Star networks have made a comeback in the realm of **local area networks**. A hub is placed at the center of the star and receives the data from many computers. Each computer has a private line of, for example, 10 Mbps to the hub. The hub can route messages from one computer to the other and can also connect the star to a very fast communication channel, with a speed of, for example, 1000 Mbps. In this way, each workstation needs only cheap twisted-pair cabling, while the communication out of the star is made using a more powerful network (e.g., gigabit Ethernet running over optical links). This would be an example of a hybrid topology, in which different segments of the network use different standards and transmission speeds as well as topology.

The most all-purpose type of network topology is a *general graph*, in which any node can be connected to any other node using private lines. This is the architecture of the **Internet**, in which local area networks are connected together in a general graph without any special structure. When a packet is to be sent over the network, it has to be routed by the computers at the nodes, which collaborate at this task. One approach that can be used to route packets over general graphs is to superimpose a *virtual topology* on the real network. A protocol is started at the nodes, and through the exchange of some messages, a *spanning tree* is found. This is a structure in which one node (the root) communicates with some children nodes, which in turn have other children nodes, and so on. In a tree, there is only one communication path from each node to any other (the packet from one node goes up to a common parent and then down to the destination node). The tree is spanning, because it covers all nodes in the network. Using this approach, once the spanning tree has been built, it is very easy to route messages. If one communication link fails, the spanning tree has to be rebuilt.

In the case of clusters of processors used for parallel computing, there are many other types of network topologies such as *mesh*, *torus*, and **hypercube**. Computers connected in a mesh are arranged in a quadratic grid, with the machines sitting at the crossings of the communication lines. If the upper and lower boundary, as well as the left and right boundary, are glued together, we obtain a torus, a doughnut-shaped structure. In a hypercube, the computers sit at the corners of three-dimensional cubes and the edges are the communication lines. Cubes in higher dimensions (hypercubes) provide more communication paths and place for more machines.

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—*Raúl Rojas*

Torres Quevedo, Leonardo

1852–1936

Spanish Engineer

Leonardo Torres Quevedo is the most renowned Spanish engineer of the twentieth century. He made important contributions to **cybernetics** and to the emerging field of computing; he is especially remembered for his **analog computers** and for his written description of a plausible **digital computer**.

Torres Quevedo published his first scientific paper in 1891 and began a 30-year period of intense activity in which he worked on many different projects. He conceived a new type of Zeppelin and, in 1905, built the first Spanish prototype. He experimented with radio control of boats and machines, a technique he called *Telekino*. Torres Quevedo also built several analog computing devices. One of them was his *algebraic machine*, an analog device that could find the roots, real or complex, of algebraic equations of up to eight terms. Moving parts were used to represent numbers in scales that could be linear or logarithmic.

The automatic chess player built by Torres Quevedo in 1912 aroused great interest across Europe. It could

play an endgame scenario against a human opponent: The **automaton** played with the black king and rook, the human with a white king. The chess player used a mechanical arm to move the chess pieces and sensors in the board to identify their positions.

Perhaps Torres Quevedo's greatest invention was one he left unfinished. In his 1913 memoir *Ensayos sobre Automática* (Essays on Automatics), he described a digital computer that would be capable of storing decimal numbers and performing binary operations. The machine would be controlled by a program, which could include conditional branches, that would be stored in a drum. The memoir also contains the first published description of **floating-point** arithmetic. Torres Quevedo did not build this machine, but his *electromechanical arithmometer*, exhibited in Paris in 1920, could perform the basic arithmetic operations on numbers typed at a **keyboard**, and print the result. The electromechanical components were similar to those described in the memoir and were many years ahead of their time.

BIOGRAPHY

Leonardo Torres Quevedo. Born 28 December 1852 in Santa Cruz de Iguña, Spain. Degree in civil engineering, 1876. Published his first scientific paper, 1891. Appointed as head of the Laboratory of Applied Mechanics, Madrid, 1901. Medal of the Spanish Science Academy, 1916. Exhibited his electromechanical arithmometer in Paris, 1920. Elected member of the French Academy of Sciences, 1927. President of the Spanish Academy of Sciences, 1928. Died 18 December 1936 during the Spanish Civil War.

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—*Raúl Rojas*

Torvalds, Linus

1969–

Finnish–U.S. Software Developer

Linus Torvalds is best known as the creator of the **Linux** operating system **software** and a major figure in the **open source** software movement. Born in Helsinki, Finland, Torvalds cites his country's public education as a major factor in his decision to create high quality freely distributed software.

Linus Torvalds's story began in 1991 when he was a computer science student at the University of Helsinki. Many of the programming assignments for his university classes required using the **Unix** operating system. Frustrated with having to rely on university computing facilities, he investigated the possibility of running Unix on his home computer. Cost made this prohibitive, with Unix software selling for U.S.$5000 and the workstation needed to run it selling for almost U.S.$10,000. Torvalds saw this as a challenge and set about to create a Unix clone that would run on his desktop computer.

Early in 1991, Torvalds created an operating system kernel he called Freax, short for "free Unix," that worked on desktop **personal computers**. He decided to post his creation on the **World Wide Web** and make it freely available to other users wishing to experiment with Unix. The Web site's **FTP** manager didn't like the name *Freax* because it reminded him of "freaks," which is sometimes a synonym for "computer hacker." He named the FTP site Linux, which was the label Torvalds had used during development. In October 1991, Torvalds released Linux .02, the first functional