on that data.

Figure 5.11 User profiles for SaaS access

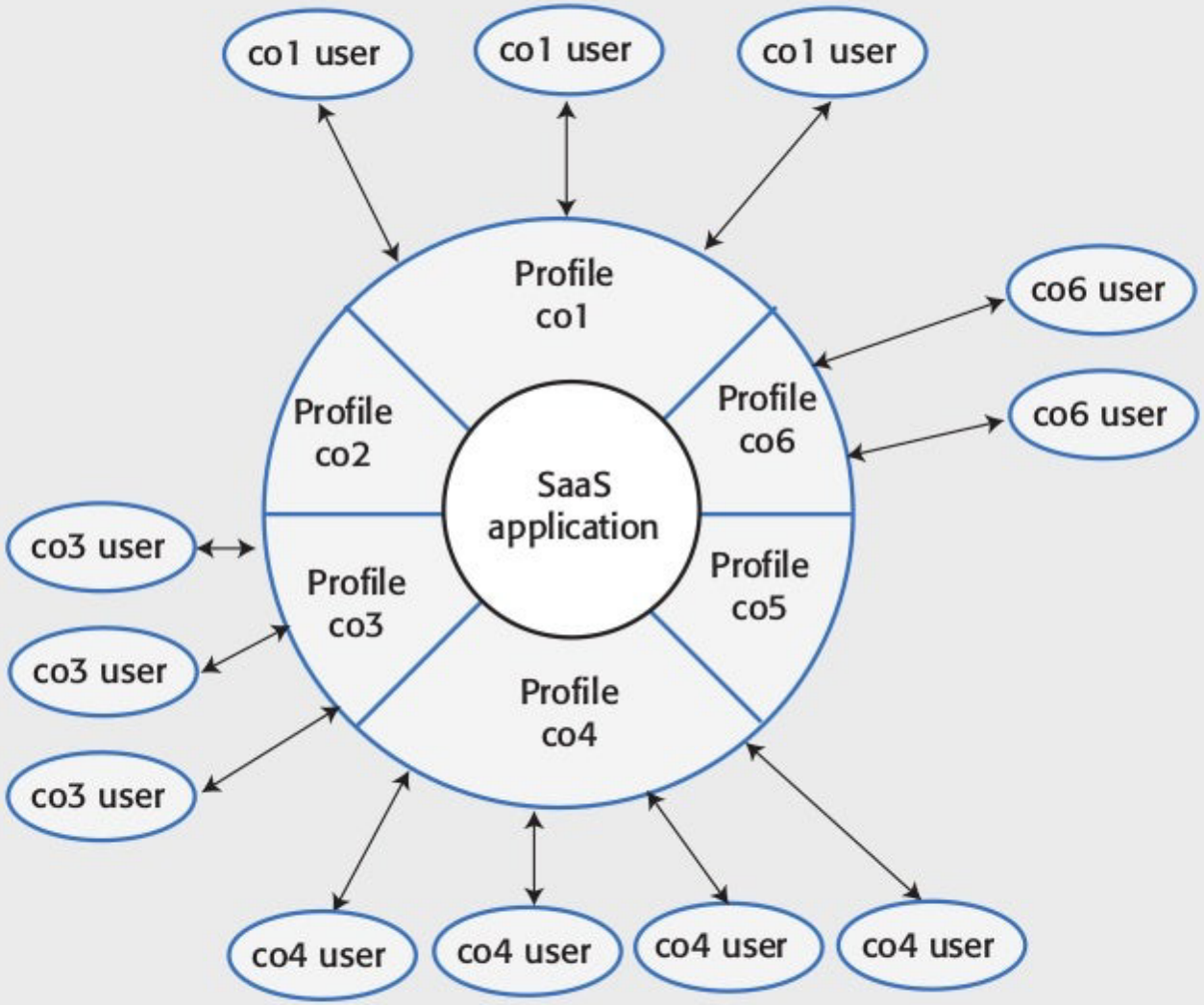


Figure 5.12 Database extensibility using additional fields

Stock management								
Tenant	Key	Item	Stock	Supplier	Ordered	Ext 1	Ext 2	Ext 3
T516	100	Widg 1	27	S13	2017/2/12			
T632	100	Obj 1	5	S13	2017/1/11			
T973	100	Thing 1	241	S13	2017/2/7			
T516	110	Widg 2	14	S13	2017/2/2			
T516	120	Widg 3	17	S13	2017/1/24			
T973	100	Thing 2	132	S26	2017/2/12			

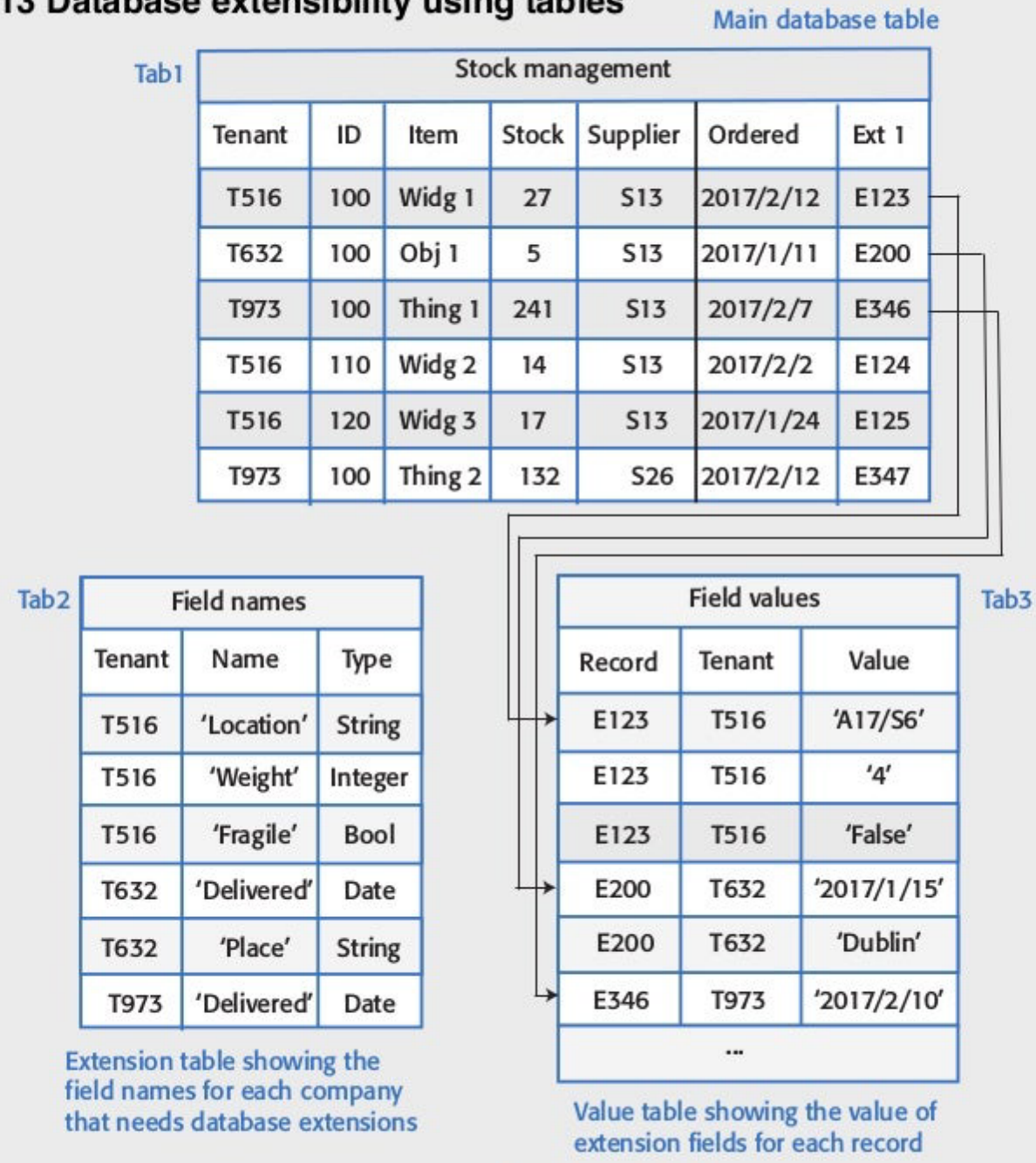
Adding fields to extend the database

- You add some extra columns to each database table and define a customer profile that maps the column names that the customer wants to these extra columns. However:
  - It is difficult to know how many extra columns you should include. If you have too few, customers will find that there aren't enough for what they need to do.
  - If you cater for customers who need a lot of extra columns, however, you will find that most customers don't use them, so you will have a lot of wasted space in your database.
  - Different customers are likely to need different types of columns.
    - For example, some customers may wish to have columns whose items are string types, others may wish to have columns that are integers.
    - You can get around this by maintaining everything as strings. However, this means that either you or your customer have to provide conversion software to create items of the correct type.

Extending a database using tables

- An alternative approach to database extensibility is to allow customers to add any number of additional fields and to define the names, types and values of these fields.
- The names and types of these values are held in a separate table, accessed using the tenant identifier.
- Unfortunately, using tables in this way adds complexity to the database management software.
  - Extra tables must be managed and information from them integrated into the database.

Figure 5.13 Database extensibility using tables



Database security

- Information from all customers is stored in the same database in a multii-multi-tenant system so a software bug or an attack could lead to the data of some or all customers being exposed to others.
- Key security issues are multilevel access control and encryption.
  - Multilevel access control means that access to data must be controlled at both the organizational level and the individual level.
  - You need to have organizational level access control to ensure that any database operations only act on that organization's data. The individual user accessing the data should also have their own access permissions.
- Encryption of data in a multitenant database reassures corporate users that their data cannot be viewed by people from other companies if some kind of system failure occurs.

Multi-instance databases

- Multi-instance systems are SaaS systems where each customer has its own system that is adapted to its needs, including its own database and security controls.
- Multi-instance, cloud-based systems are conceptually simpler than multi-tenant systems and avoid security concerns such as data leakage from one organization to another.
- There are two types of multi-instance system:
  - VM-based multi-instance systems are multi-instance systems where the software instance and database for each customer runs in its own virtual machine. All users from the same customer may access the shared system database.
  - Container-based multi-instance systems* These are multi-instance systems where each user has an isolated version of the software and database running in a set of containers.
  - This approach is suited to products in which users mostly work independently, with relatively little data sharing. Therefore, it is best used for software that serves individuals rather than business customers or for business products that are not data-intensive.

Figure 5.7 Advantages of multi-instance databases

Flexibility
Each instance of the software can be tailored and adapted to a customer's needs. Customers may use completely different database schemas and it is straightforward to transfer data from a customer database to the product database.

Security
Each customer has their own database so there is no possibility of data leakage from one customer to another.

Scaleability
Instances of the system can be scaled according to the needs of individual customers. For example, some customers may require more powerful servers than others.

Resilience
If a software failure occurs, this will probably only affect a single customers. Other customers can continue working as normal.

Table 5.7 Disadvantages of multi-instance databases

Cost
It is more expensive to use multi-instance systems because of the costs of renting many VMs in the cloud and the costs of managing multiple systems. Because of the slow startup time, VMs may have to be rented and kept running continuously, even if there is very little demand for the service.

Update management
It is more complex to manage updates to the software because many instances have to be updated. This is particularly problematic where individual instances have been tailored to the needs of specific customers.

Figure 5.14 Architectural decisions for cloud software engineering

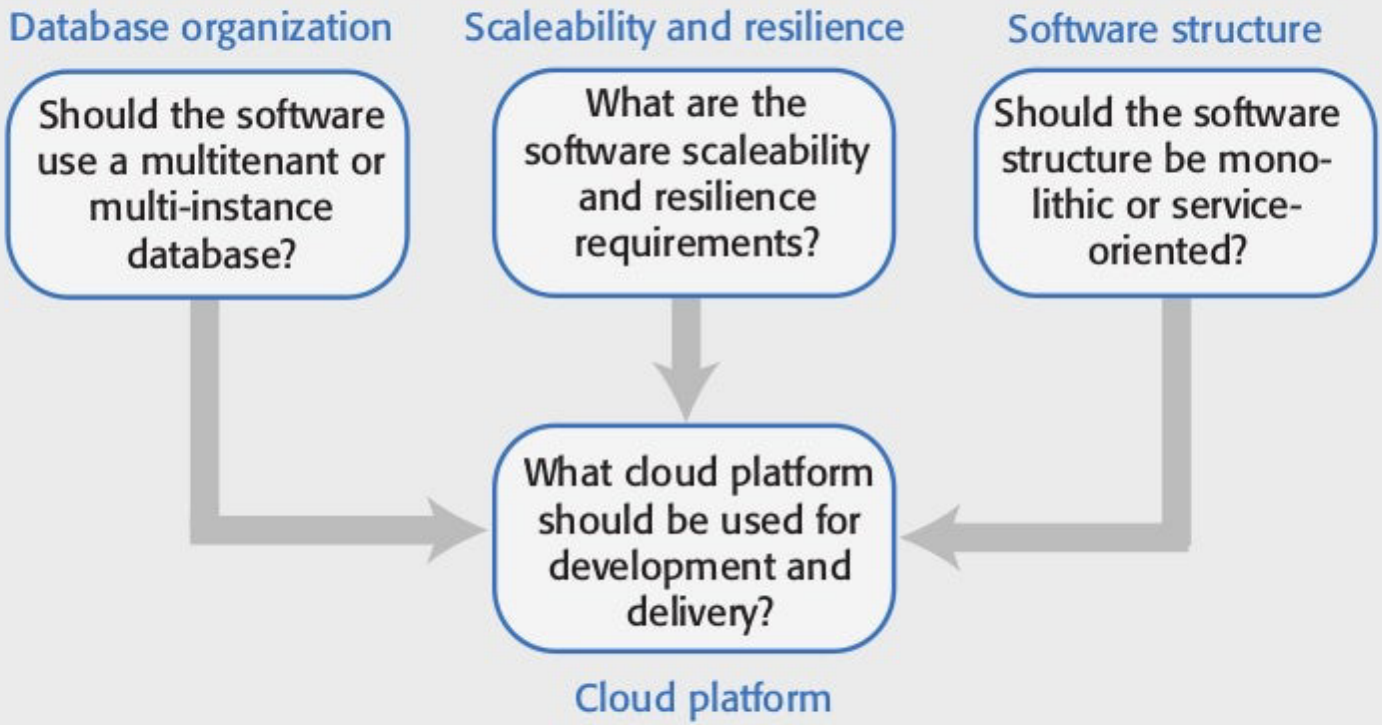


Table 5.8 Questions to ask when choosing a database organization

Target customers
Do customers require different database schemas and database personalization? Do customers have security concerns about database sharing? If so, use a multi-instance database.

Transaction requirements
Is it critical that your products support ACID transactions where the data is guaranteed to be consistent at all times? If so, use a multi-tenant database or a VM-based multi-instance database.

Database size and connectivity
How large is the typical database used by customers? How many relationships are there between database items? A multi-tenant model is usually best for very large databases as you can focus effort on optimizing performance.

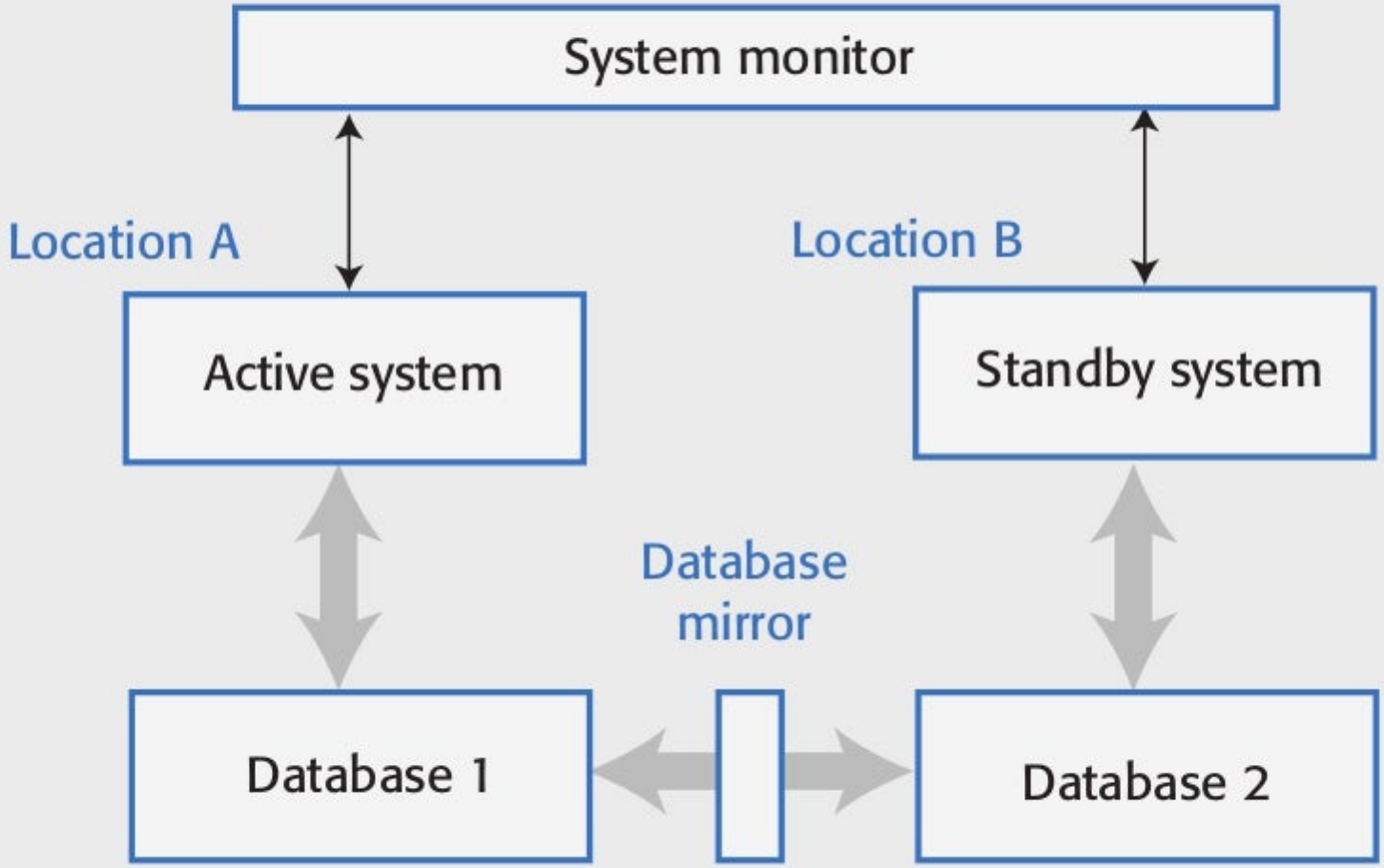
Database interoperability
Will customers wish to transfer information from existing databases? What are the differences in schemas between these and a possible multitenant database? What software support will they expect to do the data transfer? If customers have many different schemas, a multi-instance database should be used.

System structure
Are you using a service-oriented architecture for your system? Can customer databases be split into a set of individual service databases? If so, use containerized, multi-instance databases.

Scalability and resilience

- The scaleability of a system reflects its ability to adapt automatically to changes in the load on that system.
- The resilience of a system reflects its ability to continue to deliver critical services in the event of system failure or malicious system use.
- You achieve scaleability in a system by making it possible to add new virtual servers (scaling-out) or increase the power of a system server (scaling-up) in response to increasing load.
  - In cloud-based systems, scaling-out rather than scaling-up is the normal approach used. Your software has to be organized so that individual software components can be replicated and run in parallel.
- To achieve resilience, you need to be able to restart your software quickly after a hardware or software failure.

Figure 5.15 Using a standby system to provide resilience



Resilience

- Resilience relies on redundancy:
  - Replicas of the software and data are maintained in different locations.
  - Database updates are mirrored so that the standby database is a working copy of the operational database.
  - A system monitor continually checks the system status. It can switch to the standby system automatically if the operational system fails.
- You should use redundant virtual servers that are not hosted on the same physical computer and locate servers in different locations.
  - Ideally, these servers should be located in different data centers.
  - If a physical server fails or if there is a wider data center failure, then operation can be switched automatically to the software copies elsewhere.

System structure

- An object-oriented approach to software engineering has been that been extensively used for the development of client-server systems built around a shared database.
- The system itself is, logically, a monolithic system with distribution across multiple servers running large software components. The traditional multi-tier client server architecture is based on this distributed system model.
- The alternative to a monolithic approach to software organization is a service-oriented approach where the system is decomposed into fine-grain, stateless services.
  - Because it is stateless, each service is independent and can be replicated, distributed and migrated from one server to another.
  - The service-oriented approach is particularly suitable for cloud-based software, with services deployed in containers.

Cloud platform

- Cloud platforms include general-purpose clouds such as Amazon Web Services or lesser known platforms oriented around a specific application, such as the SAP Cloud Platform. There are also smaller national providers that provide more limited services but who may be more willing to adapt their services to the needs of different customers.
- There is no ‘best’ platform and you should choose a cloud provider based on your background and experience, the type of product that you are developing and the expectations of your customers.
- You need to consider both technical issues and business issues when choosing a cloud platform for your product.

Figure 5.16 Technical issues in cloud platform choice

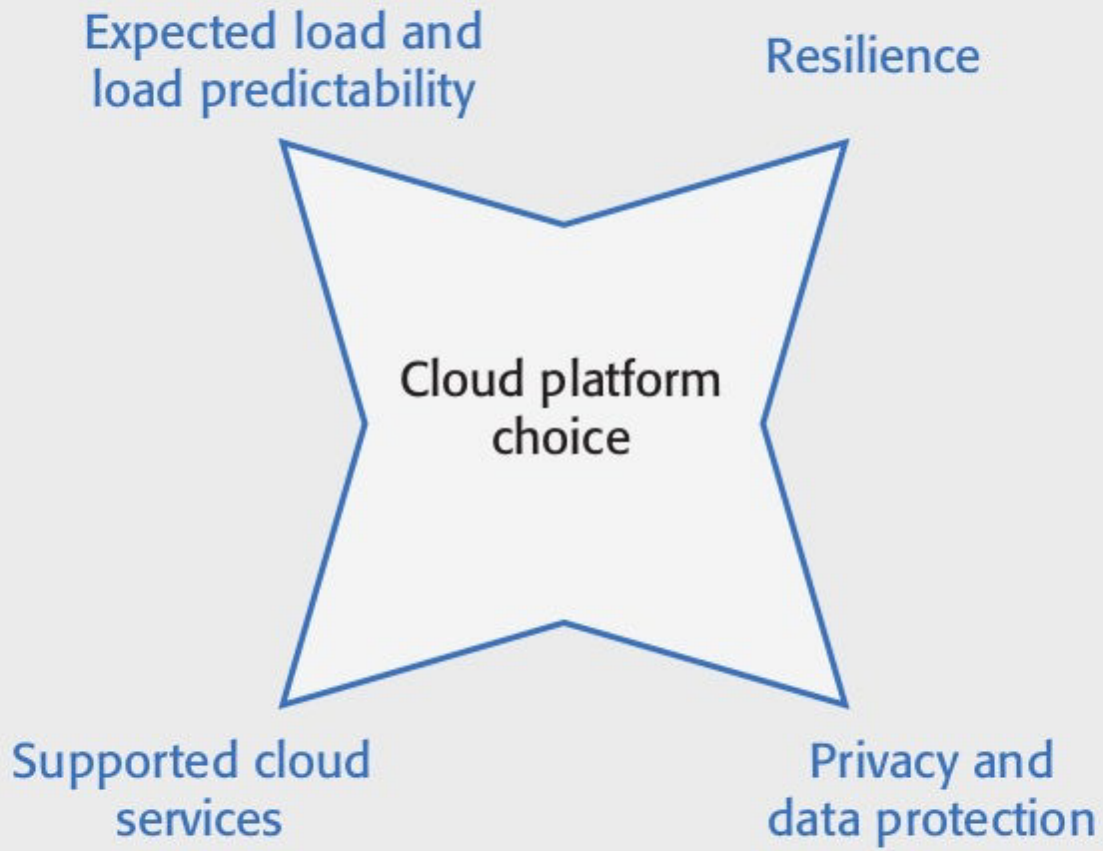
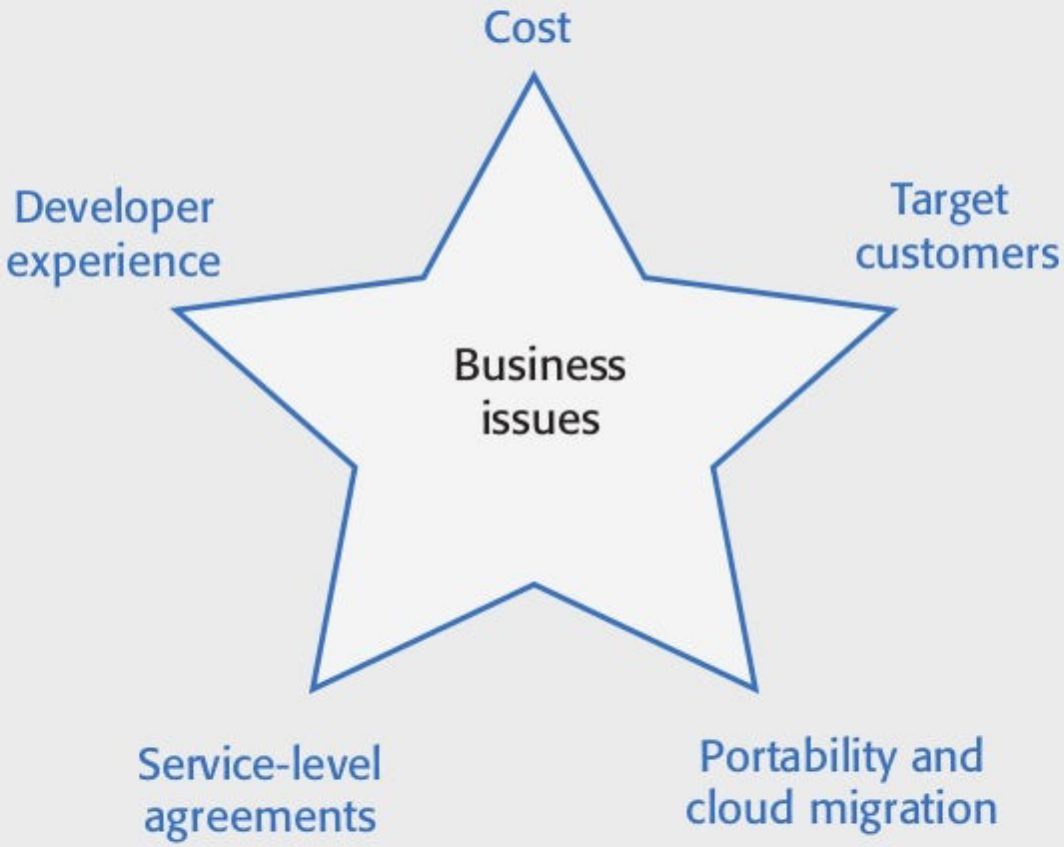


Figure 5.17 Business issues in cloud platform choice



Key points 1

- The cloud is made up of a large number of virtual servers that you can rent for your own use. You and your customers access these servers remotely over the internet and pay for the amount of server time used.
- Virtualization is a technology that allows multiple server instances to be run on the same physical computer. This means that you can create isolated instances of your software for deployment on the cloud.
- Virtual machines are physical server replicas on which you run your own operating system, technology stack and applications.
- Containers are a lightweight virtualization technology that allow rapid replication and deployment of virtual servers. All containers run the same operating system. Docker is currently the most widely used container technology.
- A fundamental feature of the cloud is that 'everything' can be delivered as a service and accessed over the internet. A service is rented rather than owned and is shared with other users.

Key points 2

- Infrastructure as a service (IaaS) means computing, storage and other services are available over the cloud. There is no need to run your own physical servers.
- Platform as a service (PaaS) means using services provided by a cloud platform vendor to make it possible to auto-scale your software in response to demand.
- Software as a service (SaaS) means that application software is delivered as a service to users. This has important benefits for users, such as lower capital costs, and software vendors, such as simpler deployment of new software releases.
- Multitenant systems are SaaS systems where all users share the same database, which may be adapted at run-time to their individual needs. Multi-instance systems are SaaS applications where each user has their own separate database.
- The key architectural issues for cloud-based software are the cloud platform to be used, whether to use a multitenant or multi-instance database, the scaleability and resilience requirements, and whether to use objects or services as the basic components in the system.