PART II

INSTITUTIONAL AND ORGANIZATIONAL FACTORS FACILITATING ENTREPRENEURSHIP AND INNOVATION

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Venture Capital and the Local Area Networking Industry

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Venture capitalists have been and continue to be important actors in facilitating the creation of new firms in Silicon Valley. In some cases, the combined effect of creating a number of firms undertaking similar activities can lead to the creation of an industry or what Joseph Schumpeter (1968) termed a 'new economic space'. One recent and important instance of new firm formation leading to the creation of new industry is the case of local area networking (LAN) in the USA. In the USA there are only two significant concentrations of LAN firms: Silicon Valley and Route 128. Because Silicon Valley has the largest concentration of firms and the first firms were established there, this chapter concentrates upon the developments in Silicon Valley.

The fact that a new technology becomes established in a set of specialized firms and a free-standing industry is often treated as unproblematic or natural. But the manner by which a technology is embedded in social institutions is not predetermined. Often, new technologies do not escape established firms to become the basis of independent firms. At other times, the technologies do escape.[1] If the technology is to be exploited by a set of new firms, then these firms and the space they will occupy needs to be constructed. In the USA in a number of newly introduced technologies, a group of financial intermediaries, the venture capitalists, have come into being to fund the firm-creation process. Venture capital enables entrepreneurs to construct their economic space.

The role of venture capitalists in the creation of the LAN industry is particularly interesting because the LAN paradigm combined with the personal-computing movement to overthrow the traditional computing model of dumb terminals linked to central computers. In the mid-1970s, only a few engineers envisioned the overthrow of the dominant computing paradigm with an alternative of distributed computing power linked by a network.

This chapter will combine insights from two theories to help understand the activities of the venture capitalists. The social construction of technology (SCOT) paradigm directs our attention to the role of human volition and decision-making in the process (Bijker *et al*. 1987). There are difficulties with the SCOT perspective because it underplays the importance of the firm, its routines, and the drive for economic gain in its analysis of the social construction process. However, the emphasis of the SCOT adherents on micro-level decision-making provides a rich paradigm for understanding how actors construct a technoeconomic system. The other useful paradigm for understanding the context of venture capital financing decisions is broadly contained under the dominant design school (see Abernathy 1978 for an early exposition). For the most part, these two intellectual strands attempting to explain technical change have remained separate, perhaps in part because the dominant design paradigm is common to management schools and economists, while the SCOT paradigm is strongest in sociology departments. We believe combining these approaches can offer a more powerful lens for understanding technical change.

This chapter begins with an overview of the SCOT and dominant design perspectives. The second section describes the role of venture capital in the new firm formation process. In the third section the pre-dominant design environment, in which various actors were trying to actualize LAN technology as an economic proposition, is described. At the pre-dominant stage securing venture capital is difficult because of the high uncertainty on many dimensions. Particularly, significant from the perspective of the venture capitalists is the difficulty of quantifying both risks and rewards. There are few benchmarks and thus no adequate way to evaluate a technological opportunity.

The fourth section discusses the impact on venture capital decision-making of the Xerox announcement opening the Ethernet protocol, the gradual acceptance of Ethernet as the standard, and the recognition that the largest market for LAN connections would be personal computers (PCs) and workstations. The fifth section discusses the role of venture capitalists in funding the final critical innovation, the hub in the creation of the Ethernet LAN. The final discussion reflects upon the role of venture capital in supporting the construction of the LAN industry.

Constructing Firms and Industries

Social scientists, at least, as long ago as Schumpeter (1964, 1968), recognized the role of technical innovation as a powerful trigger for new firm formation and, in some cases, the basis of new industries. A direct successor of the

Schumpeterian model for explaining technological innovation and industrial organization is the dominant school associated with William Abernathy (Abernathy 1978; Abernathy and Utterback 1978; Abernathy and Clark 1985). Abernathy and his colleagues coupled Schumpeterian insights with product-cycle theory, observing that at different stages in a product's life cycle different types of innovations and industrial organization were prevalent. The cycle begins with a discontinuity resulting from a technological development that creates an environment with low entry barriers facilitating new entrants and much experimentation and uncertainty. In these periods it is difficult to forecast demand, prices, or even the eventual technological outcome (Tushman and Anderson 1986). Alternative solutions are introduced and there is hesitation on the part of consumers because they are unsure which design or architecture will triumph. At this point financial backing can prove critical to small firms created to exploit the innovation. Often, they require capital to grow quickly and occupy the new economic space before larger established firms enter the market.

In the case of most technologies the period of ferment ends and a dominant design becomes the standard. Frequently, this is accompanied by a shake-out in the number of firms in the now more stable industry. At this stage innovation often shifts to incremental product and process innovations and generally there are fewer opportunities for successful venture capital investment—though this may not always be true, especially in situations in which the product innovations, though incremental, can entail significant improvements in cost/performance ratios.

The dominant design paradigm is definitely useful for periodizing the life cycles of a technology or artefact. However, the dominant design model is structural and pays little attention to the activities of individuals and firms that actually act to construct or enact the dominant design. The SCOT perspective provides a remedy for the mechanistic aspects of the dominant design paradigm by arguing that technology and its adoption are a social construction (Bijker *et al*. 1987). Misa (1994) observed that the macro-level forces detected when analysing technological evolution in broad terms are not nearly so visible at the micro-level. For them, a closer examination of the black box of technology development and adoption reveals that the dominant design is the product of an interaction between its social environment and technological development—with neither dominant. Rather than it being invented or innovated, it was more accurate to say that an artefact and, by extension, its market are socially constructed. In this sense, the social construction of technology is the creation of networks including various actors and even artefacts themselves. Within these networks there is an interactive bargaining process from and through which an acceptable artefact emerges (Cowan 1987; Bijker 1993).

The social constructionist story is one of contingency. Actors are not omniscient, but rather construct their future even though they are boundedly rational—that is, they have only an idea of what the future might be like, what the result of their actions might be, and the future they want to create. In this more uncertain environment, technological evangelism becomes as important as having the 'best' technology. Recruiting supporters, be they customers, financiers, other producers, or suppliers, is a critical activity.[2] When a firm is created, one prerequisite is financial backing. Inadequate capital makes it difficult to recruit, not only material resources, but also suppliers, legal assistance, and personnel. The social construction process differs in the magnitude of effort between pre-dominant and dominant design phases. As we shall see, the calculations of the venture capitalists also differ when a dominant design exists.

Venture Capital as an Institution

A striking feature of the post-war US national system of innovation (Lundvall 1992; Nelson 1993) has been the emergence of a set of financiers, the venture capitalists, specializing in providing the financial capital to allow entrepreneurs an opportunity to create a 'new economic space' (see Wilson 1985; Bygrave and Timmons 1992).[3] Traditionally, an entrepreneur seeking to establish a firm was required to tap informal sources, such as family, friends, and wealthy individuals. Financial institutions, such as banks or stockbrokers, were not generally organized to take risks on firms with little or no collateral. Venture capitalists play an important role in new firm formation where rapid market entry is necessary and explosive growth is a possibility. The sector most consistently exhibiting such growth potential has been high-technology electronics and it has received the most venture capital, though other fields such as medical instruments and biotechnology have also benefited from significant venture capital.

The limited partnership is the institutional form through which most venture capitalists operate. The limited partners, institutions such as university endowments, pension funds, and wealthy individuals, provide the capital. The general partners—that is, the venture capitalists—receive an annual management fee of between 2 and 3 per cent of the total capital in the partnership and approximately 20 per cent of the capital gains after the investor's initial investment has been returned. The investors are, of course, seeking the high capital gains that can accrue, if the ventures funded grow dramatically.

Venture capitalists aim to be at what the venture capitalist Bandel Carano (1995) termed 'the intersection of a dislocating long-term advantage and an explosive or compelling market application'. This is illustrated best by listing some of the greatest investment hits: Amgen, Apple Computers, Cisco

Systems, Data General, DEC, Federal Express, Genentech, Intel, Netscape, Oracle, Silicon Graphics, Sun Microsystems, Tandem Computers, and 3Com (Kenney and von Burg 1997). These discontinuity points are where new industries and dominant firms that might experience explosive growth can be found. At the level of the individual investment, venture capital investing is risky. It is commonly held that, for every ten investments, three or four are complete losses; another three or four are not losses, but it is difficult to extract the capital as the firm neither fails nor succeeds. The final two investments are the key to a fund's success. These are the investments returning anywhere from 10 to 100 times the original investment. In effect, the positive capital gains from these home runs cover all losses. In general, the larger the number of quality investments, the greater the possibility of funding one of the home runs.

The venture capitalist's dilemma is to balance between errors of omission, not investing when one should, and errors of commission, investing when one should not. Frequently, the greatest successes are those in which the market growth is unforeseen by other investors, because, if success can be foreseen, the true value of the firm can be judged. Of course, it is also true that those 'foreseeing' the future have a high likelihood of being wrong.

The role of venture capital goes beyond simply making a passive investment. Because venture capitalists are actually company owners by virtue of their equity, they have direct input into critical firm strategy decisions. Invariably, the venture capitalists demand representation on the firm's board of directors and, in some cases, even become the chairman of the board. Venture capitalists actively try to affect the outcome of their investments by offering advice, providing contacts such as law firms, commercial real-estate brokers, and potential customers, assisting in corporate recruiting, becoming involved in critical corporate decisions, and various other tasks. Also, veteran venture capitalists have witnessed first hand the difficulties and transitions fast-growing firms experience, which allows them to provide advice or even introduce the entrepreneurs to other entrepreneurs with experience in similar situations.

In the case of the Silicon Valley LAN industry, venture capitalists played an important role by selecting which firms should receive funding. Through their decision-making they validated the efforts of specific entrepreneurs and, by not acting, frustrated the efforts of others. As we will show, the venture capital process also evolved with the industry, in the sense that in the pre-dominant design stage securing venture investors was difficult and time-consuming. Later, when the dominant Ethernet design had been selected, the venture capital decision process changed and the investment decision centred upon whether the new firms had a commercially viable improvement for the Ethernet standard. With the LAN industry established and Ethernet as the dominant standard, there was less uncertainty and the social construction process was concomitantly simplified.

Background

In the 1960s, owing to the cost and complicated nature of computers, there were only a few sites boasting more than one computer, so there was little need for a LAN. Most computer connections were between remote sites or what are called wide area networks (WANs). The growth of WANs was supported by significant investment from the US Department of Defense, which wanted to link various computers into integrated systems and firms and began to link computers at distant sites using modems. By 1970 the number of computers had increased and more institutions had multiple computers at a single site. This increased interest in developing networks to interconnect those computers with higher-speed networks than were available using the telephone system and modems.

By the late 1960s, some electronics executives and engineers understood that the ability of computers to process, store, organize, and communicate information quickly could provide the technical means to create an 'office of the future'. In the 1970s, Wang Computer began to exploit this opportunity and experienced very rapid growth by providing word processors networked to a minicomputer (Kenney 1992). Other firms, such as IBM and DEC, also sought ways to computerize the office by integrating various devices into an office automation system. These companies based their activities on the model of a relatively large central computer serving dumb terminals with shared peripherals, such as printers and data storage devices.

Xerox was particularly interested in office automation, because its entire business was based on the office copier and its executives worried that the new computer-based developments might replace the copier. And yet it had no vested interest in large central computers, so it could think outside the conventional computing paradigm. In 1970 Xerox established a centre in Palo Alto to conduct research aimed at creating an 'office of the future' (Pake 1985). Xerox Palo Alto Research Center (PARC) researchers developed a new model based on each office worker having a desktop computer or what they called a 'workstation'. Here, the PARC researchers recognized the continuing tendency of computers to shrink in size and cost and believed this would permit every office worker to have a desktop computer. To actualize this vision PARC engineers designed and built a desktop computer, the Alto. In this new electronic office, then expensive peripherals, such as laser printers, would be shared, so it was also necessary to connect these workstations to other computers, storage devices, printers, and information-processing peripherals. For this purpose they developed a LAN including a set of rules or protocols for information transmission and reception that the inventor, Robert Metcalfe, named Ethernet (Bell 1988).

Xerox was not alone in experimenting with computer networks. Companies such as DEC, IBM, and Wang were also designing networks. Curiously, the oil company Exxon, flush with windfall profits generated by the 1974 oil crisis, decided to invest in the 'office of the future'. To do this, in November 1974 Exxon funded Federico Faggin and Ralph Ungermann, both Intel alumni, to establish Zilog in Cupertino, California (LeBoss and Marshall 1981). Faggin had already played a critical role in designing Intel's microprocessor architecture. Already in the 1970s Faggin foresaw a new computing architecture based upon microprocessor-based computers connected to networks: 'This new [computer system] architecture that could best take advantage of VLSI technology would be highly parallel in the sense that it would include a number of more or less independent processors and other resources, all interconnected to permit communication among elements of the architecture' (Faggin 1978: 29). From experience, both he and Ungermann believed the cost of microprocessors would decrease dramatically and make it possible to have a microcomputer on every office desk (Jackson 1997: 117). They followed this line of thought further, concluding that the then dominant design of computing based on central computers and dumb terminals would become obsolete and the dominant computing architecture would be based upon microprocessor-based small computers interconnected by a high-speed network.

Initially, Zilog focused on microprocessors and developed the Z-80, a popular 8-bit microprocessor used in the Radio Shack TRS-80, Kaypro, and Osborne I computers (Langlois 1992). In the mid-1970s, Zilog began developing a LAN based on its already successful communications peripheral chip for input/output devices (Ungermann 1996). To facilitate this development, it hired a group of engineers including Charles Bass to develop a network. Zilog then developed not only an operating system called Leo for controlling a number of microprocessors, but also a personal computer LAN, the ZNet. However, ZNet had technical problems and could not be marketed successfully.

In the late 1970s Exxon's interest in Zilog waned, the company weakened, and leading engineers began to leave. Zilog was to become an important source of LAN industry entrepreneurs. In 1979 Ralph Ungermann and Charles Bass left. Then, in 1981, William Carrico, Judith Estrin, and Eric Benhamou left to establish Bridge Communications. Kanwal Rekhi, hired by Zilog to continue the work of those who left for Bridge Communications, left within a year to found Excelan. Zilog, an innovative failure, seeded the Silicon Valley with LAN entrepreneurs (*Data Channels* 1983).

Initial LAN research was contained within various established firms, the preponderance of which were not in Silicon Valley, but throughout the country and the world. The established companies such as IBM, Xerox, DEC, and Datapoint in Texas concentrated their efforts on developing proprietary networks to link their own computers and exclude others from the network. The size of the LAN industry, quite naturally, is determined by the number of computers in existence to be networked. To use a metaphor, they are the substrate upon which the LAN rests. Through time, as this substrate changed its composition—for example, from mainframes to minicomputers to PCs, computer density increased and opportunities arose for the creation of LAN firms to service each new class of computers. Since each new class of computer was smaller and less expensive than its predecessors, more computers were sold and the market for connections grew dramatically.

Venture Capital and the LAN Pioneers

In the 1970s venture capitalists were already funding some computer networking start-ups seeking to establish time-sharing systems and factory-automation networks. The number of investments and the amount invested was modest, and, for the most part, these start-ups had modest returns. The only pure LAN company that was funded was Network Systems in Minneapolis, established in 1974 to network mainframes. After nearly two years, it received financing in 1976 from Norwest Venture Capital Management. Network Systems would grow in step with its customer base, mainframe computer users, but, even though successful, its growth was limited by its base in mainframe computers.

In 1979 the potential for LAN technology appeared limited because the existing installed base of minicomputers and mainframes was small, but there were customers. For example, General Electric retained Ungermann-Bass (U-B) to upgrade the throughput of its existing connections by replacing the telephone lines and modems by a LAN. But, venture investors generally do not fund consulting firms, instead they favour firms intending to deliver products. There was great uncertainty regarding the market, technology, standards, and competitors. Risk was high so ultimately the primary investment criteria were acceptance of the entrepreneur's vision of the evolution of computing technology and the faith that a market would emerge. For the venture capitalist, this meant several leaps of faith in a world at that time dominated by IBM, closed computer systems, and few computer LANs.

Ralph Ungermann and Charles Bass left Zilog and established U-B in July 1979. Their strategy was to start a company in a field with great potential but no entrenched competition. They also recognized the need to avoid an extended pioneering effort (*Electronics News* 1980: 17). This strategy, though excellent from an entrepreneurship perspective, made it difficult to secure venture capital, since there were no benchmarks with which to evaluate the market and value the company. Similarly, there was no agreement on the protocol or standard to be used. Further, there was no way to predict which protocol would be adopted and few observers believed a start-up would successfully induce larger players to adopt its protocol. According to Ralph Ungermann (1996), 'Everybody in the venture community turned us down because they believed that the ISO [International Standards Organization] standard was coming and the computer companies would build the network that would interconnect each other's equipment. So, there [would be] no room for a stand-alone networking company.' In other words, the venture capitalists could not envision an economic space. Therefore, despite his record as a leading Intel engineer and co-founder of Zilog, Ungermann (1996) contacted virtually 'every venture capitalist in the United States and in the world really' with little success. It took eight months before U-B could close the investment.

U-B developed a proprietary LAN system and marketed it to companies interested in connecting minicomputer and mainframe systems through the use of smaller terminal server computers. In effect, in the early period U-B was operating in near total isolation, with very few competitors, but also no environment or infrastructure upon which to draw. As an example of the difficulties, few chip firms were willing to design integrated circuits for such a small company. Things changed dramatically when Xerox announced it was licensing the Ethernet protocol; U-B immediately declared it would purchase a licence and offer Ethernet products.[4] Since DEC, the largest minicomputer vendor, and Intel, an already well-known integrated circuit company, also backed Ethernet, this provided credibility for U-B in the minicomputer market.

It was hardly surprising that venture capitalists saw little prospect that large capital gains could be made funding LAN start-ups. However, the East Coast venture firm Bessemer Securities committed to invest in U-B, if a co-investor could be found. In December 1980 another venture capitalist, James Swartz, attended a McGraw-Hill Conference on data communications in New York, where Robert Metcalfe, formerly of Xerox PARC and the inventor of Ethernet, presented a seminar and proselytized for the adoption of the Ethernet protocol. On one slide there was a list of the small companies adopting Ethernet, which included U-B. Since Swartz, a former Citicorp venture capitalist who had left and formed a partnership with Fred Adler, was interested in computer networking, he decided to visit the listed companies (Swartz 1995).

Swartz was uniquely prepared to see the potential of LANs because he had made an earlier investment in Amdax, a company trying to commercialize a broadband technology for factory automation. Soon after the investment, the founder had died, and Swartz had managed Amdax until a successor could be found. As the temporary CEO, he had become acquainted with the potential for computer networking.[5] So, by the time he visited U-B, he was primed to make an investment. Swartz (1995) recalled his meeting with the two founders:

> I met Ralph and Charlie [and discussed their business]. At the end of the day I said, 'Jesus, this is terrific. I really like what you guys are doing. You are absolutely right on everything. I can tell you I want to do this.' So, I called Fred [Fred Adler, his partner] that evening and told him what I was doing. He said, 'Fine, go do it.' And, so that evening or the next day, I called Ralph and committed to him.

Since Bessemer Securities had already committed to invest in U-B, the deal was quickly finalized, with Oak Investment also joining (Ungermann 1996). Swartz, Neil Brownstein of Bessemer Venture Partners, and Stewart Greenfield of Oak Investment Partners invested an initial $1.5 million in February 1980. All of these venture capital partnerships were East Coast firms. In total, the investors committed $10 million before the company went public in June 1983 with a total valuation of $48 million (Hofmeister 1989).

For investments in sectors where there is no industry and no market, there are questions about what information is valuable and how does one gather it. In the case of U-B, Swartz (1995), when asked whether in the due diligence process he contacted personnel in large companies, such as IBM, DEC, or Xerox, said, 'If I had tried to do that kind of due diligence, I would have been absolutely convinced that [the U-B investment] was something I should not do.' Since Swartz had some idea of the potential inherent in the technology, he described the decision-making process in this way: '[The investment] became a people thing, who [the founding team] are and what they have done—classic résumé tracking. And then it becomes a very gut level feel of, "Gee, are these credible people? Do they have the right integrity and right ethics?"' He believed in the founders, Ralph Ungermann and Charles Bass, and decided to invest.

In this period, securing venture capital was not a foregone conclusion. A counter-example was the pioneering firm Nestar, established in October 1978. Its founders, Harry Saal and Leonard Shustek, were inspired by the feverish experimentation with microcomputers in the Silicon Valley area (for a description of this environment, see Freiberger and Swaine 1984). At the time, Saal was working at the IBM Palo Alto Laboratory and then later the IBM Santa Theresa Laboratory, where he developed interactive time-sharing systems for mainframes. From there he followed the development of the early microprocessors and the initial microcomputers built by hobbyists in Silicon Valley. The computing power and responsiveness of what many thought were simply toys impressed them. But Saal and Shustek recognized that an important limitation for these microcomputers was that peripherals such as hard-disk drives and printers were too expensive.[6] They were intrigued and became 'interested in the idea of building large distributed systems of personal computers, networking them, and connecting them together' (Saal 1995). He tried to convince IBM to let him work on these ideas, but IBM was uninterested. So Saal resigned and started Nestar, a company dedicated to building microcomputer LANs.

In 1978, while building a first LAN prototype for the Commodore PET, Nestar tried fruitlessly to raise venture capital in the Silicon Valley and New York. The venture capitalists expressed little interest. Saal recalled,

> I think they really did not believe that these types of computers would ever be used in a real commercial-type environment or that people would have large numbers of them networked together. I got a fantastic rejection from all of them. They said this [company would] not go anywhere, that these toy computers were never going to be serious and if they were serious, nobody would have many of them at a time together. (Saal 1995)

The venture capitalists further questioned the reasons why IBM did not invest, if his idea was so good.[7] Only later did Nestar receive capital from the Rank organization in the UK.

Nestar was too early. To be legitimated in the business world, the microcomputer would have to wait until IBM introduced the PC. The microcomputer was still the province of hobbyists and there was not yet a large installed base (see Fig. 6.1). Nestar never had sales of more than $10 million and was eventually merged with another company and closed in 1986.[8]

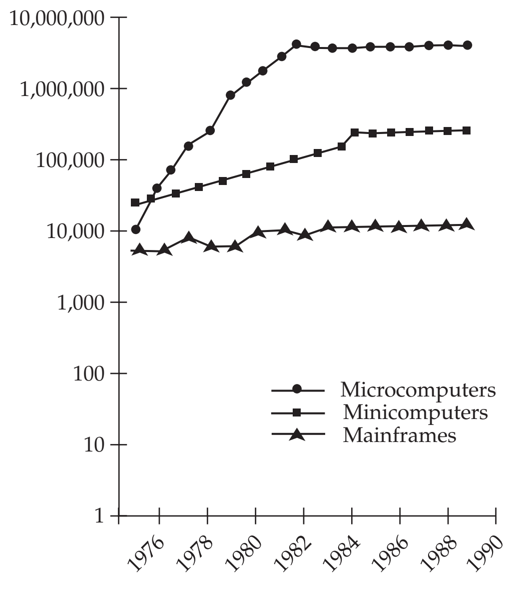

Fig 6.1. *Number of units of microcomputers, minicomputers, and mainframes sold annually, 1975–1990*

Source: Juliussen and Petska-Juliussen (1994: 317).

Saal and Shustek were the typical pioneers that had all the elements right, but they were unable to unify them into a stable system. Since it was early, Nestar had to wait for the microcomputer market to develop, and to create a workable network it had to develop all its own hardware and much of its software. Nestar provides an interesting example of how venture capitalists are often unwilling to support an entrepreneur's vision that ultimately is quite accurate. With sufficient funding Nestar might have had the wherewithal to find a market for its LAN.

Two other early start-ups found financing from other sources. Sytek decided, rather than accept venture capital investment, it would secure funding from General Instruments, which was a major provider of coaxial cable. Sytek believed it could be more successful with a strategic partnership than with venture capital. The Sytek business model was based on providing a proprietary LAN to link microcomputers together. Sytek experienced only momentary success and eventually was purchased by General Instruments. Another early entrant, Corvus, developed a LAN technology to allow users to share the disk drives that it produced. It received funding from an early backer of its disk-drive business. Initially, Corvus was successful, but the firm failed because of the ferocious competition in the disk-drive portion of its business.

In this earliest period, there were a few other start-ups, but U-B and Nestar were the most prominent. Still, at this point there was little agreement as to what standard or protocol should be adopted (Klee and Verity 1982). U-B successfully secured financing through the agency of Robert Metcalfe who was proselytising for Ethernet. In this early period venture capitalists were generally reluctant to invest in LAN firms and many smaller firms such as Nestar did not receive financing.

Xerox Changes the Equation

In 1980 Xerox announced its decision to license the Ethernet protocols developed at Xerox PARC. It eschewed royalties and set a low licensing fee ($1,000) (Liddle 1995), because Xerox management believed the widespread adoption of Ethernet would permit Xerox to sell its peripherals to customers that would otherwise be unavailable because they were locked into the proprietary systems offered by Wang, DEC, and IBM. To assist in its scheme to popularize Ethernet, Xerox recruited DEC and Intel (later referred to as DIX) as alliance members and sought formal IEEE (Institute of Electrical and Electronics Engineers) approval for Ethernet as a standard. DEC and Xerox, which intended to sell minicomputers and printers, respectively, hoped an open network protocol would ignite competition in network component manufacturing, thereby lowering price and encouraging innovation. Also, for DEC it solved the problem of having to design its own protocol.

Intel was included in the alliance because it was expected to design and fabricate the semiconductors necessary to build transceivers. Semiconductors were the key to shrinking the size of the computer adapter that converted the electronic data emitted by the computer into a common 'electronic language', Ethernet. The earliest Ethernet transceivers were actually small computers front-ending a mainframe or minicomputer and they transmitted the data to the terminals. However, the increasing ability to integrate circuitry allowed the merger of a large number of chips into an ever fewer number of chips and a concomitant decrease in adapter cost and size (see Table 6.1). For example, implementing Ethernet with VLSI chips allowed a reduction of chips used in an adapter from approximately 100 to five in the early 1980s.

The DIX group approached the IEEE committee (the so-called IEEE 802 committee) working on LAN standards and offered Ethernet. The IEEE committee's mandate was to secure agreement on stable and predictable specifications that all parties could use to facilitate computer interconnection and for which third-party vendors could build LAN communications (for an in-depth discussion, see von Burg 1998). IEEE involvement was important, because it assured adopters that a single dominant firm would make no arbitrary manipulation of technical features. In other words, a company producing Ethernet-compatible products was protected from having its business controlled by an outside company (for an interesting discussion of proprietary issues in standards, see Borrus and Zysman 1997). Finally, being early, workable, and open, Ethernet quickly attracted entrepreneurs in companies that were already operating such as U-B and start-ups such as 3Com and Interlan (in Boston).

Table 6.1. *Ethernet versus Token Ring, 1980–1992*

Year	Ethernet	Token Ring
1980	Adapter price = $4,000	
1982	Adapter price = $950	
1985	Installed base = 419,000	Installed base = 0
	Adapter price = $400	
1986		Adapter price = $695
1987	Shipments by 3Com = 180.000	Shipments by IBM = 166,000
1989	Shipments by 3Com = 2,200,000	Shipments by IBM = 1,400,000
1992	Installed base = 25,000,000	Installed base = 8,000,000
	Adapter price = $214	Adapter price = $585

Source: various industry journals.

3Com: The First Start-Up Dedicated to Ethernet and the Personal Computer

In the early 1980s two significant events occurring outside the fledgling LAN industry would make distributed, networked computing a reality and create a market. First, there was the introduction of IBM PC in August 1981 and its immediate and overwhelming success. The second event was the establishment of Sun Microsystems, an engineering workstation developer, operating on the basis of a strategy of adopting industry standards—one of which was Ethernet (Garud and Kumaraswamy 1993; Baldwin and Clark 1995). Within five years, the PC and the workstation seriously undermined the minicomputer industry and in the process created an enormous market for LAN equipment (see Fig. 6.1). U-B, while growing fast because of the success of the DEC VAX computers, was so intent on serving its first-wave customers that it missed the far larger and more powerful movement to desktop computing.

After leaving Xerox PARC and prior to founding 3Com, Metcalfe consulted for DEC about Ethernet and helped adapt it to be compatible with DEC's new VAX minicomputer product line. Robert Metcalfe, the inventor of Ethernet, and Gregory Shaw, founded 3Com on 4 June 1979 (Crane 1995). 3Com initially continued Metcalfe's consulting practice, and the most important customers were General Electric and Exxon Office Systems (Charney 1995). Metcalfe established 3Com to exploit the Ethernet standard, which he had encouraged Xerox to license at favourable terms. Developing hardware required capital. Because consulting fees could not support the investments necessary for either manufacturing or R & D, 3Com began to search for venture capital. The 3Com founders had never started or managed a company. Metcalfe's experience had been in the university and research environment and he had no experience as a business manager. The other team members also had limited management experience. None had either raised venture capital or written a business plan.

Howard Charney, the original Secretary and Vice-President of Operations, looking back, described their presentations to the venture capitalists as 'meandering'. They intended to target desktop computers, but in October 1980 there was a small installed base and the IBM PC had not yet been introduced. Written in the last quarter of 1980, 3Com's business plan was necessarily vague, increasing the difficulty in funding venture capital. According to the 3Com venture capital briefing document dated 6 October 1980 put together for David Arscott and Leal Norton, then a prominent venture capital partnership, it wanted to capitalize on Xerox's Information Outlet (Ethernet) to provide multi-vendor compatibility in local networks (3Com Corporation 1980). But, given the vagueness of the business plan, the lack of a clear market, and fears that large companies such as IBM and DEC would control the market, Arscott and Norton and many others in the venture capital community turned the deal down (Richman 1989). One of the original venture capitalists who backed the deal, Richard Kramlich (1995), said that Metcalfe came in, described his background, and sketched out the Ethernet idea. The business plan was vague and difficult to understand. Kramlich remembered the meeting and discussing an investment in 3Com:

> He [Metcalfe] told me about his background and where he had been. He sketched out his Ethernet idea. I will never forget because he brought in his business plan and it amounted to a series of clouds. I was trying my best to understand what he was talking about and I had a vague understanding of it. But, I did not know any of the technology at the time.

Because of Metcalfe's reputation at Xerox PARC, there was interest in the venture capital community. Wallace Davis at Mayfield offered $7 per share to Metcalfe, who quickly turned him down believing he could get a higher valuation. Richard Kramlich at New Enterprise Associates put together an offer for $13 a share and Metcalfe turned him down, also. Metcalfe then managed to secure a $21 per share offer from a Boston venture capitalist. However, the Boston firm never closed the deal. After presentations to nearly forty venture capital groups, Metcalfe returned to the Silicon Valley venture capitalists: Jack Melchor of Melchor Venture Management, Richard Kramlich, and Wallace Davis and closed the deal (Wilson 1985: 177–9). At the end of this six-month search period 3Com received $1.05 million on 28 February 1981—the same day 3Com actually ran out of money (Charney 1995).

Kramlich invested in 3Com because Metcalfe and the technical expertise of the team Metcalfe had gathered impressed him. Kramlich (1995) attributes his decision to invest to his involvement in Apple Computer, which alerted him to 'the logic of going from a personal computer to a network. Resource sharing was going to be the wave of the future.' As with Swartz in the U-B deal, Kramlich appears to have had an experience that prepared him for his pioneering investment, even though most other venture capitalists chose not to invest at the price Metcalfe demanded.

One important component in closing the 3Com financing was the understanding that 3Com would hire a seasoned manager to handle the general management issues. The venture capitalists were involved in this recruitment, which brought in an executive from Hewlett Packard, William Krause, as the CEO. In this recruitment the venture capitalists actually assisted the company in the search and selection process.

Initially, 3Com grew slowly, but it changed its strategy dramatically in August 1981 when IBM introduced the IBM PC. Almost immediately, Metcalfe decided 3Com should design an Ethernet adapter card for the IBM PC using the less expensive and more capable VSLI circuits. These chips made the adapter cheaper and decreased the size of the supporting printed circuit board sufficiently to allow it to be plugged into the PC mainboard. Metcalfe focused 3Com's resources upon the IBM PC because he believed minicomputers and mainframes were 'dying' technologies. His objective in inventing Ethernet at Xerox PARC had been to develop a high-speed data communications system for desktop computers. For him, connecting terminals and hosts was a poor utilization of Ethernet. At first, providing Ethernet connections for the only recently developed microcomputers was not a large business because of the small installed base of desktop computers. After 1984 the brilliance of this decision became apparent as 3Com's sales accelerated in concert with widespread acceptance of the IBM PC and PC compatibles.

During this initial market formation stage, it was difficult to be sure of anything. Confusion and experimentation were the rule. At that time, it was impossible to identify market segments, competitors, customers, and viable corporate strategies. James Swartz (1995), the lead investor in U-B, remembers: 'sitting in U-B board meetings talking about Novell (the firm that developed the dominant network operating system) and nobody having a clue what the hell they were doing and why they were being successful'. In other words, the market was sufficiently opaque that even some participants did not understand it completely.

Other Early Entrants

Other start-ups also entered the LAN business. One of the most significant of these was Bridge Communications, established in September 1981 by William Carrico, Judith Estrin, and Eric Benhamou, alumni of Zilog's Z-Net (Bridge Communications Inc. 1985). Bridge Communications was created to address the problem of the wide variety of LAN protocols, which prevented interconnection. The founders believed this incompatibility provided an opportunity for a firm able to build a 'bridge' between the systems—hence the name, Bridge Communications. However, during the funding process they realized that their business plan was flawed because there were not yet enough LANs to interconnect (Brinton 1981). As a result, they complemented their product line by offering other networking equipment and did not focus on internetworking (Estrin 1995). They also adopted Xerox's Ethernet standard as soon as it was available (Bridge Communications Inc. 1986).

For Bridge Communications, finding venture funding was a slow process, but after a six-month search in December 1981 it closed the deal, receiving $1.8 million for 60 per cent of the equity from Weiss, Peck & Greer Venture Partners (WPG); Merrill, Pickard, Anderson & Eyre (MPA&E); and later Warburg, Pincus Investors (Hofmeister 1989). One of the founders, Judith Estrin (1995), felt that, in the case of Bridge Communications, the venture capitalists made their decision on the basis of the entrepreneurs, because she thought most of them did not understand the technology.[9]

As more LANs were installed, the market caught up with Bridge Communications, but, as was the case for U-B, Bridge Communications specialized in minicomputer-oriented LANs and was late in recognizing the significance of the PC. Thereby, it missed an opportunity to become a dominant vendor for devices to interconnect LANs. In the mid-1980s the general-purpose LAN vendors consolidated, as the cutting edge of the market shifted to PC- and workstation-centred LANs. The minicomputer-centred LAN vendors merged into other firms and disappeared. In 1987 3Com purchased Bridge Communications for $325 million, providing substantial capital gains for both the venture capitalists and the founders. Interestingly, according to Kramlich (1995), he had to prevent William Krause from merging 3Com with a company, Convergent Technologies, that went bankrupt only six months after the aborted merger. In this case the venture capitalists used their power on the Board of Directors to prevent what would have been a disastrous merger.

After the Bridge Communications merger with 3Com, an internal debate raged between the 3Com and Bridge Communications executives about the merged firm's direction. The Bridge founders clearly saw the future of interconnecting LANs, which eventually Cisco Systems would occupy. The problem was that it was a little too early and after the merger Bridge's vision of LAN interconnection was lost by 3Com's management. As a result, Carrico and Estrin left 3Com and became involved in another start-up, securing funding from the same venture capitalists that had funded Bridge.[10] In effect, when they left 3Com, they took their venture capitalists with them.

The 1979–83 period was filled with uncertainty for two reasons. First, there was no dominant technological design. Thus, for the venture capitalists it was difficult to be sure the firm seeking funds was choosing a technology that would receive support. Secondly, there was little understanding of how large the market might be or how fast it would grow.[11] There were a large number of other firms formed to exploit various proprietary LAN systems, but by 1983 these were fading from the scene. Ethernet adoptions were increasing and it was beginning to be accepted as a standard and a 'bandwagon' effect was forming.[12] Increasingly, new start-ups concentrated on developing products that were Ethernet-compatible. Despite its success, Ethernet required expensive, hard-to-install, and difficult-to-maintain cables. In the mid-1980s, Ethernet was an adequate solution, yet there was the looming threat of a well-designed alternative, Token Ring, developed and supported by IBM, but because of delays it was finally introduced in 1986. Though the start-ups had established a thriving and rapidly growing industry based on the Ethernet standard, it still was not clear they could survive an IBM-supported Token Ring standard that had significant technical advantages.

In the case of the LAN industry, the adoption of the PC by business was critical to the success of the LAN industry. PC adoption meant the general-purpose LAN firms such as U-B were being overtaken and surpassed by firms such as 3Com that were dedicated to networking PCs. Venture capitalists are often in a position to see larger market developments that the management of start-up firms cannot see because they are so involved in the daily process of managing rapid growth and focusing on their customers. When this occurs, the role of the venture capitalist is to convey this information to the firm's management. For example, in the case of U-B, as the market evolved from being centred upon connecting minicomputers to terminals to centring upon interconnecting PCs and workstations, Swartz (1995) said he had 'many tough discussions' at the Board of Director meetings. But it was difficult for U-B's management to see and reorganize to serve the next wave of LAN customers—the desktop computer users.[13] By 1987 the success of desktop computing had changed the environment dramatically. U-B was not properly positioned and was sold to Tandem Computer.

The PC and LAN industries developed synergistically. As the price of Ethernet adapter cards and network installation decreased owing to economies of scale, increased competition, and, most important, continuing innovation, the number of adopters increased (Arthur 1994, 1996). File sharing emerged as a critical application encouraging the connection of even more computers to the network. This quite naturally increased the size of the market for LANs. In other words, a self-reinforcing spiral of growth ensued. But, before the widespread acceptance of LANs occurred, it was necessary to simplify installation and maintenance.

Fixing Ethernet: The Second Great Wave

In 1985 Ethernet was the leading protocol as the closed LAN protocols lost market share. Ethernet was the leader but it had not yet become the dominant design. Retarding adoption were the cost and expense of installing and maintaining Ethernet systems. Though the Ethernet adapters had dramatically dropped in cost and the simplicity of the protocol encouraged adoption, network operation was difficult. The technology had initially been developed by and for engineers who were quite capable of repairing any problems in the system. However, for more general usage Ethernet was still problematic.

A solution was being developed. In 1980 Xerox PARC hired Ronald Schmidt to develop an Ethernet version for fibre optic cable. While experimenting with fibre optic Ethernet, Schmidt replaced Ethernet's bus topology with a hub-based star topology to enhance reliability and ease of use (see Fig. 6.2 for an illustration of these two topologies). To publish a few academic papers and to help Xerox PARC, which had come under attack in the press for its unsuccessful commercialization track record, Schmidt developed a fibre optic Ethernet product prototype of a hub-based star system. Schmidt even wrote a business plan aimed at interesting Xerox's management in commercializing his invention. After some consideration, Xerox decided against commercializing this new topology, even though Xerox's own real-estate consulting unit said the new configuration could solve the Ethernet cabling difficulties in their office buildings (Schmidt 1995).

The hub was an important advance. Since Ethernet was a bus system, a problem anywhere caused the entire LAN to fail. Without any indication as to the location of the failure, the entire ring had to be painstakingly tested. By building a star topology going through the hub, the various segments could be isolated and tested individually at the central point. This

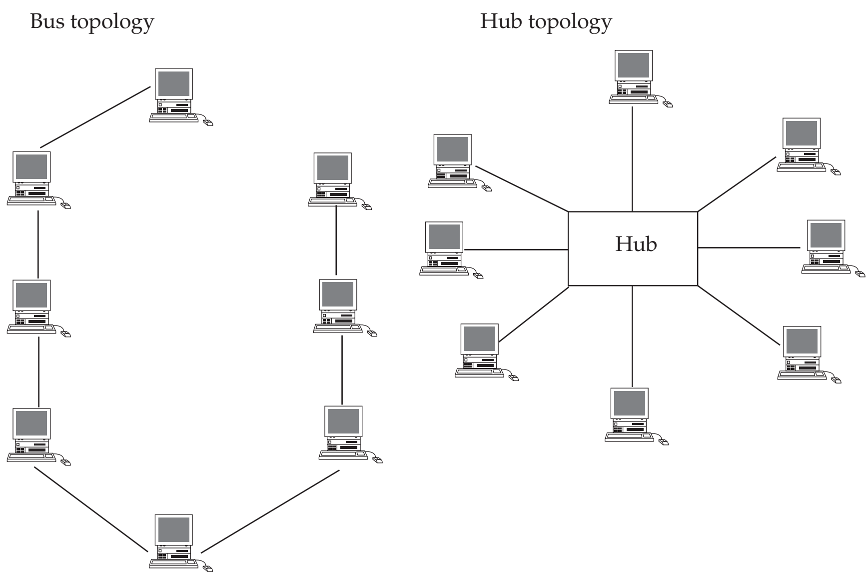

Fig 6.2. *The two Ethernet topologies*

narrowed the failure down to one node and dramatically simplified maintenance. The hub technology was not so sophisticated, but easing troubleshooting problems and simplifying the addition of a new node were an improvement that could substantially lower the cost of ownership, thereby encouraging a dramatic expansion in the market.

Even as Xerox rejected Schmidt's business plan, in May 1984 IBM announced the IBM Cabling System as part of its long-delayed Token Ring system (Bartik 1984). The topology of the IBM Cabling System was strikingly similar to Schmidt's hub-based fibre optic Ethernet. Because of these similarities, Ronald Schmidt and Andrew Ludwick, who had become involved with Schmidt's project as a manager of new business opportunities at Xerox, decided to adapt their initial design to operate on IBM cable, which was a close relative to inexpensive, easy-to-use, and ubiquitous telephone cable. Within a few weeks, Ronald Schmidt had redesigned his previous prototype so that it operated with either the IBM Cabling System or fibre optic cable. Thomas Bredt (1995) described the problem SynOptics solved:

> The way Ethernet worked was you strung a yellow cable about as thick as your thumb through the crawl space in the ceiling or through the walls. And any place you wanted to attach a workstation to the Ethernet you used what was known as a 'vampire clamp' which had prongs on two sides. You would position it on either side of this cable and then tighten it down so that it pierced the cable and made contact with the appropriate levels inside the yellow cable to establish connectivity. The problem of this architecture is: first of all you don't have any clue as to where the taps are located and second this piercing is not very reliable.

In the terms used by Hughes (1983), SynOptics was able to eliminate this reverse salient. SynOptics made two important technical improvements. First, Ethernet could now operate as a hub-based system, simplifying maintenance, as all testing of particular nodes could be done at the hub. Secondly, the clumsy, unreliable Ethernet cable could be replaced by the less expensive IBM cable. Despite these advantages, Xerox continued to reject commercialization. In 1985 Xerox, however, permitted Schmidt and Ludwick to license the technology and establish a firm to commercialize the technology. In return, for using its intellectual property Xerox received equity in the start-up (Borsook 1988; Schmidt 1995). The company was incorporated in June 1985 by Andrew Ludwick, Ronald Schmidt, Shelby Carter, and Xerox as Astra Communications, but soon changed its name to SynOptics (SynOptics Inc. 1988). Almost immediately SynOptics was profitable (SynOptics Inc. 1988). In fiscal year 1985 it earned $485,000 on $1.18 million in sales.

In early 1986 SynOptics began to search for venture capital. As with the previous companies, SynOptics had considerable difficulty raising venture capital. Many prestigious venture capitalists turned the deal down or missed it. For example, Richard Kramlich at New Enterprise Associates (NEA) saw the SynOptics deal early because one of his partners was a fraternity brother of one of the founders. Kramlich (1995), a successful 3Com investor, recalled, 'We should have done it. I knew it was going to be a great deal.' However, for a variety of reasons, centred upon valuation and disagreements among venture partners, NEA did not invest. A number of other venture capitalists, such as Donald Valentine (1995), also said they saw the deal but did not do it for various reasons.

There were various reasons for the decisions not to invest in SynOptics. Many venture capitalists believed that the market for Ethernet-based fibre optic cable networks and the IBM Cabling System would be small (*Data Channels* 1985; Jeffery 1986). In this they were correct, but SynOptics soon developed a hub-based, 10 Mbps Ethernet LAN on telephone wire. Because the initial hub implementation was relatively low technology, many venture capitalists were concerned that the low barriers to entry would not allow SynOptics sufficient profitability and competitors would quickly erode its first-mover advantages. Once again, their analysis was correct: the hub was not high technology or software intensive enough to deter the larger, incumbent LAN vendors such as 3Com, Hewlett Packard (HP), or U-B. What this did not take into consideration was that the hub could become a platform upon which high-value software and firmware could be added, and the first-mover advantage combined with rapid innovation would permit SynOptics to dominate later entrants (Bredt 1995).

Curiously, these concerns were reinforced as the venture capitalists investigated the business plan by talking to the incumbent LAN vendors. These companies said the SynOptics' product was trivial and easy to imitate. Ronald Schmidt (1995) described the situation: 'The VC [Venture Capitalists] all [talk to] the winners. They went and talked to 3Com. 3Com said it's trivial what they are doing, we can do it with our hands tied behind our back and one-eye blindfolded. And then, that went out to the entire VC community. So you had to find people who would not think as part of the herd instinct.'

The entrepreneurs escaped this 'herd' instinct when John Lewis of Paragon Partners agreed to invest. Lewis was then joined by Thomas Bredt of Menlo Ventures, a prestigious Silicon Valley partnership, and this solidified the deal. The other venture capital firm to join the deal was Rust Ventures from Austin, Texas, and the investment closed in August 1986. So why did venture capitalists from Austin and Thomas Bredt invest when the others were uninterested? Thomas Bredt had experience with LANs from his previous employment at HP and Dataquest. He said it was obvious to him that the SynOptics' implementation of Ethernet had significant advantages over coaxial Ethernet. The hub and adoption of telephone wire radically simplified installing and maintaining an Ethernet LAN.

SynOptics inherited a powerful patent position from Xerox. But, to have its system certified by the IEEE, it had to license the patent freely, thereby losing this protection. The decision to license the patent openly was a critical issue. The decision to open the patient was discussed at the Board of Directors meeting, where the venture capitalists agreed with management that this was the correct strategy. According to Bredt (1995), he agreed because of his previous investment experience at Network Equipment Technology. In this case it is hard to establish who initially developed the idea of opening the patent, but certainly the venture capitalists were active participants involved in the discussions.

As with the other firms in our study, the SynOptics deal was shopped to many venture capitalists, but most did not invest. Since the technology was comparatively simple, it was difficult to envision how the cost of ownership benefits would combine with the increasing number of PCs in such a way as to create an explosion of demand. Further, they could not envision the hub as a site for embedding high value-added software and specialized integrated circuitry increasing its value to the customer, thereby embodying greater value-added in the hub. Finally, they did not believe that the first-mover advantages in the hubs would be so important. In high-technology electronics the ability to be the first to move down the learning curve (especially learning from customers, as pointed out by von Hippel 1988) and secure market share often translates into a highly profitable and sustainable advantage.

SynOptics was a tremendous success for its investors. It also played a vital role in ensuring Ethernet became the dominant design by integrating two of IBM Token Ring's greatest advantages over Ethernet, while retaining Ethernet's price advantage. Venture capitalists played the simple, but important, role of providing funding for SynOptics. This allowed SynOptics to add a critical new feature/component to the emerging Ethernet LAN industry and contributed to a dramatic increase in the number of installed LANs.

The decision to fund SynOptics differed significantly from the decisions to fund LAN start-ups in the earlier period. In this case it was not so much the entrepreneurs, but rather the technology, that affected the decision. The SynOptics' solution addressed two important reverse salients in Ethernet. For the venture capitalists there was far more market and technology information available: they knew Ethernet was a winning technology, there was a community of firms and individuals to consult (though many offered the wrong advice), and there were already examples of financial successes in the LAN industry. At least some venture capitalists claimed they wanted to invest, though they did not, indicating some awareness of the technology's value. Their decisions boiled down to a question of whether technology provided a profitable opportunity. The parameters of variation to be considered were far fewer than in the 1978–91 period.

Risk, of course, still existed, but the vision needed was about execution, speed, and adding value—not whether the entire project was realistic. Thus, the vision of the future did not need to be so speculative.

Discussion

Most social constructionist studies of technology examine the period before a dominant design has been selected (or, in the terms of the constructionists, 'closure'). In this chaotic period the constructionist framework provides a useful perspective for understanding how firms and industries are formed. In this chapter we have shown how venture capitalists can play an important role by providing funding and other non-financial forms of assistance to fledgling firms. As both theories indicate, to create a separate industry, infrastructure must be created, customers must be found, and human resources have to be recruited. Without sufficient capital to support a small firm in this construction process, it would have been difficult to construct the support network necessary for these small firms to survive.

The establishment of the firms and industry was not an orderly process; rather it was more of an organic creation process in which actor wilfulness was tempered by contingency, opposition, and indifference. Rather than conscious construction, the process was far less rational; the various actors in the drama seemed to be cobbling things together. If the cobbled-together network experiences some success in attracting capital and sales—that is, it grows—then it can become more established rewarding the 'cobblers' and attracting new adherents.

As we showed, initially the venture capitalists were reluctant to fund the early networking firms. At the time, there was no real industry or apparent market for these start-ups, so it was difficult to envision LANs as a standalone industry. The claims made by the large established companies such as IBM, DEC, Wang, and HP that they could and would provide the networks to link their computers seemed plausible and, if true, meant there would be little economic space for new companies. To risk capital—that is, to invest—a venture capitalist had to believe that building the network and its critical components could be a business separate from the computer industry. From today's perspective, the decision by most venture capitalists not to invest in these opportunities appears foolish, but foreseeing success in real time had elements of a leap of faith.

SynOptics is an interesting juxtaposition to the earlier start-ups. When it was established in 1985, the LAN business space was more clearly delineated. Ethernet was already the most used protocol, early start-ups were profitable, their stock was already public or larger firms had acquired the smaller firms, and the installed base of PCs and workstations was growing rapidly. Though uncertainty continued, the pervasive chaos of the unformed market in the late 1970s and early 1980s had been dispelled. Now, the obstacles of difficult installation and maintenance could be identified, thereby making a decision to fund a LAN start-up to solve such problems less risky. In other words, it was easier to assess the potential value of a prospective firm—notwithstanding the fact that most venture capitalists made a wrong assessment.

Before a dominant design emerged, the venture capitalist had to bet on the entrepreneurs presenting the business plan—that is, bet on people. The difference between a radical innovation with massive capital gains and a stupid idea with no chance of success may not be easy to discern before it is tried. Many apparently sure things and great entrepreneurial visions ultimately look foolish, cannot be solved technically, or come to fruition only years or even decades after the first investments. Thus, often the initial chaos and opaqueness of a technology or market are sufficient to discourage venture capital investors as a group. The critical point, however, is that the venture capitalists, though often herdlike, experience success as individuals and partnerships, and, on the basis of their unique personal experiences, sometimes break ranks and provide funding. And, it only requires one backer (or a small syndicate) to create a firm.

NOTES

1. For example, biotechnology escaped the large pharmaceutical and chemical companies to become the basis of the biotechnology industry (Kenney 1986).
2. Pascal Griset (this volume) explicitly mentions the difficulty various entrepreneurs in the radio industry had in recruiting financial backing. It is interesting to speculate on how important this was in allowing the large established firms to absorb the new start-ups.
3. Though the bulk of formal venture capital investments are in the high-technology arena, they do not confine themselves to technology investments. For example, Federal Express was started with venture capital funds and a number of funds invest in franchising start-ups.
4. Charles Bass was a friend of Robert Metcalfe through their earlier work on the DARPANET.

5. In 1983 U-B acquired Amdax.
6. A number of other companies were built in the belief that saving on the cost of peripherals would drive the LAN industry. In the early period, this was an important factor, as magnetic memory was expensive, as were printers. However, the cost of both dropped significantly during the 1980s.
7. Remember this was still the period when IBM appeared invincible.
8. But failure is not final. In 1986 Harry Saal and Leonard Shustek left Nestar to start another LAN company, Network General, 'with a blank piece of paper' (Saal 1995). At Network General, Saal and Shustek controlled nearly 60% of the stock. For the most part, they bootstrapped the company and brought in the venture capital partnership TA Associates of Boston only later. Network General went public in 1987 and is now a medium-sized LAN company.
9. In an interview, Philip Greer (1996) of WPG agreed with Estrin's assessment that he did not completely understand the technology. However, he apparently did understand good entrepreneurs.
10. In 1985 a start-up, Cisco Systems Inc., was established that would pursue the interconnection market and in the process become the most successful computer networking start-up in history and one of the most successful initial public stock offerings in history.
11. For a discussion of the dominant design literature, see Abernathy and Clark (1985).
12. For a discussion of standards creation and bandwagon effects, see Arthur (1989); Bresnahan and Chopra (1990); Katz and Shapiro (1994).
13. For a discussion of the difficulties of seeing new markets emerge because the existing firms are concentrating on their current markets' needs, see Christensen (1992); Christensen and Bower (1996).

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