networks

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A network is a set of connections (links) between nodes. A two-way network allows the links to be operated in both directions, whereas a one-way network has distinct directionality. Two-way networks include railroads and telephone systems.

Figure 1 shows a simple star network, where A can communicate with B through a switch S. B can also communicate with A by reversing the direction of the link (viz. a telephone call). In Figure 1, we have eight nodes (A through G) linked through a switch S. If this were a two-way network, AB and BA would be distinct products (different telephone calls, different rail journeys). The total number of products in the network would be 56, that is, $n(n-1)$ where $n =$ the number of nodes. If there were to be a ninth member (the dotted lines to H in Figure 1) this would increase the total number of products to 72 (n is now 9), a total increase of 16 products available from the expanded network. If the value to each user of being in the network is proportional to the number of users then the value of this network has just increased by 28.5% (16 as a % of 56) even though the size of the network has increased by only 12.5% (one added to eight).[1] This is an algebraic characteristic of network economies of scale that the value rises disproportionately higher than the increase in network size as long as prices are constant and products are independent. Intuitively we might expect that beyond a certain size an increase in network size beyond a certain point has little value.[2] If this network were a one-way network there would be half the number of products, but the value of the network would, nevertheless, increase at the same rate but achieving only half the extra value.

The analysis of complementarity is equivalent to the analysis of a one-way network. Figure 1 can be extended as in Figure 2 to show a typical one-way network. Here, we can interpret the A_i as automatic teller machines (ATMs) and the B_j as banks. The network runs only from A to B. The significance of the two switches S_A and S_B is that they have only one link. This means that there is compatibility between all ATMs and all banks. This maximizes the value of the network but increases the competition between banks for customers through ATMs.[3] It is this compatibility that makes the complementarity actual and the network operational. For complex products, actual complementarity has to be achieved through adherence to specific technical standards. Other complementary products can be visualized in terms of Figure 2. Blu-ray disks and Blu-ray players could be the B_j. Think also of copier paper and copiers, or printer paper and printers, or car accessories and cars, or local and long distance telephone networks.

Networks can be real or virtual. Real networks are found in industries such as telephony and railways, where a physical network is present. Virtual networks are typified by computer and software platforms, where the interconnection between users is intangible.

In real networks the interconnection between users is tangible. Examples are cable networks for telephone users and radio transmissions in mobile phones. Electricity grids, telecommunications networks encompassing telephones, fax machines, online services, and the Internet are typical examples of products or services within real networks. There are one-way networks, such as broadcast television, where information flows in one direction only. In two-way networks, such as railroads and telephone systems, links are operated in both directions. Any network may be viewed as a set of connections (links) between nodes. A two-way network allows the links to be operated in both directions, whereas a one-way network has specific direction. Two-way networks include railroads and telephone systems.

In virtual networks the interconnections between users are intangible, but users remain interdependent. Relatively new, yet ubiquitous virtual networks are online social networks such as Facebook and Linkedin. Operating systems are typical of virtual networks. For example, Mac users are part of the Mac network, with Apple as the sponsor of the network. Mac users are locked into a network determined by the technology standard of this platform. They can only use software that is compatible to the system and can exchange files with users within the system. Operating systems such as Windows and Unix are other examples of virtual networks.

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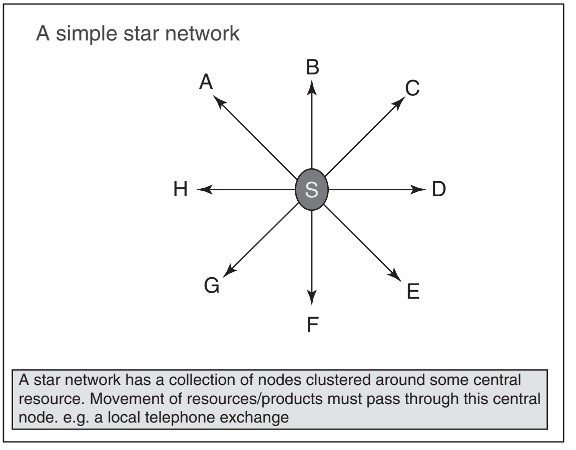

Figure 1 A two-way network.

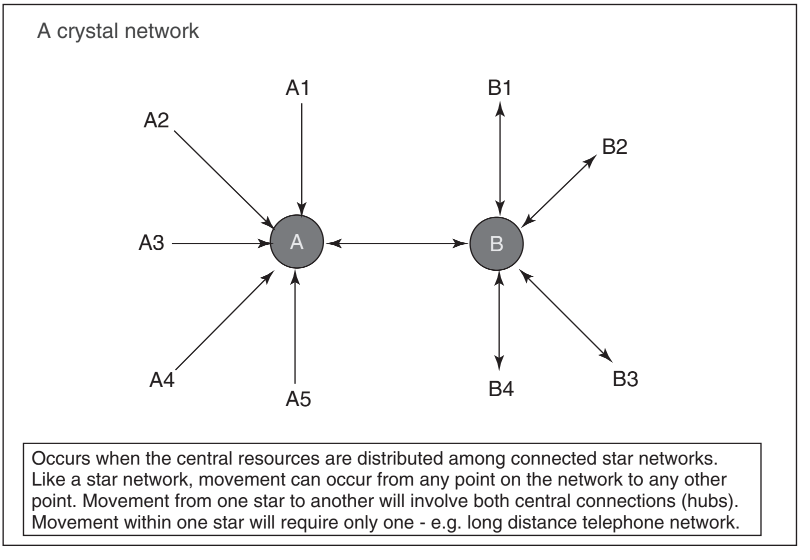

Figure 2 A one-way network.

Virtual network dynamics also operate in the entertainment industry for Sony Playstation, Microsoft Xbox, and Nintendo's Gamecube networks.

Network size is still important in virtual networks in that a large consumer base makes production viable and usage possible. In addition, the value of a product increases as the number or the variety of the complementary goods or services increases. Indirect network effects in the computer industry are referred to as the hardware–software paradigm. The success of an operating system for personal computers depends on the variety of software applications available in the market. Value may depend more critically on software applications.

The strategic relevance of recognizing network products is that they are ruled by a specific set of market dynamics. Network products benefit from the mechanism of network effects (also referred to as network externalities) that fuel rapid adoption, evident in the take off of the Internet, the Windows platform, iTunes, and Gmail. Network effects are defined as the increasing utility that a user derives from consumption of a product as the number of other users who consume the same product increases. Success breeds even more success for network products. The more users adopt a network product, the more likely it is that others will follow, as was the case with mobile telephones, Office software, and the Apples suite of iPod, iPhone, and iPad products. Network effects are the new drivers of the network economy (*see* NETWORK EXTERNALITIES).

The principle of network effects also applies to products with high brand equity, where the success of the brand tends to bring further success in terms of distribution, adoption, and high market share. The network in this case is made of the interaction of the brand, the distribution channel, and the consumer base. A high market share brand is likely to be carried in more stores, which increases the probability of a brand being accessible to consumers for trial and for repeat purchase. The higher a brand's equity, the more likely it is to benefit from another company's marketing, while its own marketing is likely to have a smaller effect on sales of other brands. The concept of "double jeopardy" implies that larger networks have more subscribers, who have a higher level of usage and who are more likely to retain their subscription. This mechanism demonstrates the characteristics of increasing returns, whereby the more successful companies enjoy even more advantages. Companies with consistent brand identities are higher performers, exhibiting higher growth rates, which are sustained over an extended period of time.

Networks have been the subject of research in economics, which provides the theoretical framework of network effects and innovation diffusion. More recently, networks are being analyzed from the perspective of complexity theory (*see* COMPLEXITY THEORY), which adds a dynamic dimension to the subject. It provides an understanding of how networks of interacting agents (such as hardware platforms, software platforms, and consumer platforms) evolve and flourish through the collective behavior of adaptation, cooperation, and self-organization. What complexity brings into the equation is a set of insights on how to encourage the growth of networks by adopting the features of complex adaptive systems (*see* COMPLEX ADAPTIVE SYSTEMS) to create more responsive and agile organizations. These are precisely the principles that have been adopted intuitively or intentionally by some of the world's most widely diffused networks, namely, Google's search engine, eBay's many-to-many retail business and Facebook's social network.

See also *complementary products*; *critical mass*; *network externalities*; *network industry strategies*

Endnotes

[1] Assuming for convenience in this example that prices are constant.

[2] Using calculus we would expect the first derivative to be positive but the second derivative to be negative. Therefore, total value increases but at a decreasing rate.

[3] Two complementary components A and B are compatible when they can be combined to produce a composite good. A VHS player is compatible with VHS tapes. Two substitute components A_1 and A_2 are compatible when each of them can be combined with a complementary good B to produce a composite good. Thus two VHS tapes are compatible, and two VHS players are compatible.

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