Software architecture

Software architecture

To create a reliable, secure and efficient product, you need to pay attention to architectural design which includes:

- its overall organization,
- how the software is decomposed into components,
- the server organization
- the technologies that you use to build the software.The architecture of a software product affects its performance, usability, security, reliability and maintainability.

There are many different interpretations of the term ‘software architecture’.

- Some focus on ‘architecture’ as a noun - the structure of a system and others consider ‘architecture’ to be a verb - the process of defining these structures.

Table 4.1 The IEEE definition of software architecture

Architecture is the fundamental organization of a software system embodied in its components, their relationships to each other and to the environment, and the principles guiding its design and evolution.

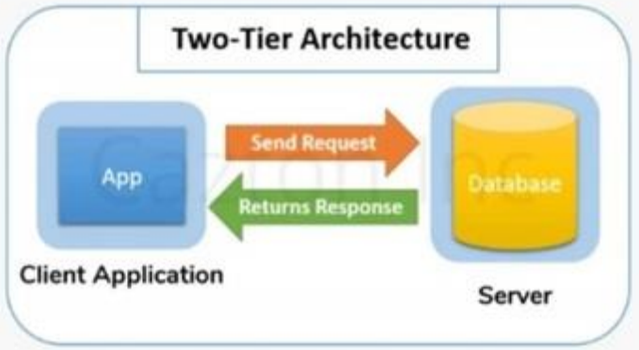
Software architecture and components

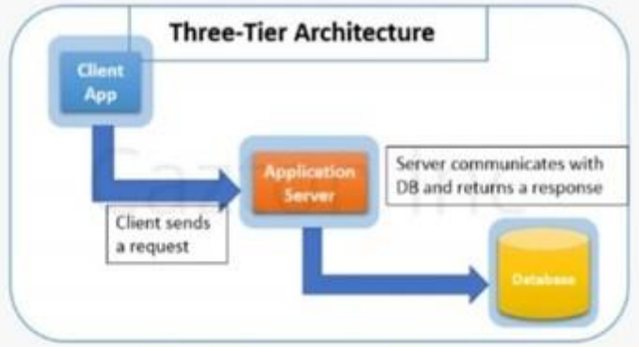
A component is an element that implements a coherent set of functionality or features.

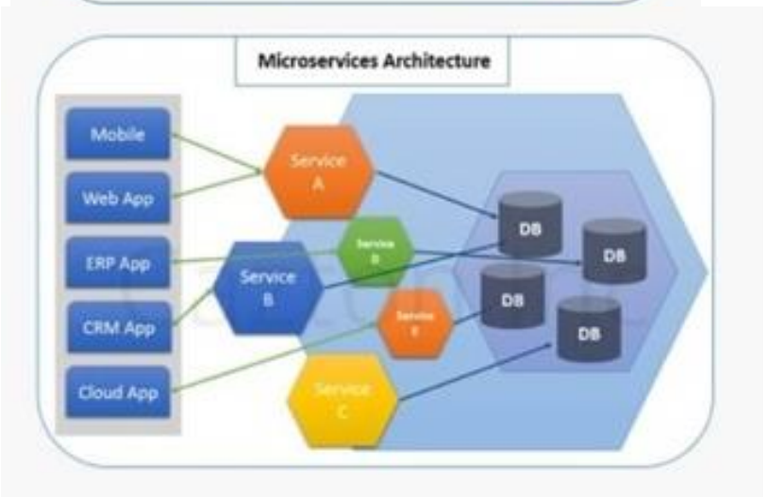
Software component can be considered as a collection of one or more services that may be used by other components.

When designing software architecture, you don’t have to decide how an architectural element or component is to be implemented.

Rather, you design the component interface and leave the implementation of that interface to a later stage of the development process.







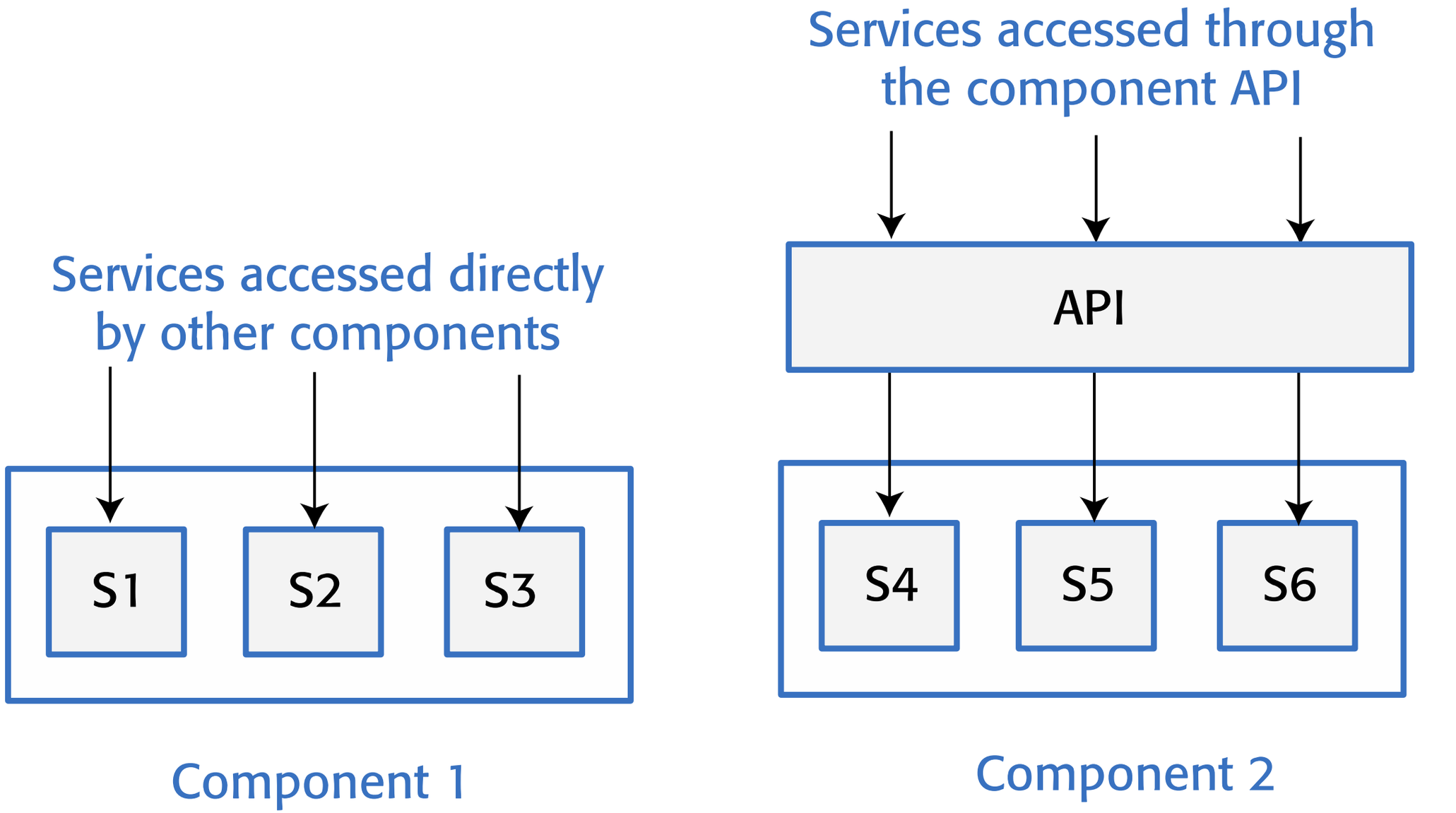
Architecture

"Architecture is about the important stuff. Whatever that is."

[Architecture is] the decisions you wish you could get right early in a project.

Ralph Johnson, co-author of Design Patterns: Elements of Reusable Object-Oriented Software. GoF

Figure 4.1 Access to services provided by software components



Why is architecture important?

Architecture is important because the architecture of a system has a fundamental influence on the non-functional system properties, shown in Table 4.2.

Architectural design involves understanding the issues that affect the architecture of your product and creating an architectural description that shows the critical components and their relationships.

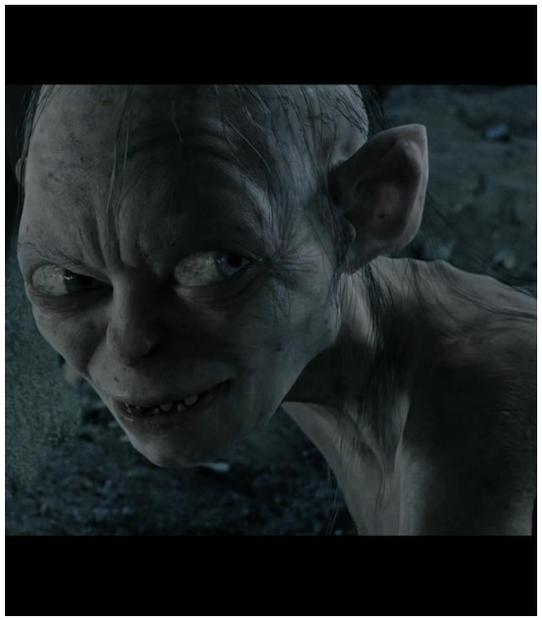
Minimizing complexity should be an important goal for architectural designers.

- The more complex a system, the more difficult and expensive it is to understand and change.
- Programmers are more likely to make mistakes and introduce bugs and security vulnerabilities when they are modifying or extending a complex system..

YAGNI:
"You Aren't Gonna Need It".

Minas Tirith’te bir sigorta yazılımı:

Fırtınalara karşı fiyat hesaplama



«Korsanlara karşı da bir fiyat hesaplama modülü
Çünkü 6 ay içinde buna ihtiyacımısss varrr»

YAGNI: Dur bunu yapma!

En azından 4 ay süreceğini düşünüyorsan 2 ay bekle

GONDOR donanması

https://martinfowler.com/bliki/Yagni.html

YAGNI:
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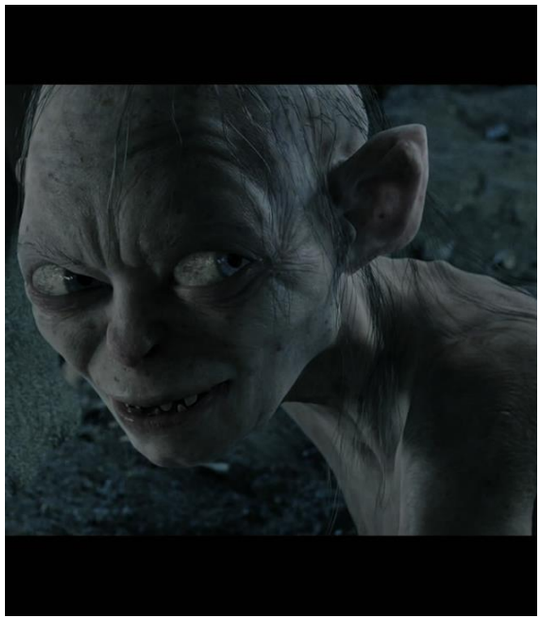
Minas Tirith'te bir sigorta yazılımı:

Fırtınalara karşı fiyat hesaplama



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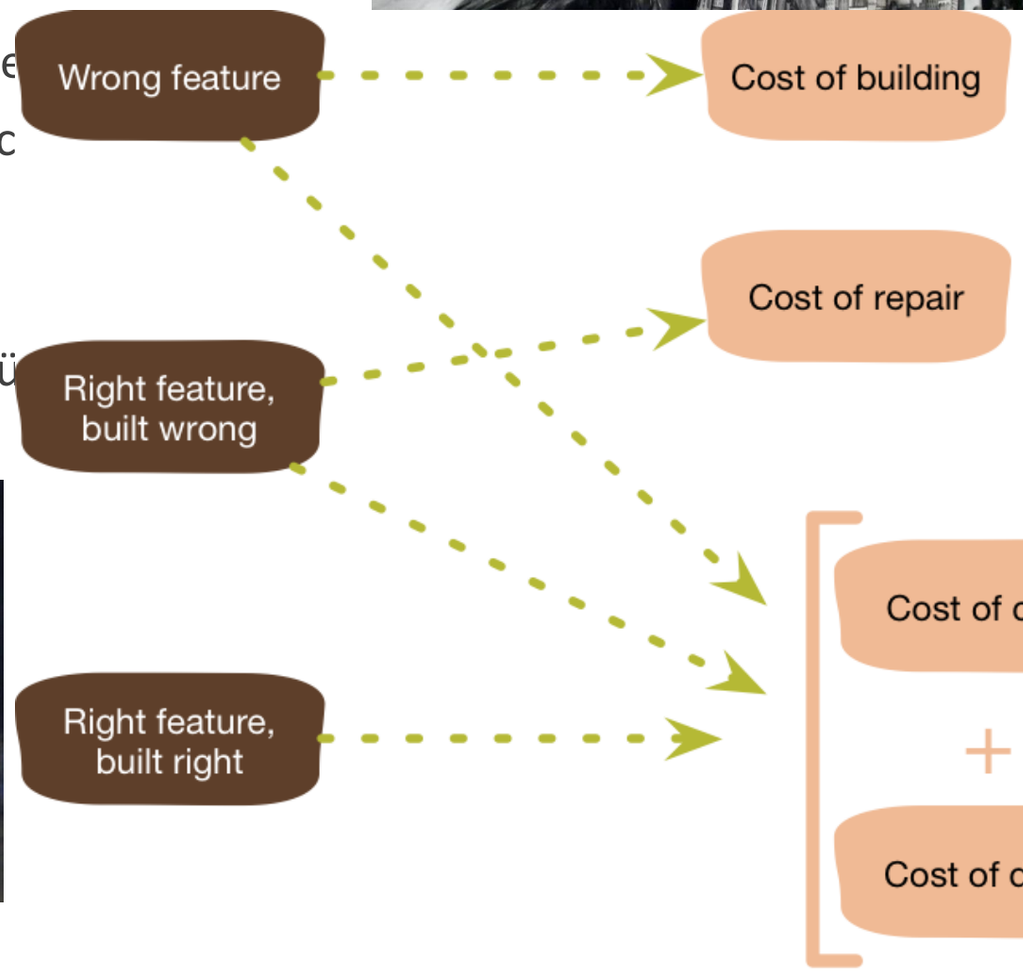
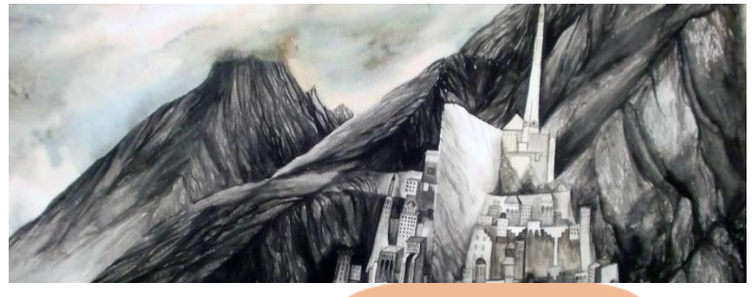


https://martinfowler.com/bliki/Yagni.html

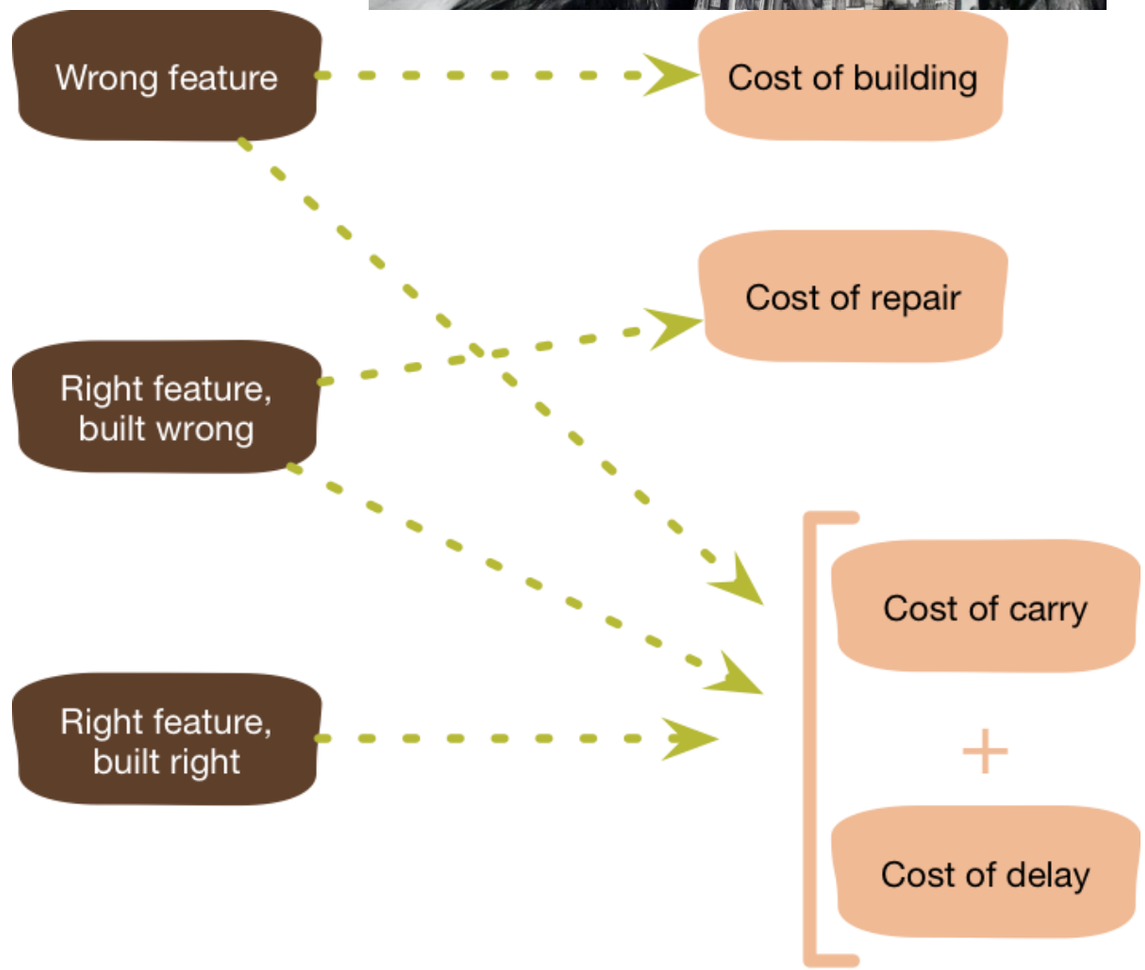
YAGNI:
"You Aren't Gonna Need It".

Availability



Having said all this, there are times when applying yagni does cause a problem, and you are faced with an expensive change when an earlier change would have been much cheaper.

The tricky thing here is that these cases are hard to spot in advance, and much easier to remember than the cases where yagni saved effort.



https://martinfowler.com/bliki/Yagni.html

Table 4.2 Non-functional system quality attributes

Responsiveness
Does the system return results to users in a reasonable time?

Reliability
Do the system features behave as expected by both developers and users?

Availability
Can the system deliver its services when requested by users?

Security
Does the system protect itself and users' data from unauthorized attacks and intrusions?

Usability
Can system users access the features that they need and use them quickly and without errors?

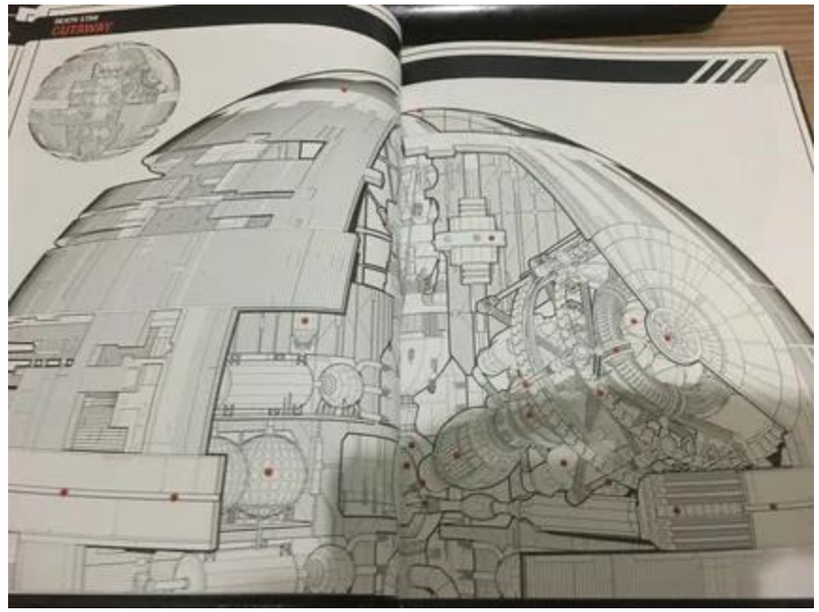
Maintainability
Can the system be readily updated and new features added without undue costs?

Resilience
Can the system continue to deliver user services in the event of partial failure or external attack?

The attributes, rather than product features, that influence user judgements about the quality of your software. If your product is unreliable, insecure, or difficult to use, then it is almost bound to be a failure.

Table 4.3 The influence on architecture of system security

A centralized security architecture
In the Star Wars prequel Rogue One (https://en.wikipedia.org/wiki/Rogue_One), the evil Empire have stored the plans for all of their equipment in a single, highly secure, well-guarded, remote location. This is called a centralized security architecture. It is based on the principle that if you maintain all of your information in one place, then you can apply lots of resources to protect that information and ensure that intruders can't get hold of it.



Unfortunately (for the Empire), the rebels managed to breach their security. They stole the plans for the Death Star, an event which underpins the whole Star Wars saga. In trying to stop them, the Empire destroyed their entire archive of system documentation with who knows what resultant costs. Had the Empire chosen a distributed security architecture, with different parts of the Death Star plans stored in different locations, then stealing the plans would have been more difficult. The rebels would have had to breach security in all locations to steal the complete Death Star blueprints.

Centralized security architectures

The benefits of a centralized security architecture are that it is easier to design and build protection and that the protected information can be accessed more efficiently.

However, if your security is breached, you lose everything.

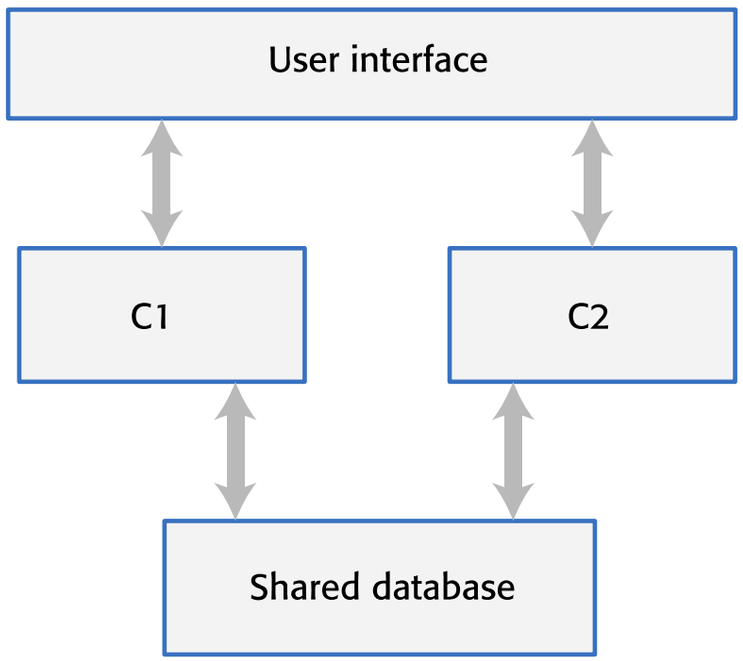
If you distribute information, it takes longer to access all of the information and costs more to protect it.

If security is breached in one location, you only lose the information that you have stored there.

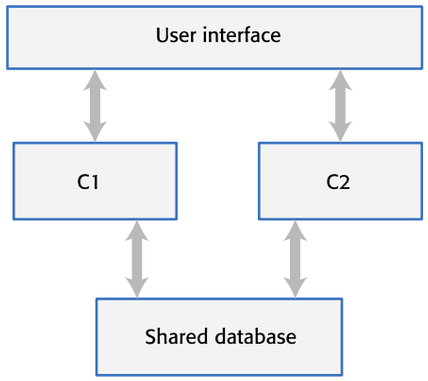
Maintainability and performance

Figure 4.2 shows a system with two components (C1 and C2) that share a common database.

- Assume C1 runs slowly because it has to reorganize the information in the database before using it.
- The only way to make C1 faster might be to change the database. This means that C2 also has to be changed, which may, potentially, affect its response time.

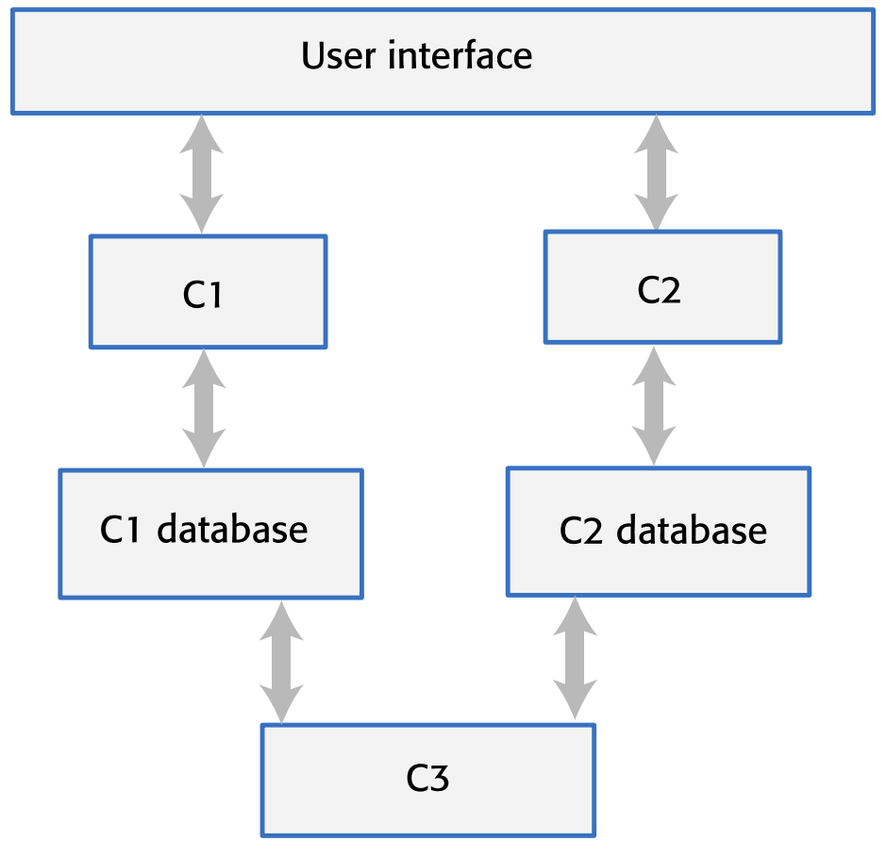


Maintainability and performance



In Figure 4.3, a different architecture is used where each component has its own copy of the parts of the database that it needs.

- If one component needs to change the database organization, this does not affect the other component.

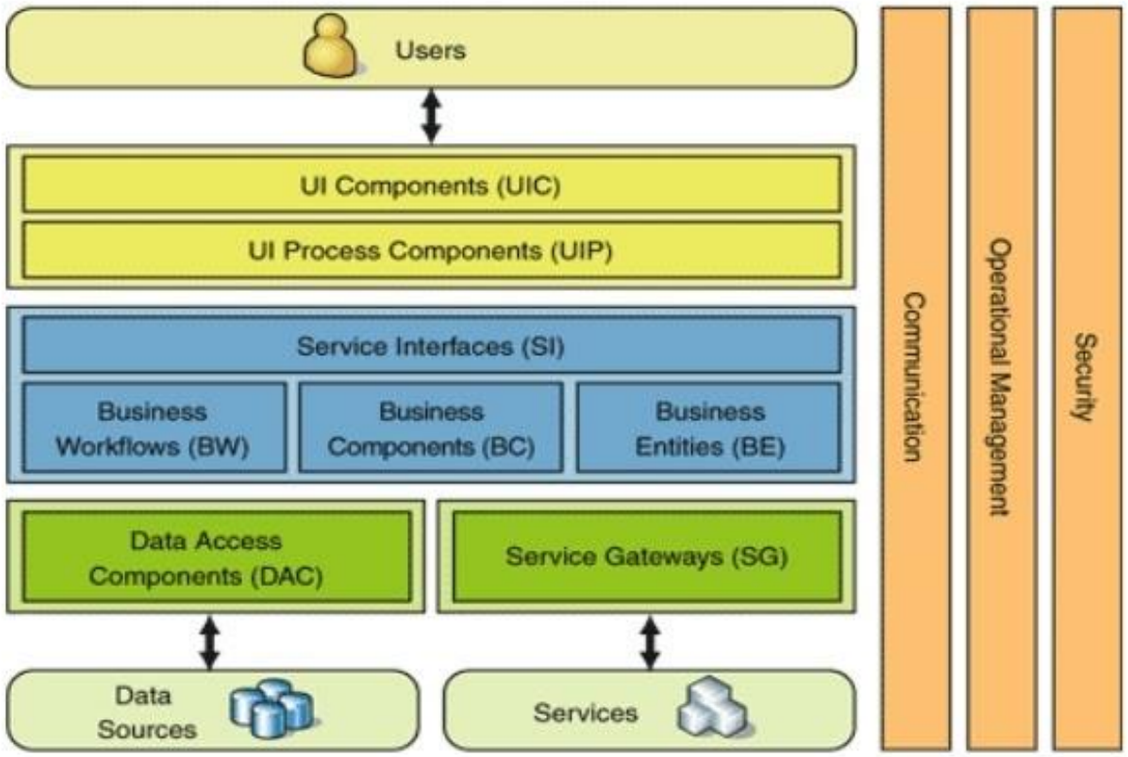


Database reconciliation

However, a multi-database architecture may run more slowly and may cost more to implement and change.

- A multi-database architecture needs a mechanism (component C3) to ensure that the data shared by C1 and C2 is kept consistent when it is changed.

Web Based Application Architecture



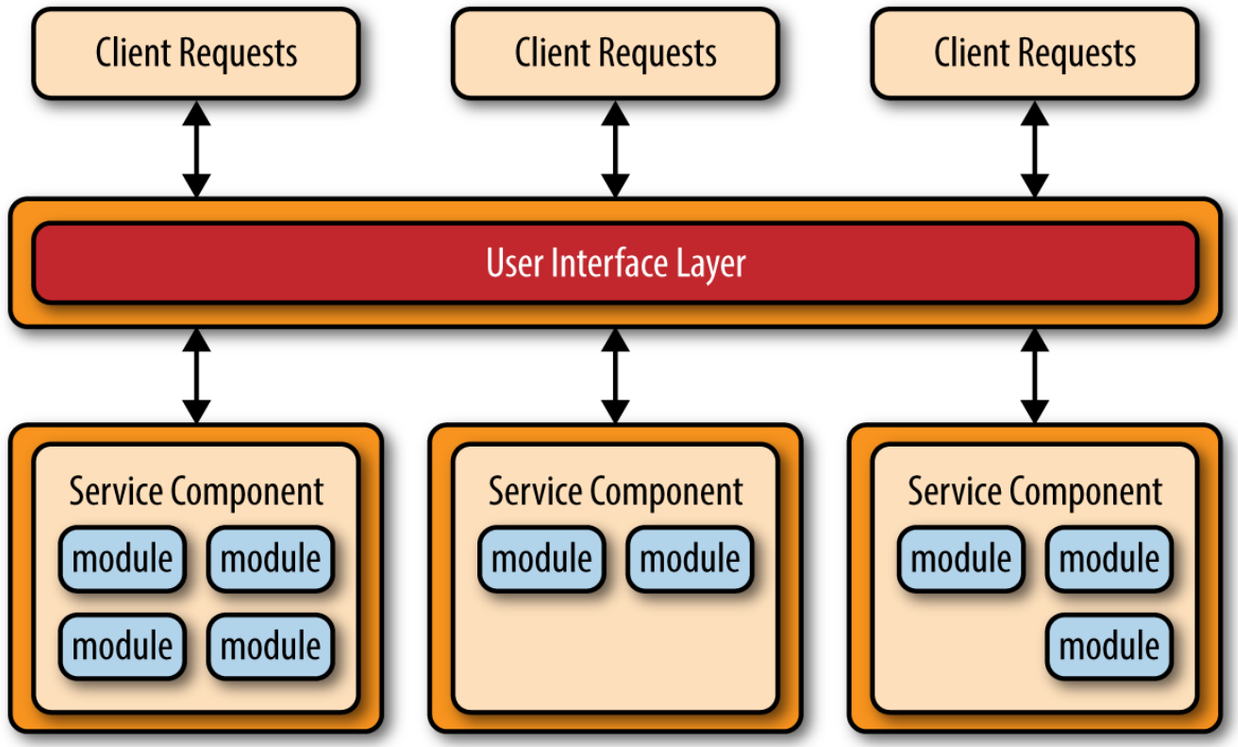


Figure 4.4 Issues that influence architectural decisions

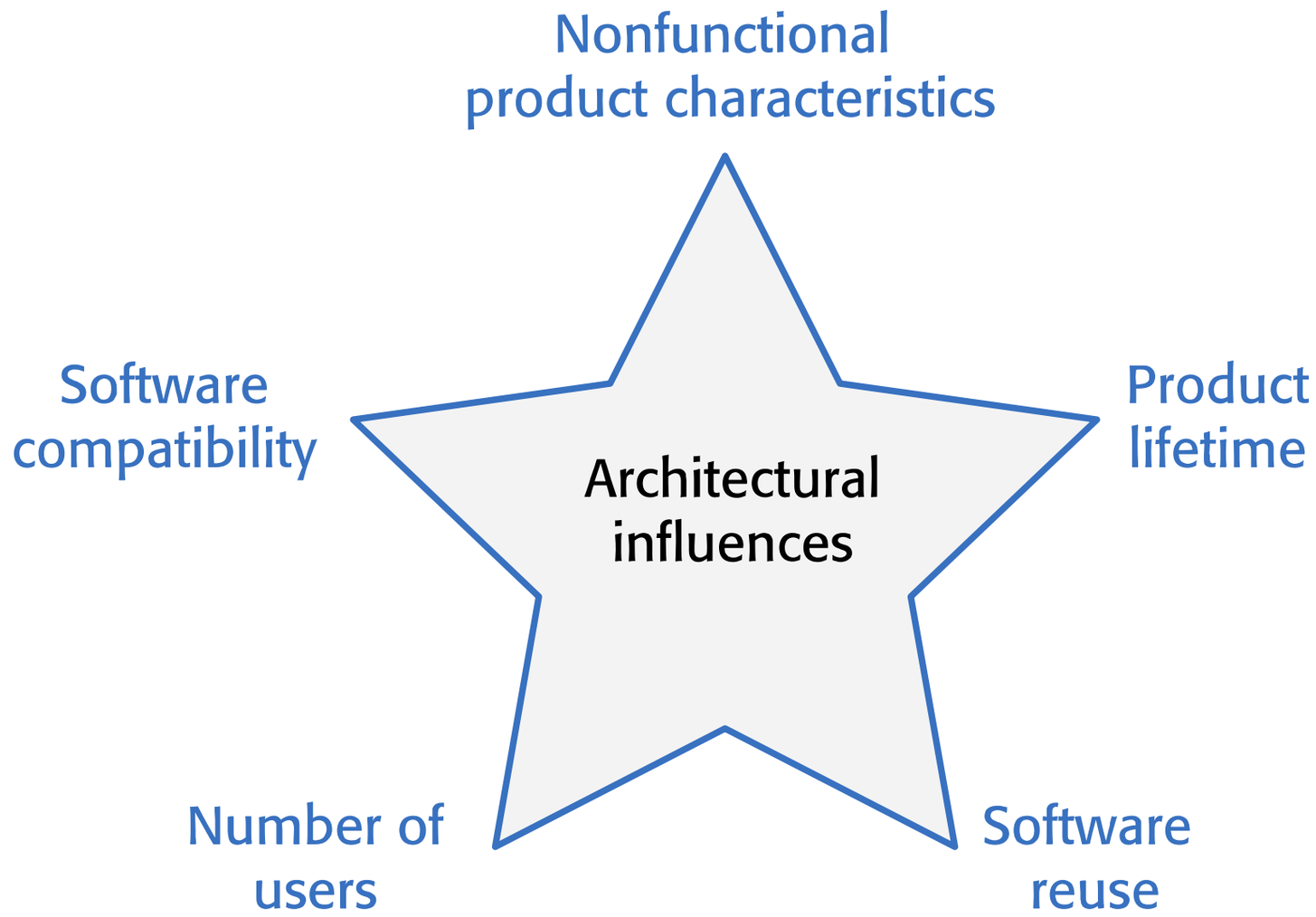


Table 4.4 The importance of architectural design issues

Nonfunctional product characteristics

Nonfunctional product characteristics such as security and performance affect all users. If you get these wrong, your product is will unlikely to be a commercial success. Unfortunately, some **characteristics are opposing**, so you can only optimize the most important.

Product lifetime

If you anticipate a long product lifetime, you will need to create regular product revisions. You therefore need an architecture that is evolvable, so that it can be adapted to accommodate new features and technology.

Software reuse

You can save a lot of time and effort, if you can reuse large components from other products or open-source software. However, this constrains your architectural choices because you must fit your design around the software that is being reused.

Number of users

If you are developing consumer software delivered over the Internet, the number of users can change very quickly. This can lead to serious performance degradation unless you design your architecture so that your system can be quickly scaled up and down.

Software compatibility

For some products, it is important to maintain compatibility with other software so that users can adopt your product and use data prepared using a different system. This may limit architectural choices, such as the database software that you can use.

"isveç çeliğine ancak bu kadar şekil verebildik"

Trade-off

Architectural design involves considering these issues and deciding on essential compromises that allow you to create a system that is "good enough" and can be delivered on time and on budget.

Because it is impossible to optimize everything, you have to make a series of trade-offs when choosing an architecture for your system.

Trade off: Maintainability vs performance

System maintainability is an attribute that reflects how difficult and expensive it is to make changes to a system after it has been released to customers.

- You improve maintainability by building a system from small self-contained parts, each of which can be replaced or enhanced if changes are required.

In architectural terms, this means that the system should be decomposed into fine-grain components, each of which does one thing and one thing only.

- However, it takes time for components to communicate with each other. Consequently, if many components are involved in implementing a product feature, the software will be slower.

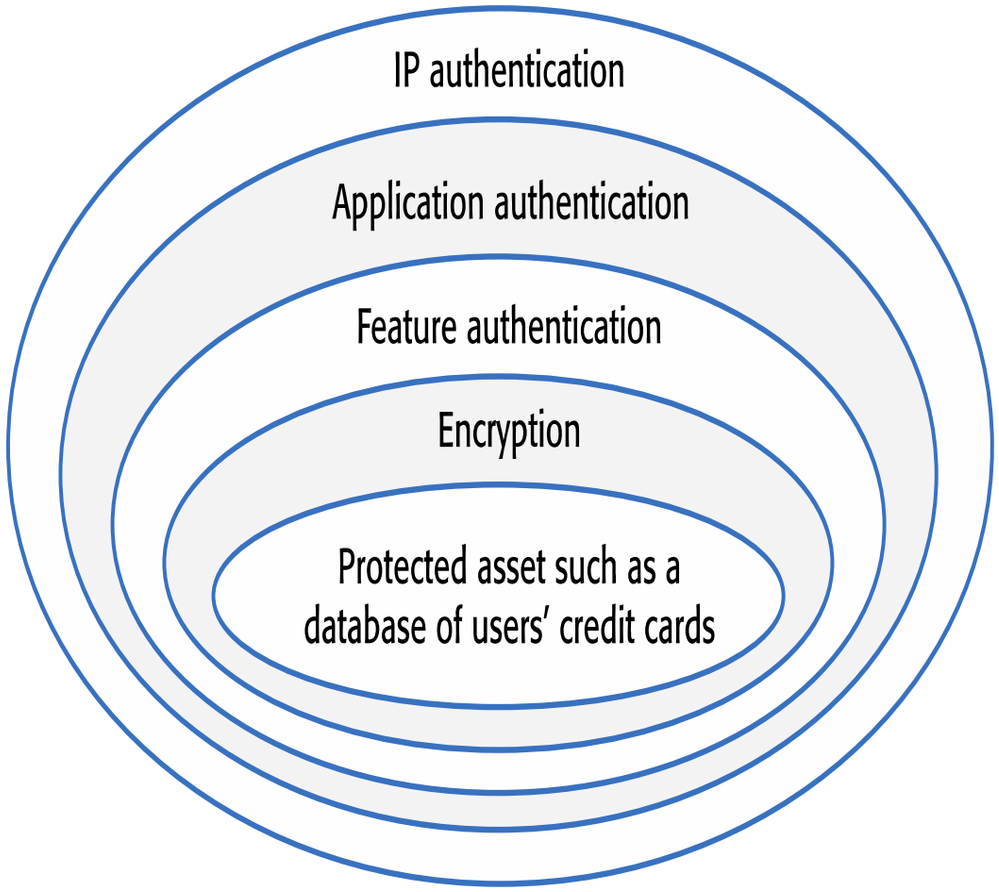
Trade off: Security vs usability

You can achieve security by designing the system protection as a series of layers (Figure 4.5).

- An attacker has to penetrate all of those layers before the system is compromised.

Layers might include system authentication layers, a separate critical feature authentication layer, an encryption layer and so on.

Architecturally, you can implement each of these layers as separate components so that if one of these components is compromised by an attacker, then the other layers remain intact.



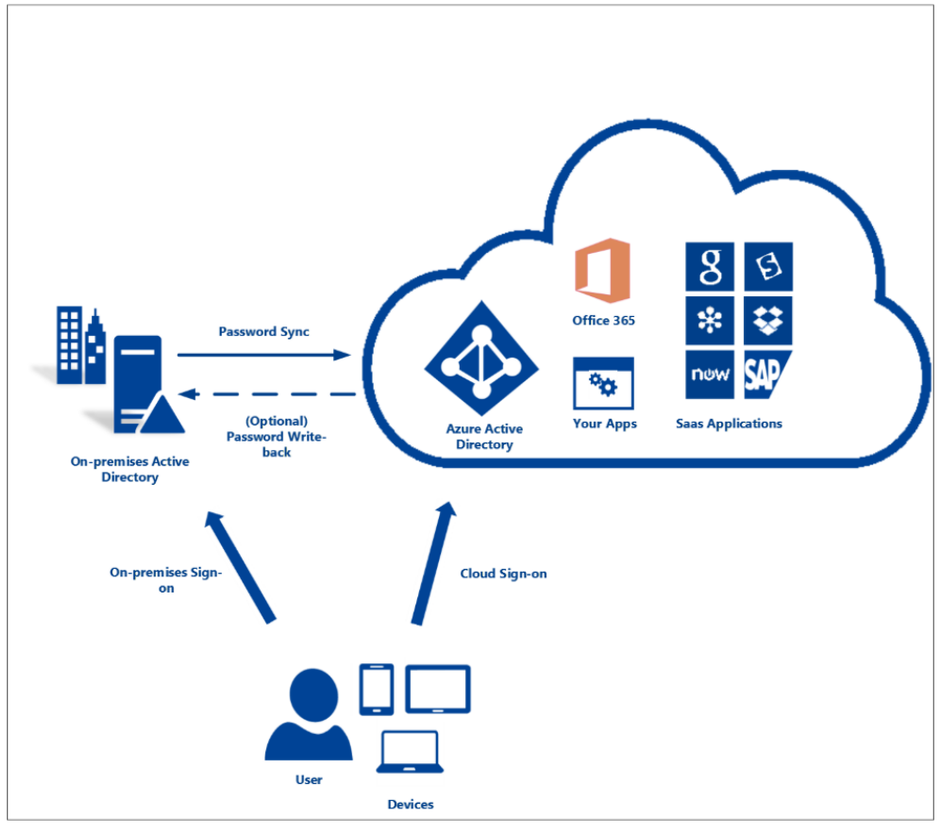
Usability issues

A layered approach to security affects the usability of the software.

- Users have to remember information, like passwords, that is needed to penetrate a security layer. Their interaction with the system is inevitably slowed down by its security features.
- Many users find this irritating and often look for work-arounds so that they do not have to re-authenticate to access system features or data.

To avoid this, you need an architecture:

- that doesn't have too many security layers,
- that doesn't enforce unnecessary security,
- that provides helper components that reduce the load on users.



Trade off: Availability vs time-to-market

Availability is particularly important in enterprise products, such as products for the finance industry, where 24/7 operation is expected.

The availability of a system is a measure of the amount of ‘uptime’ of that system.

- Availability is normally expressed as a percentage of the time that a system is available to deliver user services.

Architecturally, you achieve availability by having redundant components in a system.

- To make use of redundancy, you include sensor components that detect failure, and switching components that switch operation to a redundant component when a failure is detected.

Implementing extra components takes time and increases the cost of system development. It adds complexity to the system and therefore increases the chances of introducing bugs and vulnerabilities.

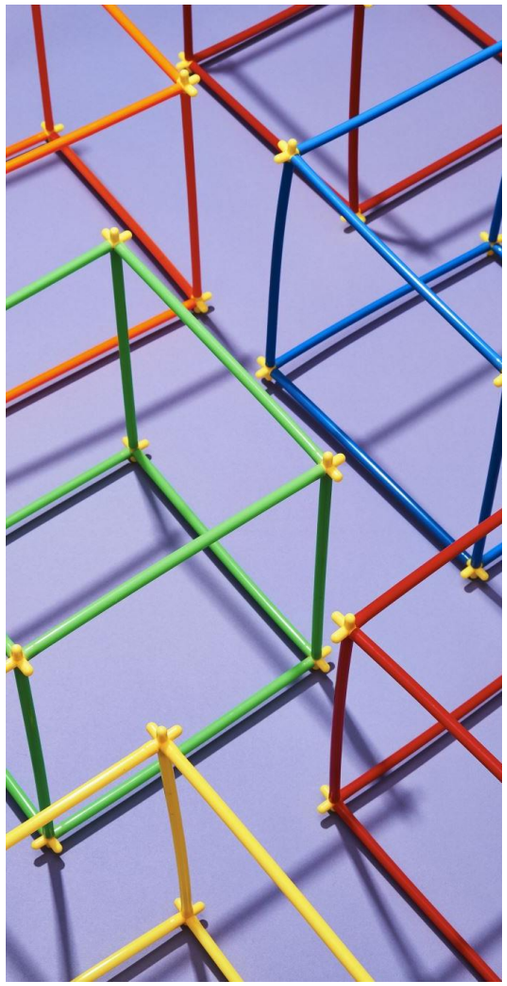
Architectural design questions

How should the system be organized as a set of architectural components, where each of these components provides a subset of the overall system functionality?

- The organization should deliver the system security, reliability and performance that you need.

How should these architectural components be distributed and communicate with each other?

What technologies should you use in building the system and what components should be reused?



Component organization

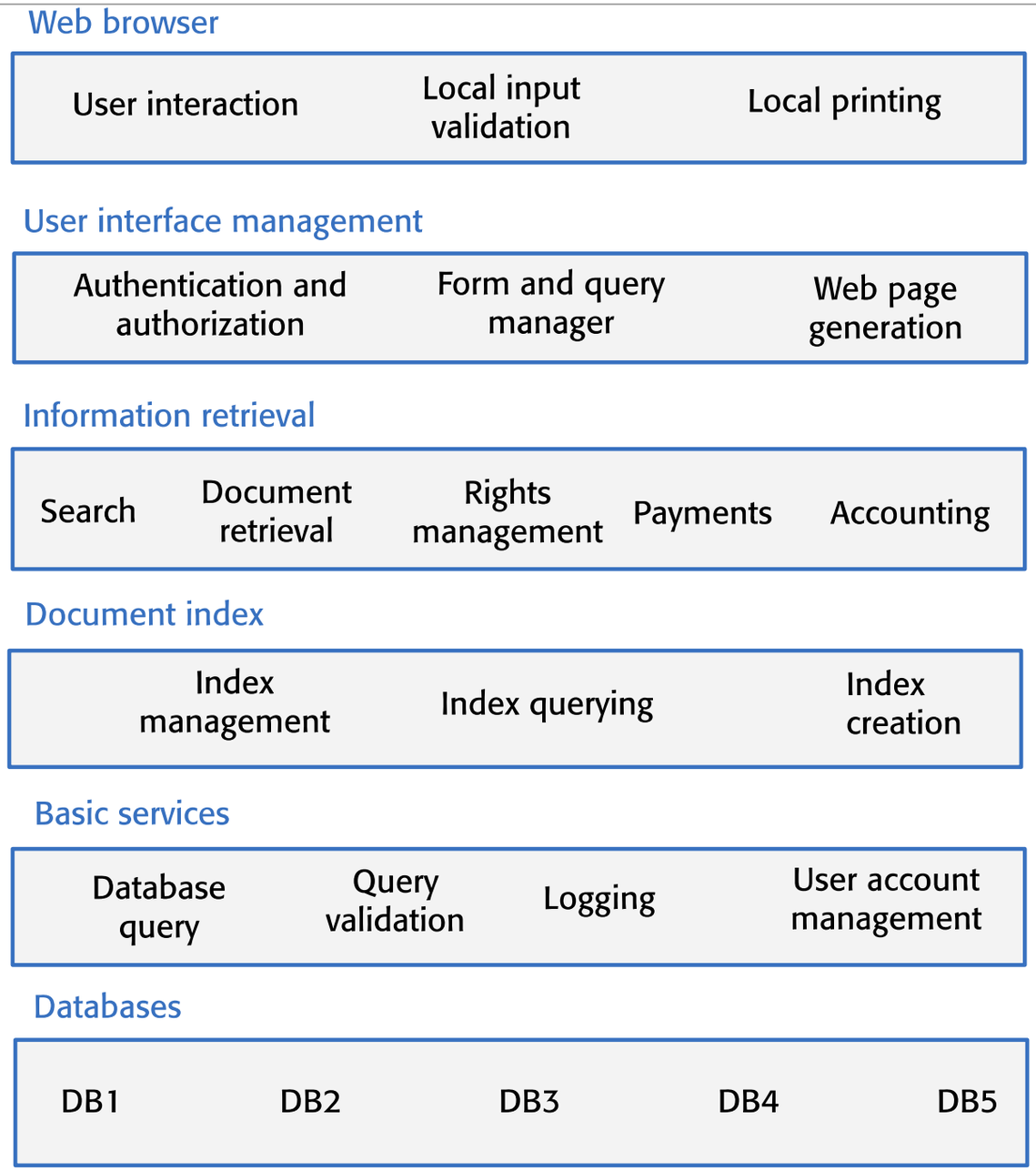
Abstraction in software design means that you focus on the essential elements of a system or software component without concern for its details.

At the architectural level, your concern should be on large-scale architectural components.

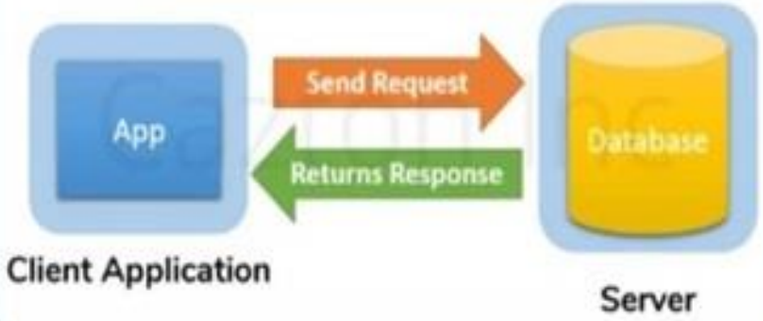
Decomposition involves analysing these large-scale components and representing them as a set of finer-grain components.

Layered models are often used to illustrate how a system is composed of components.

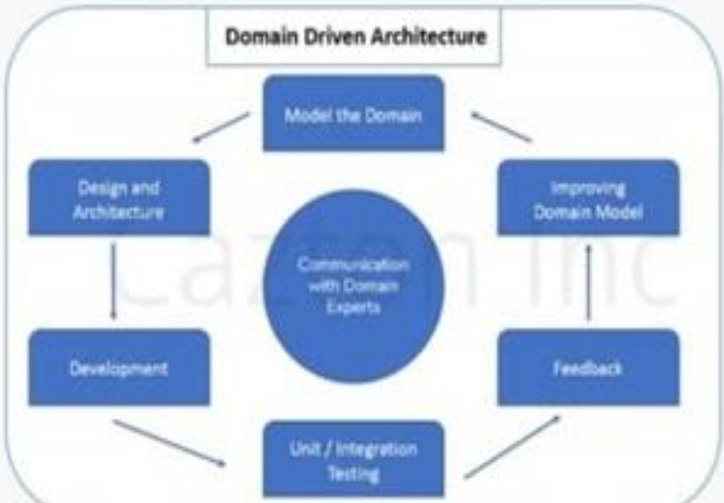
Figure 4.6 An architectural model of a document retrieval system



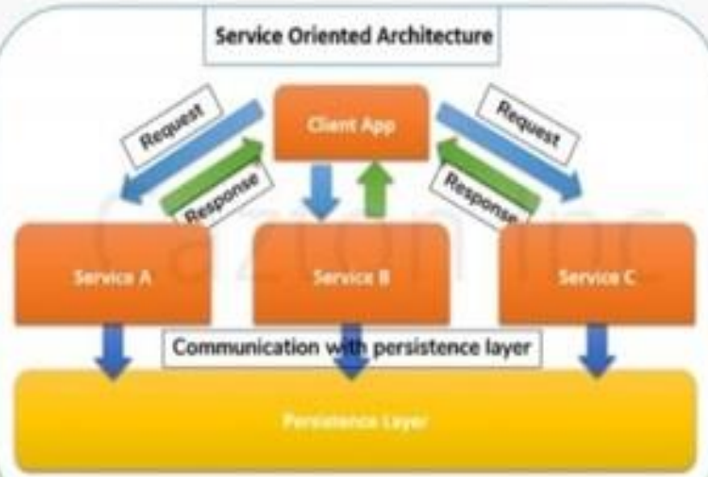
Two-Tier Architecture



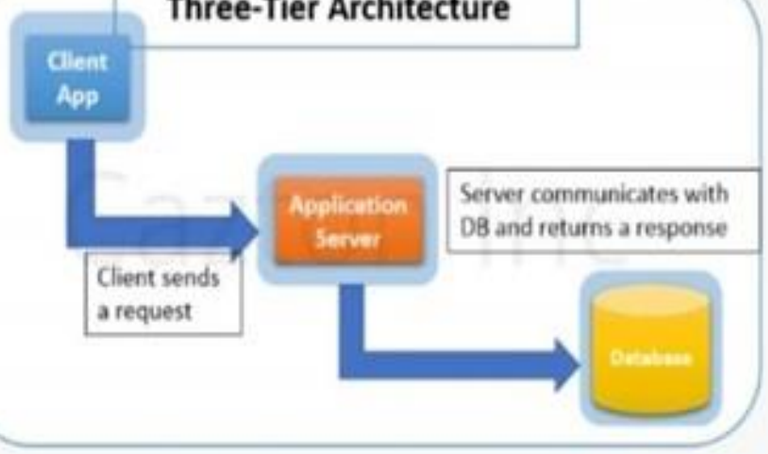
Domain Driven Architecture



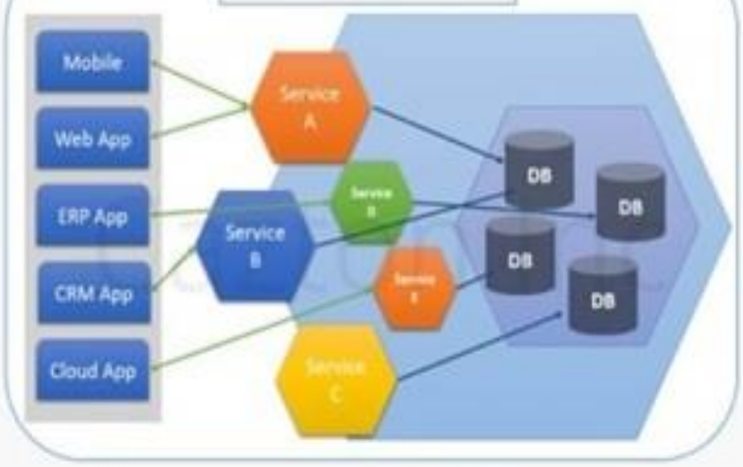
Service Oriented Architecture



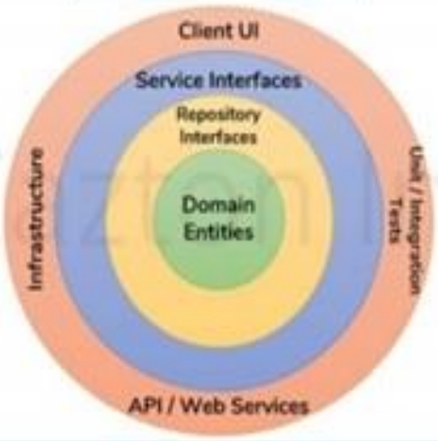
Three-Tier Architecture



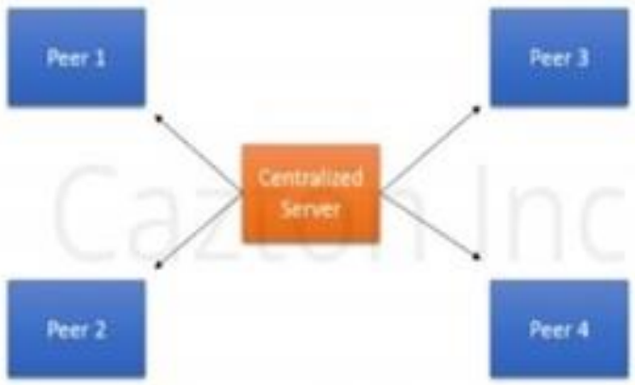
Microservices Architecture



Onion Architecture

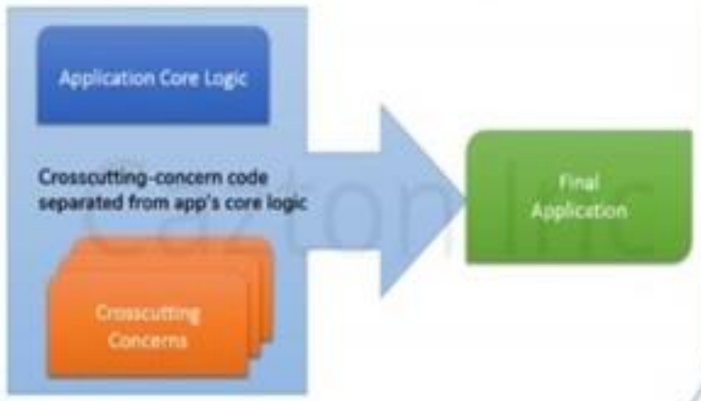


N-Tier Architecture



Resources are shared between peers through a centralized server.

Aspect Oriented Architecture



Event Based Architecture

Kitabımızdaki bazı terim karşılıkları

A service is a coherent unit of functionality. This may mean different things at different levels of the system. For example, a system may offer an email service and this email service may itself include services for creating, sending, reading, and storing email.

A component is a named software unit that offers one or more services to other software components or to the end-users of the software. When used by other components, these services are accessed through an API. Components may use several other components to implement their services.

A module is a named set of components. The components in a module should have something in common. For example, they may provide a set of related services.

Architectural complexity

Complexity in a system architecture arises because of the number and the nature of the relationships between components in that system.

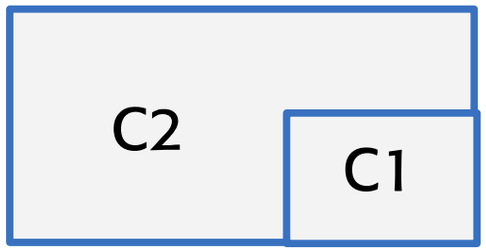
When decomposing a system into components, you should try to avoid unnecessary software complexity.

- *Localize relationships*
  If there are relationships between components A and B, these are easier to understand if A and B are defined in the same module.
- *Reduce shared dependencies*
  Where components A and B depend on some other component or data, complexity increases because changes to the shared component mean you have to understand how these changes affect both A and B.

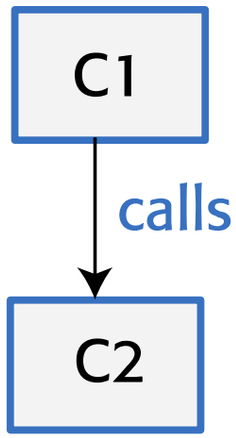
It is always preferable to use local data wherever possible and to avoid sharing data if you can.

Figure 4.7 Examples of component relationships

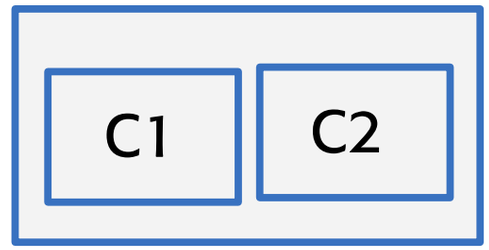
C1 is-part-of C2



C1 uses C2



C1 is-located-with C2

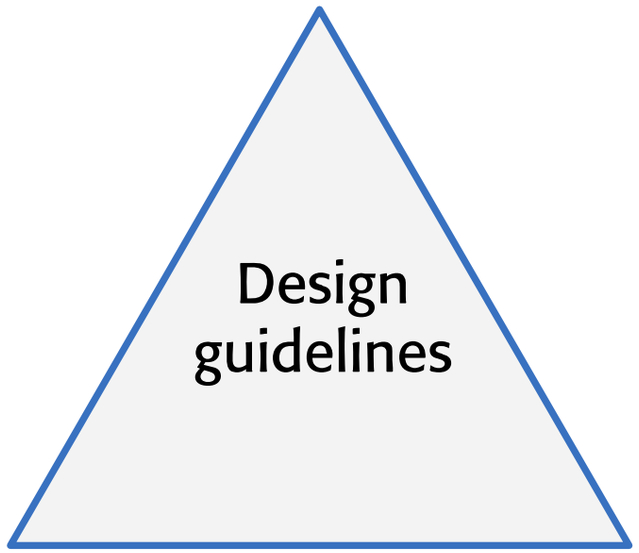


C1 shares-data-with C2

Figure 4.8 Architectural design guidelines

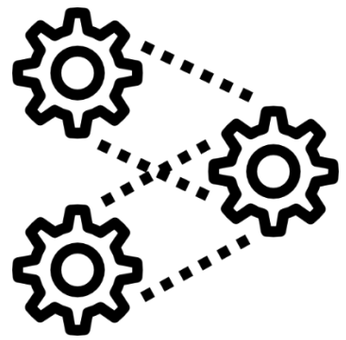
Separation of concerns
Organize your architecture into components that focus on a single concern

e.g. user interaction, authentication, system monitoring, and database management.



Stable interfaces
Design component interfaces that are coherent and that change slowly

Implement once
Avoid duplicating functionality at different places in your architecture



Design guidelines and layered architectures

Each layer is an area of concern and is considered separately from other layers.

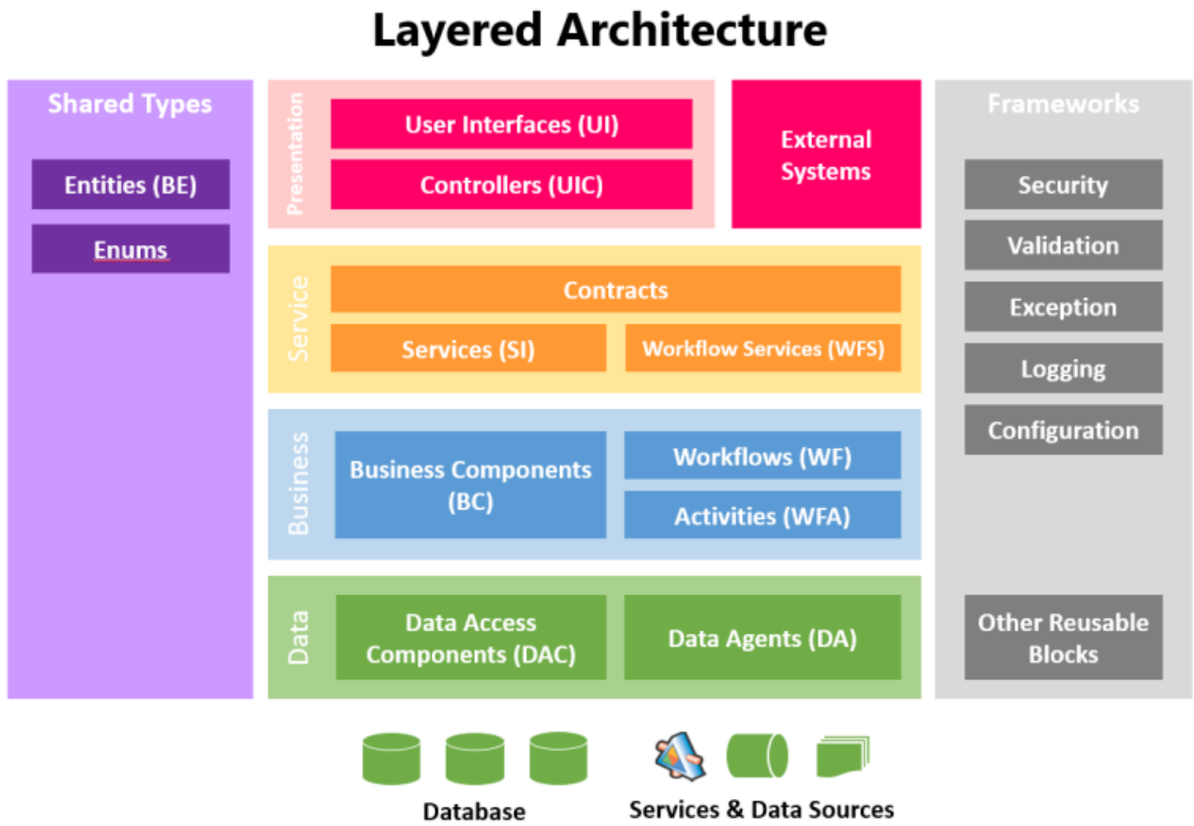
- The top layer is concerned with user interaction, the next layer down with user interface management, the third layer with information retrieval and so on.

Within each layer, the components are independent and do not overlap in functionality.

- The lower layers include components that provide general functionality so there is no need to replicate this in the components in a higher level.

The architectural model is a high-level model that does not include implementation information.

- Ideally, components at level X (say) should only interact with the APIs of the components in level X-1. That is, interactions should be between layers and not across layers.



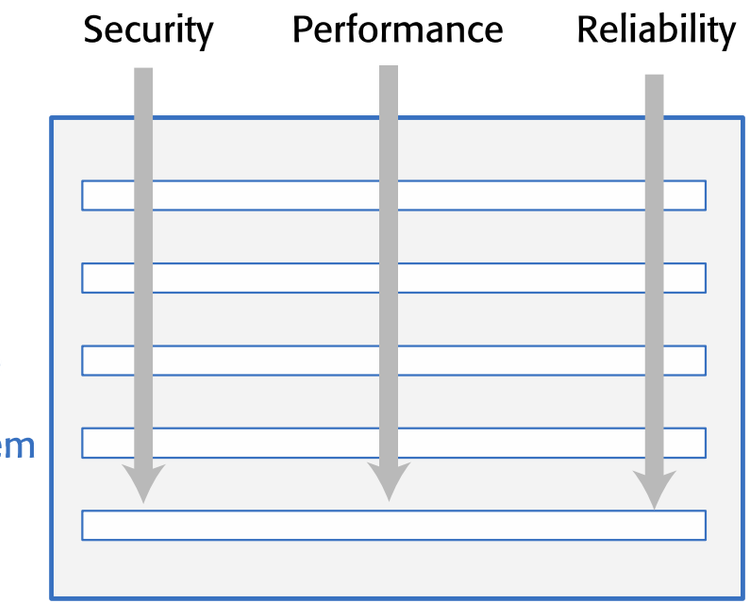
Logical layers

Cross-cutting concerns

Cross-cutting concerns are concerns that are systemic, that is, they affect the whole system.

In a layered architecture, cross-cutting concerns affect all layers in the system as well as the way in which people use the system.

Cross-cutting concerns are completely different from the functional concerns represented by layers in a software architecture.



Every layer has to take them into account and there are inevitably interactions between the layers because of these concerns.
The existence of cross-cutting concerns is the reason why modifying a system after it has been designed to improve its security is often difficult.

Table 4.5 Security as a cross-cutting concern

Security architecture
Different technologies are used in different layers, such as an SQL database or a Firefox browser. Attackers can try to use of vulnerabilities in these technologies to gain access.

Consequently, you need protection from attacks at each layer as well as protection, at lower layers in the system, from successful attacks that have occurred at higher-level layers.

If there is only a single security component in a system, this represents a critical system vulnerability. If all security checking goes through that component and it stops working properly or is compromised in an attack, then you have no reliable security in your system.

By distributing security across the layers, your system is more resilient to attacks and software failure (remember the Rogue One example earlier in the chapter).

Figure 4.10 A generic layered architecture for a web-based application

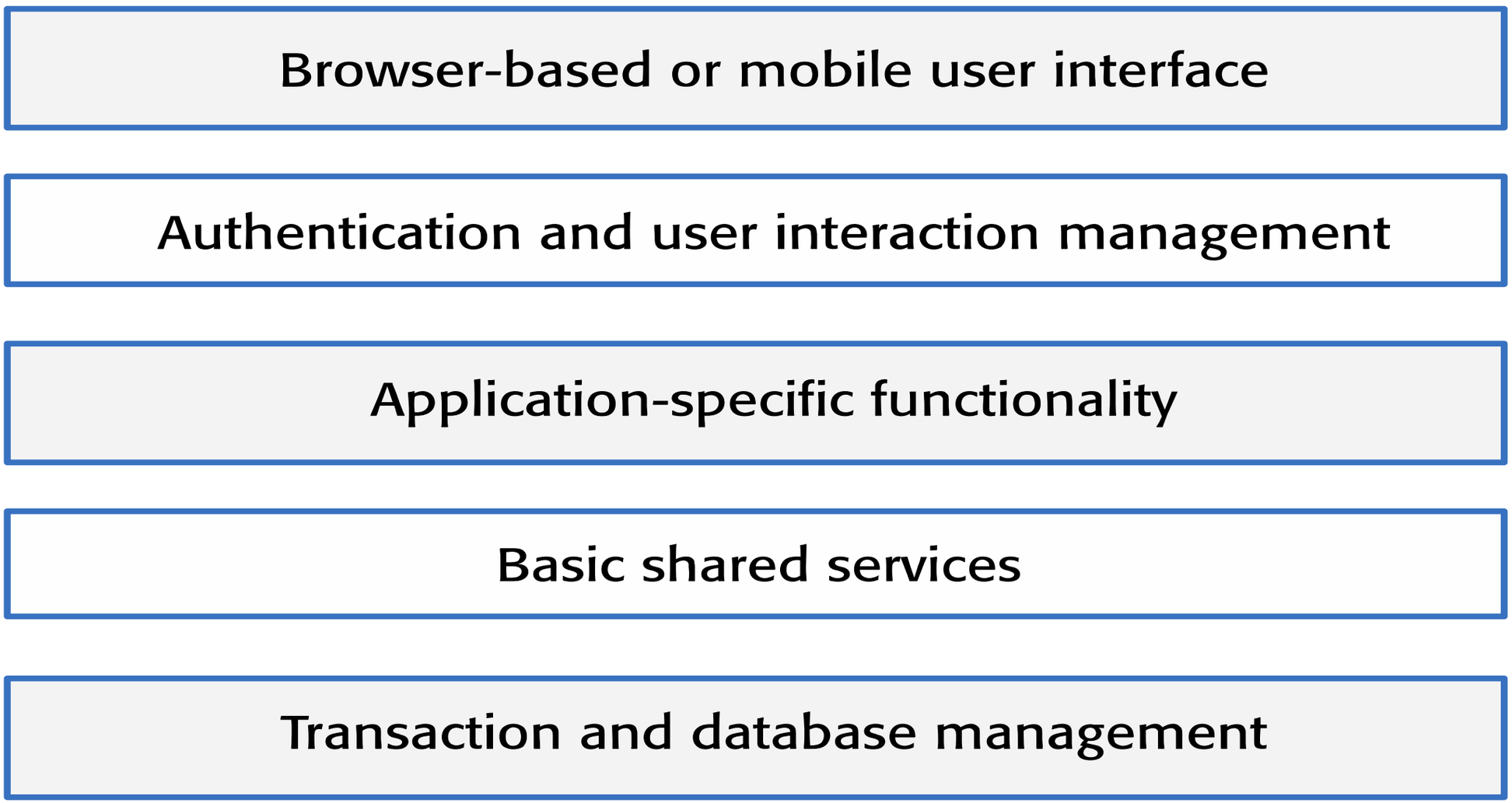


Table 4.6 Layer functionality in a web-based application

Browser-based or mobile user interface
A web browser system interface in which HTML forms are often used to collect user input. Javascript components for local actions, such as input validation, should also be included at this level. Alternatively, a mobile interface may be implemented as an app.

Authentication and UI management
A user interface management layer that may include components for user authentication and web page generation.

Application-specific functionality
An 'application' layer that provides functionality of the application. Sometimes, this may be expanded into more than one layer.

Basic shared services
A shared services layer, which includes components that provide services used by the application layer components.

Database and transaction management
A database layer that provides services such as transaction management and recovery. If your application does not use a database then this may not be required.

Table 4.7 iLearn architectural design principles

Replaceability
It should be possible for users to replace applications in the system with alternatives and to add new applications. Consequently, the list of applications included should not be hard-wired into the system.

Extensibility
It should be possible for users or system administrators to create their own versions of the system, which may extend or limit the 'standard' system.

Age-appropriate
Alternative user interfaces should be supported so that age-appropriate interfaces for students at different levels can be created.

Programmability
It should be easy for users to create their own applications by linking existing applications in the system.

Minimum work
Users who do not wish to change the system should not have to do extra work so that other users can make changes.

iLearn design principles

Our goal in designing the iLearn system was to create an adaptable, universal system that could be easily updated as new learning tools became available.

- This means that it must be possible to change and replace components and services in the system (principles (1) and (2)).
- Because the potential system users spanned an age range from 3 to 18, we needed to provide age-appropriate user interfaces and to make it easy to choose an interface (principle (3)).
- Principle (4) also contributes to system adaptability and principle (5) was included to ensure that this adaptability did not adversely affect users who did not require it.

Designing iLearn as a service-oriented system

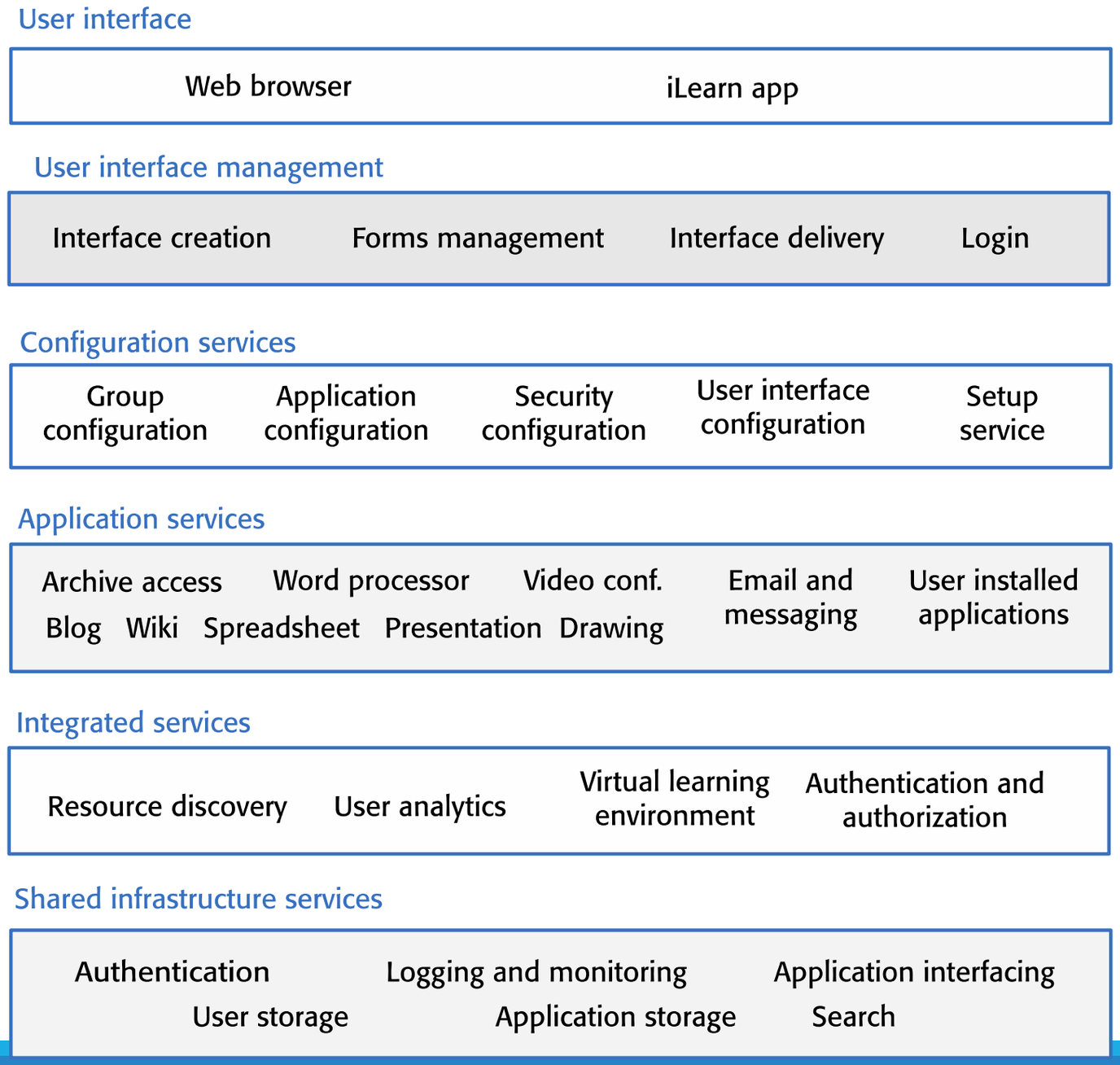
These principles led us to an architectural design decision that the iLearn system should be service-oriented.

Every component in the system is a service. Any service is potentially replaceable and new services can be created by combining existing services. Different services delivering comparable functionality can be provided for students of different ages.

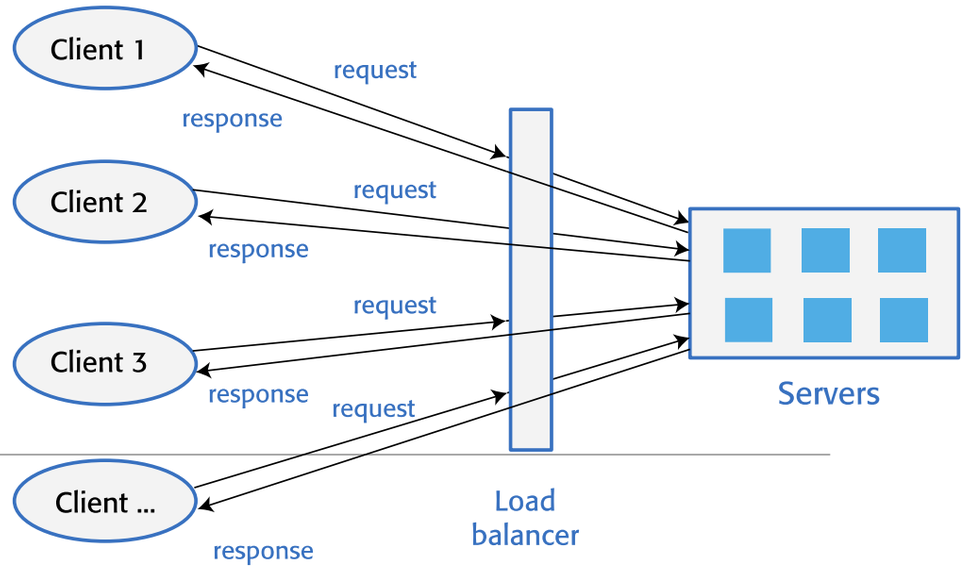
Service integration

- *Full integration* Services are aware of and can communicate with other services through their APIs.
- *Partial integration* Services may share service components and databases but are not aware of and cannot communicate directly with other application services.
- *Independent* These services do not use any shared system services or databases and they are unaware of any other services in the system. They can be replaced by any other comparable service.

Figure 4.11. A layered architectural model of the iLearn system



Distribution architecture

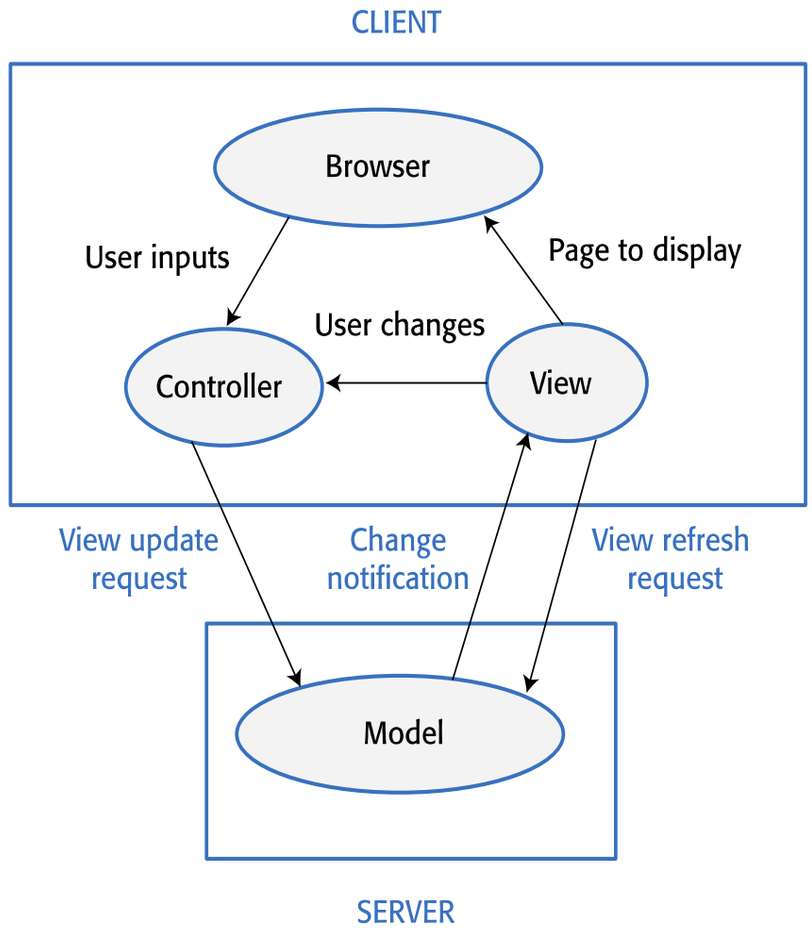


The distribution architecture of a software system defines the servers in the system and the allocation of components to these servers.

Client-server architectures are a type of distribution architecture that is suited to applications where clients access a shared database and business logic operations on that data.

In this architecture, the user interface is implemented on the user's own computer or mobile device.

- Functionality is distributed between the client and one or more server computers.



Client-server communication

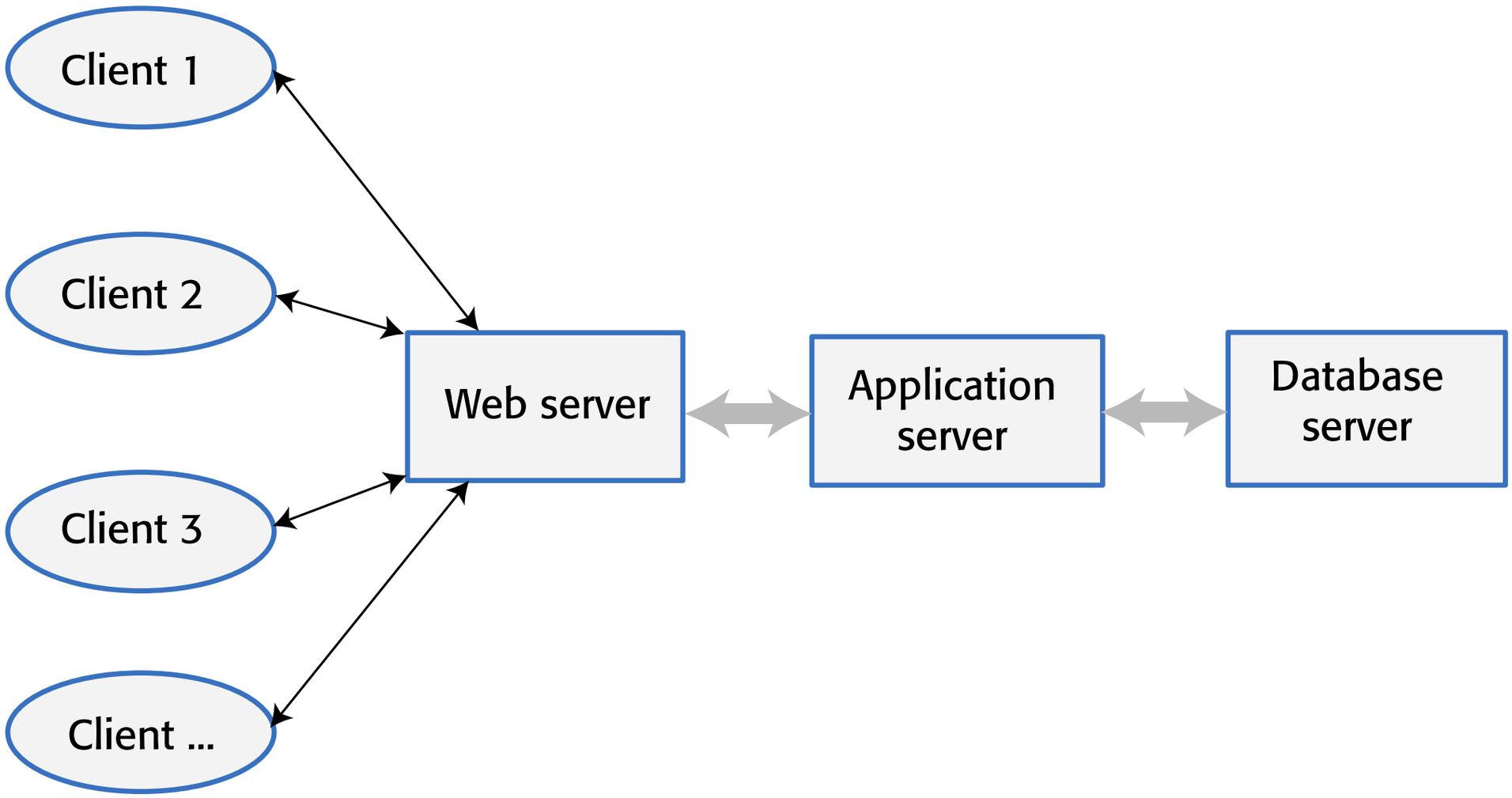
Client-server communication normally uses the HTTP protocol.

- The client sends a message to the server that includes an instruction such as GET or POST along with the identifier of a resource (usually a URL) on which that instruction should operate. The message may also include additional information, such as information collected from a form.

HTTP is a text-only protocol so structured data has to be represented as text. There are two ways of representing this data that are widely used, namely XML and JSON.

- XML is a markup language with tags used to identify each data item.
- JSON is a simpler representation based on the representation of objects in the Javascript language.

Figure 4.14 Multi-tier client-server architecture

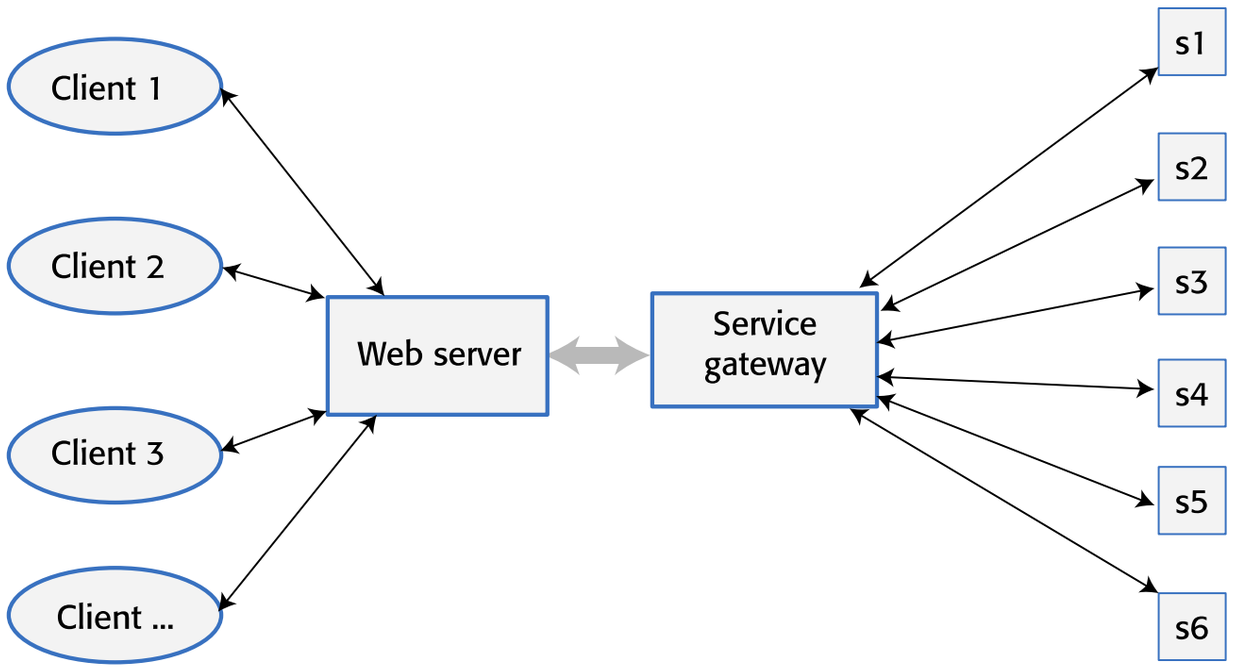


Service-oriented architecture

Services in a service-oriented architecture are stateless components, which means that they can be replicated and can migrate from one computer to another.

Many servers may be involved in providing services

A service-oriented architecture is usually easier to scale as demand increases and is resilient to failure.



Services

Issues in architectural choice

Data type and data updates

- If you are mostly using structured data that may be updated by different system features, it is usually best to have a single shared database that provides locking and transaction management. If data is distributed across services, you need a way to keep it consistent and this adds overhead to your system.

Change frequency

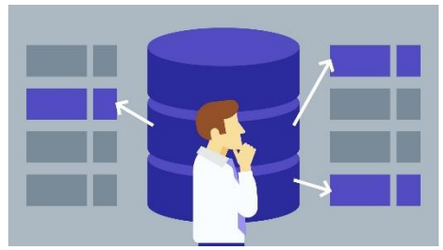
- If you anticipate that system components will be regularly changed or replaced, then isolating these components as separate services simplifies those changes.

The system execution platform

- If you plan to run your system on the cloud with users accessing it over the Internet, it is usually best to implement it as a service-oriented architecture because scaling the system is simpler.
- If your product is a business system that runs on local servers, a multi-tier architecture may be more appropriate.

Table 4.8 Technology choices

Database
Should you use a relational SQL database or an unstructured NOSQL database?

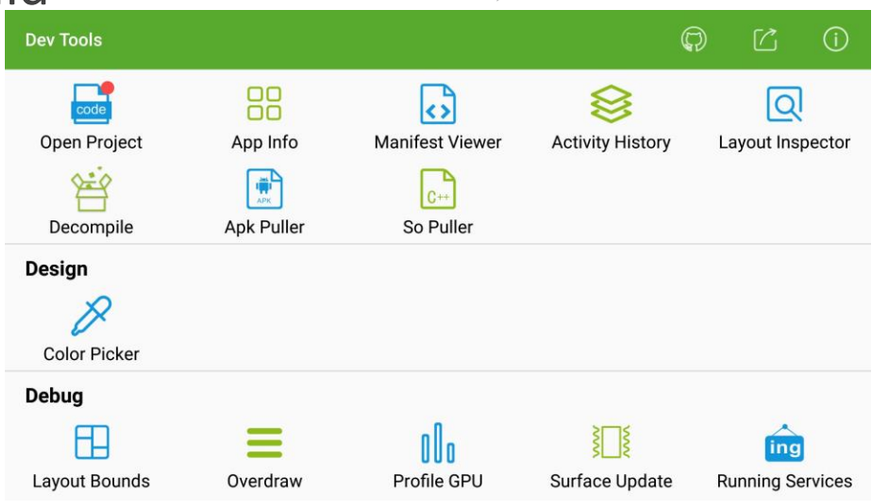


Platform
Should you deliver your product on a mobile app and/or a web platform?

Server
Should you use dedicated in-house servers or design your system to run on a public cloud? If a public cloud, should you use Amazon, Google, Microsoft, or some other option?

Open source
Are there suitable open-source components that you could incorporate into your products?

Development tools
Do your development tools embed architectural assumptions about the software being developed that limit your architectural choices?



Database

There are two kinds of database that are now commonly used:

- Relational databases, where the data is organised into structured tables
- NoSQL databases, in which the data has a more flexible, user-defined organization.

Relational databases, such as MySQL, are particularly suitable for situations where you need transaction management and the data structures are predictable and fairly simple.

NoSQL databases, such as MongoDB, are more flexible and potentially more efficient than relational databases for data analysis.

- NoSQL databases allow data to be organized hierarchically rather than as flat tables and this allows for more efficient concurrent processing of ‘big data’.

Delivery platform

Delivery can be as a web-based or a mobile product or both

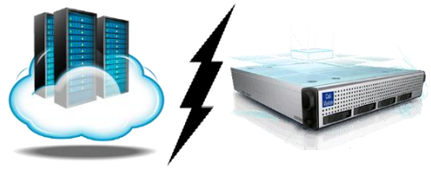
Mobile issues:

- *Intermittent connectivity* You must be able to provide a limited service without network connectivity.
- *Processor power* Mobile devices have less powerful processors, so you need to minimize computationally-intensive operations.
- *Power management* Mobile battery life is limited so you should try to minimize the power used by your application.
- *On-screen keyboard* On-screen keyboards are slow and error-prone. You should minimize input using the screen keyboard to reduce user frustration.

To deal with these differences, you usually need separate browser-based and mobile versions of your product front-end.

- You may need a completely different decomposition architecture in these different versions to ensure that performance and other characteristics are maintained.

Server



A key decision that you have to make is whether to design your system to run on customer servers or to run on the cloud.

For consumer products that are not simply mobile apps I think it almost always makes sense to develop for the cloud.

For business products, it is a more difficult decision.

- Some businesses are concerned about cloud security and prefer to run their systems on in-house servers. They may have a predictable pattern of system usage so there is less need to design your system to cope with large changes in demand.

An important choice you have to make if you are running your software on the cloud is which cloud provider to use.

Open source

Open source software is software that is available freely, which you can change and modify as you wish.

- The advantage is that you can reuse rather than implement new software, which reduces development costs and time to market.
- The disadvantages of using open-source software is that you are constrained by that software and have no control over its evolution.

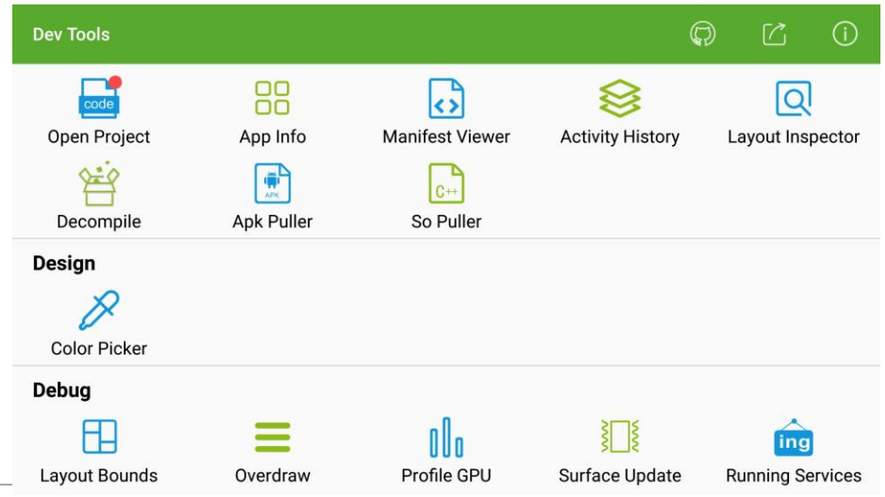
The decision on the use of open-source software also depends on the availability, maturity and continuing support of open source components.

Open source license issues may impose constraints on how you use the software.

Your choice of open source software should depend on the type of product that you are developing, your target market and the expertise of your development team.

https://choosealicense.com/

Development tools



Development technologies, such as a mobile development toolkit or a web application framework, influence the architecture of your software.

- These technologies have built-in assumptions about system architectures and you have to conform to these assumptions to use the development system.

The development technology that you use may also have an indirect influence on the system architecture.

- Developers usually favour architectural choices that use familiar technologies that they understand. For example, if your team have a lot of experience of relational databases, they may argue for this instead of a NoSQL database.

Key points 1

Software architecture is the fundamental organization of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution.

The architecture of a software system has a significant influence on non-functional system properties such as reliability, efficiency and security.

Architectural design involves understanding the issues that are critical for your product and creating system descriptions that shows components and their relationships.

The principal role of architectural descriptions is to provide a basis for the development team to discuss the system organization. Informal architectural diagrams are effective in architectural description because they are fast and easy to draw and share.

System decomposition involves analyzing architectural components and representing them as a set of finer-grain components.

Key points 2

To minimize complexity, you should separate concerns, avoid functional duplication and focus on component interfaces.

Web-based systems often have a common layered structure including user interface layers, application-specific layers and a database layer.

The distribution architecture in a system defines the organization of the servers in that system and the allocation of components to these servers.

Multi-tier client-server and service-oriented architectures are the most commonly used architectures for web-based systems.

Making decisions on technologies such as database and cloud technologies are an important part of the architectural design process.