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a **distributed system** as one in which hardware or software components located at networked computers communicate and coordinate their actions only by passing messages.

Computers that are connected by a network may be spatially separated by any distance. They may be on separate continents, in the same building or in the same room.

characteristics of distributed systems: concurrency of components, lack of a global clock and independent failures of components

Concurrency: In a network of computers, concurrent program execution is the norm. I can do my work on my computer while you do your work on yours, sharing resources such as web pages or files when necessary. The capacity of the system to handle shared resources can be increased by adding more resources

No global clock - computers in a network can synchronize their clocks – there is no single global notion of the correct time. This is a direct consequence of the fact that the only communication is by sending messages through a network

Independent failures: Each component of the system can fail independently, leaving the others still running

Examples of distributed systems

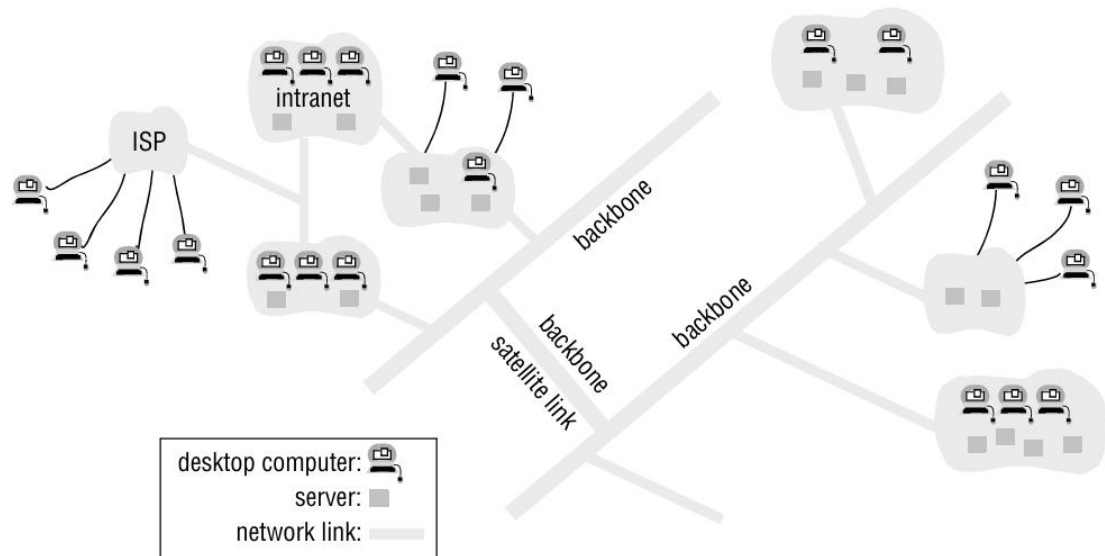
Internet

The modern Internet is a vast interconnected collection of computer networks of many different types, with the range of types increasing all the time and now including, for example, a wide range of wireless communication technologies such as WiFi, WiMAX, Bluetooth and third-generation mobile phone networks. The net result is that networking has become a pervasive resource and devices can be connected (if desired) at any time and in any place.

- illustrates a typical portion of the Internet.
- Programs running on the computers connected to it interact by passing messages,
- The Internet is also a very large distributed system.
- It enables users, wherever they are, to make use of services such as the World Wide Web, email and file transfer.
- The set of services is open-ended – it can be extended by the addition of server computers and new types of service.
- The figure shows a collection of intranets – subnetworks operated by companies and other organizations and typically protected by firewalls. The role of a firewall is to protect an intranet by preventing unauthorized messages from leaving or entering.
- Internet Service Providers (ISPs) are companies that provide broadband links and other types of connection to individual users and small organizations, enabling them to access services anywhere in the Internet as well as providing local services such as email and web hosting.
- The intranets are linked together by backbones.

- A backbone is a network link with a high transmission capacity, employing satellite connections, fibre optic cables and other high-bandwidth circuits.

Figure 1.3 A typical portion of the Internet



Intranet

A portion of the Internet that is separately administered and has a boundary that can be configured to enforce local security policies –

Composed of several LANs linked by backbone connections –

Be connected to the Internet via a router.

Main issues in the design of components for the use in intranet

- File services
- Firewall
- The cost of software installation and support

Mobile and ubiquitous computing

Technological advances in device miniaturization and wireless networking have led increasingly to the integration of small and portable computing devices into distributed systems.

These devices include:

- Laptop computers.
- Handheld devices, including mobile phones, smart phones, GPS-enabled devices, pagers, personal digital assistants (PDAs), video cameras and digital cameras.
- Wearable devices, such as smart watches with functionality similar to a PDA.

- Devices embedded in appliances such as washing machines, hi-fi systems, cars and refrigerators.

- The portability of many of these devices, together with their ability to connect conveniently to networks in different places, makes mobile computing possible.
- Mobile computing is the performance of computing tasks while the user is on the move, or visiting places other than their usual environment.
- In mobile computing, users who are away from their 'home' intranet (the intranet at work, or their residence) are still provided with access to resources via the devices they carry with them.
- They can continue to access the Internet; they can continue to access resources in their home intranet; and there is increasing provision for users to utilize resources such as printers or even sales points that are conveniently nearby as they move around. The latter is also known as location-aware or context-aware computing.
- Mobility introduces a number of challenges for distributed systems, including the need to deal with variable connectivity and indeed disconnection, and the need to maintain operation in the face of device mobility

- Ubiquitous computing is the harnessing of many small, cheap computational devices that are present in users' physical environments, including the home, office and even natural settings.

- The term 'ubiquitous' is intended to suggest that small computing devices will eventually become so pervasive in everyday objects that they are scarcely noticed. That is, their computational behaviour will be transparently and intimately tied up with their physical function.

- The presence of computers everywhere only becomes useful when they can communicate with one another. For example, it may be convenient for users to control their washing machine or their entertainment system from their phone or a 'universal remote control' device in the home. Equally, the washing machine could notify the user via a smart badge or phone when the washing is done.

- Ubiquitous and mobile computing overlap, since the mobile user can in principle benefit from computers that are everywhere. But they are distinct, in general. Ubiquitous computing could benefit users while they remain in a single environment such as the home or a hospital. Similarly, mobile computing has advantages even if it involves only conventional, discrete computers and devices such as laptops and printers.

- shows a user who is visiting a host organization. The figure shows the user's home intranet and the host intranet at the site that the user is visiting. Both intranets are connected to the rest of the Internet. The user has access to three forms of wireless connection. Their laptop has a means of connecting to the host's wireless LAN. This network provides coverage of a few hundred metres (a floor of a building, say). It

connects to the rest of the host intranet via a gateway or access point. The user also has a mobile (cellular) telephone, which is connected to the Internet. The phone gives access to the Web and other Internet services, constrained only by what can be presented on its small display, and may also provide location information via built-in GPS functionality. Finally, the user carries a digital camera, which can communicate over a personal area wireless network (with range up to about 10m) with a device such as a printer.

Portable and handheld devices in a distributed system

