

Bluetooth: Towards a Cooperative Model of Technological Innovation in Mobile Telephony

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Abstract

This paper notes the creative tension created by network industries in high technology production. The tension emerges due to firms' needs to both focus on developing strong and defensible competencies and also the need to share knowledge as part of wider development networks. The paper looks at the development of the Bluetooth wireless standard within this context. We find that Bluetooth's promoters made the standard open to create support within a competitive technical environment. Downstream profits will flow to the technology's developers both through the creation of patentable technologies relating to the standard's use, and also through the ability of the technology to extend the role and importance of the promoter firms' core products.

Introduction

As products and services in the information technology and telecommunications industries have become more interconnected and complex, it has become increasingly important for all participants to develop positions of sustainable competitive advantage based upon some degree of knowledge leadership. An over-reliance on knowledge, though, can also become a trap for firms. Collis (1994) noted that organisational knowledge and capabilities may be subject to erosion within markets. Firms that are too reliant a certain set of competencies tend to find themselves in a precarious game of catch-up during periods of discontinuous technological change.

These technological discontinuities are becoming more frequent as technological change drives increasing cycles of innovation and redundancy. As complexity in information technology and telecommunications has increased, a degree of vertical and horizontal disintegration has occurred in these industries (Lamming, 1993), requiring firms to cooperate within both design and supply chains to develop products and services. Processes of disintegration have created both the opportunity and need for network development between firms in developing complex products or services that are compatible with complex broader systems. The days of the large multinational firm dominating entire segments of the technology industries, as IBM did for a short time in its history, are far behind us.

Thus a strategic dichotomy has emerged for many industry participants in high technology endeavours. A degree of knowledge sharing is necessary to ensure a role in a broader complex system, while a degree of exclusivity is also necessary to ensure differentiation from other industry participants.

Accepting the need for some interconnectedness in the knowledge generation process, the nature and degree of this knowledge sharing process then emerges as an important area of investigation. In 1962, Thomas Kuhn noted that:

Scientific knowledge, like language, is intrinsically the common property of a group or else nothing at all. To understand it we shall need to know the special characteristics of the groups that create and use it.

In the business environment of information technology today, the first sentence of this statement seems quaint, though the second sentence's prescience is striking. Industrial power in network-based industries flows from control of knowledge through patents, intellectual property rights and research and development leadership. Knowledge created within firms during a period of research and innovation tends to be tacit in nature, often only partially codified and tightly protected. As the technology matures firms tend to codify and legally protect the knowledge through patenting. In discussing the effect of protecting knowledge, Sanchez and Heene (1997) argue that by keeping it in a tacit form embedded in localised routines and highly protected internalised knowledge, its transferability within and between firms is severely reduced. In the same way, strong protection of knowledge through legal or other forms limits its diffusion across firms.

To a large degree the fluidity of transfer of knowledge relates to this formalisation of the control and ownership of knowledge through patent based controls of intellectual property rights (IPRs). Patents and IPRs form the very basis of what has become described as "intellectual capitalism" (Granstrand, 1999, 318). They provide the initial impetus and support for research and development of knowledge assets. These assets, like all others, require the investment of time, energy and capital.

Continuing the dynamic tension analogy, IPRs by their very nature hinder the flow of knowledge between firms and applications. The process of creating new technological knowledge thus features a dynamic and creative tension between knowledge controls and knowledge flows. The patent process tends to externalise the implicit knowledge, though the innovation processes in today's information technology industry require rapid iterations of knowledge sharing and progression. Thus the degree to which the knowledge underlying products and service structures is protected versus made accessible has a strong determinative impact on the type and level of innovation observed across a product category. This situation drives the emergence of opportunity costs created by knowledge control which must be weighed against the potential diminished strategic value of the knowledge should it be incorporated into competitors' products.

The Role of Standards

The opportunity costs of knowledge control are exacerbated by technological competition among competing standards. A firm may have ownership and control of an excellent technological solution to a market driven opportunity, though if that solution lags others to market due to long development times or other factors, the firm will not benefit. Building installed base is the key, and the complexity of systems based upon information technology ensure that standards to ensure interoperability are central for product or service success.

Such observations are not new. Paradigmatic papers from the microeconomics field (Farrell and Saloner, 1985; Katz and Shapiro, 1985) stressed the strong network effects (positive network externalities) that can support the diffusion

of a new technological standard within the competitive context. Katz and Shapiro (1985, 424) for example noted that “there are numerous products for which the utility of a user derives from consumption increases with the number of other users consuming the good”.

In the information technology industry a critical dimension of organisational success is the extent to which a technical standard can be broadly adopted, and this in turn is influenced by the degree of openness and competition allowed. An open and non-proprietary approach to the knowledge of the introductory technology can and does facilitate its uptake by vendors, users and innovators. From an industrial perspective, when a standard is developed within a knowledge architecture that features explicit and widely accessible knowledge, a number of desirable outcomes are facilitated to assist this end, namely:

- reduced barriers to entry into the industry,
- accelerated diffusion of technical standards,
- more regular incremental and modular innovations and
- enhanced learning opportunities.

Examples from information technology are plentiful, and include:

- The IBM personal computer was conceived as an open system. Through an open architecture, the personal computer (PC) by IBM (and clones) has advanced very rapidly. Even though many believe the Macintosh to be a superior system, the PC has become the dominant design because of complementary products such as software and the rapid development of the product through having multiple suppliers involved. Apple succeeded on their second attempt with the Macintosh (following the Lisa) due in part to the fact that it allowed third parties to become involved at the software development level through having an architecture that was not quite as closed as previous hardware releases (Morris and Ferguson, 1993).
- The case of the rise of Sun Microsystems and the fall of Apollo show some of the advantages associated with open standards based products. Sun started from a weaker position, but rapidly overtook Apollo by utilising the potential of their open architecture approach and allowing other suppliers to become involved in manufacturing using the Sun architecture (Garud and Kumaraswamy, 1993). This case simultaneously demonstrates the problems of a completely open architecture, as Sun is now embroiled in a battle with a range of other competitors that have entered the workstation market, using the same basic architecture (Baldwin and Clark, 1997).
- The GSM mobile telecommunications standard has emerged as a dominant standard among digital offerings, outstretching its competing North American and Japanese alternatives in takeup. This has in turn proved to be a strong driver of success for European firms, and most especially the Nordic duo of Ericsson and Nokia who could leverage their TDMA competencies in the development of new GSM equipment. GSM tended to be far less proprietary with regards to technology diffusion and royalty requirements than the competing CDMA solutions from the US and the proprietary NTT solutions from Japan.

Open Architectures – Potential and Problems

Products with open architectures are constructed using information structures that can be accessed (directly or indirectly) by others within the industry. This generally occurs when the developing firm does not try to protect the information structure or even actively encourages the assimilation of it into the industry. In contrast, closed product architectures utilise information structures that are tightly controlled by the developing firms. The accessibility and transferability of the various elements of the information structure that underlie products are the key determining factors as to whether the product's architecture is open or closed.

Beyond the lowering of barriers to entry within an industry and the opportunities for a geographically dispersed industry to develop, an open architecture provides greater opportunities for a product to become the dominant design. Products normally go through two stages in terms of evolutionary development; the pre-paradigmatic stage when multiple architectures are available, and the paradigmatic stage, where there is acceptance of a particular 'standard' (Teece, 1986). To achieve a dominant design position, a product must be floated in the market such that acceptance of the product can be gained.

There is evident risk of leakage of technological competencies at this point for lead developers. In the case of a closed architecture these risks are limited through legal protection mechanisms, though problems can and do emerge through information leakage via component suppliers and the potential for reverse engineering by competitors of products with similar functionality. An open architecture allows relatively easy duplication by competitors due to the nature of the underlying information structure and the type of knowledge within it. However, an open architecture also allows for competitors and suppliers to become involved in the further development of the product such that the technological advances made through this joint effort can lead to a dominant standard very quickly. This is particularly important in the case of a system of products as the number, quality and availability of complementary products often determine their success.

The strategic objective of releasing an open and closed standards based product is thus quite different. Teece (1986) suggests the achievement of a dominant design is one of the three building blocks to reaping profits from an innovation. Whilst profiting from an innovation can occasionally occur because of the higher margins that can be achieved, more commonly, success comes from capturing a large share of the market. Certainly a dominant design on the basis of an open architecture is unlikely to allow for higher margins to be achieved, but it does allow for rapid development of the product or system, rapid growth and possibly financial success through a larger market share.

Growth can and does occur at the periphery of the product, where the supplier of the open standard product may develop complementary and compatible products and services. As information technology has moved towards a solutions focus, the sales of software and hardware have become a central though early stage aspect of market strength for vendors. Later sales of complementary solutions and services are emerging as important areas of market activity.

An open standard, though, may not necessarily draw in firms unless this is facilitated through cooperative means.

Open standards may facilitate the rapid development of the product if other firms become involved in the design process. The attractiveness of entry for other firms increases if an open standard emerges as a dominant design.

Open Standards, Open Partnerships?

Once a decision has been made to freely disseminate information regarding a standard, it would seem to logically flow that firms might wish to collaborate cooperatively in the processes of research and development. Such a focus accelerates product introduction and tends to ensure the creation of a variety of products early in the competitive product cycle. This will tend to build installed based of standard compatible equipment of both core and complementary products by consumers.

Within projects developing new technologies, such rapidity is a prerequisite for success. The use of concurrent engineering, where a number of firms and research groups are involved early in the research, development and commercialisation process, has been shown to assist in the development of new technologies. Within the context of high technology industry, the use of concurrent engineering by US technology firms has successfully brought forward key strategic decisions regarding the technology that may have otherwise hindered its diffusion (Zirger and Maidique, 1990).

Doz (1986) noted the benefits of open alliances in developing technologies. He found that open projects (where partnership between firms are facilitated), technological innovation tended to cycle through iterations of learning, re-evaluation, and readjustment more rapidly than in closed projects. The pace of development of the extant technology is clearly in strong consideration in an environment of competitive standards setting (as is the case examined here).

The potential for an open partnership system seems to be consistent with many of the aims of open standards, namely creating vendor commitment and rapidly getting products to the market. Further, for the lead firms who have made the choice to make the core technology freely available, it seems to offer the strong advantage of accelerating standard take-up, with limited risks.

Mowery et al. (1996) found that open partnerships in the development of technological products created specialisation among the member firms. It could be expected that the specialisation process would support the larger firms dominating core products and smaller firms tending to specialise in the development of peripheral or complementary products or services. Lead firms, who tend to be the founders of the basic technology, will be leaders in the development of products that meet with mass-market demand.

All firms, though especially the leading firms, need to be mindful that within a cooperative alliance there is a need to manage the distribution of common and private benefits among and between firms. Khanna et al. (1998) noted from an empirical study that where the ratio of private to common benefit is high, competitive pressures negate much of the potential for shared learning. If a key objective of the open standard model is to accelerate development beyond that achieved by rival standards, this sharing of potential rewards needs to be carefully considered.

Brief Comments on Research Methods and Data Gathering

A number of steps were taken to gather the data for this paper. The data was gathered primarily as part of a broader investigation for the principal author's PhD. This has investigated management strategies employed to facilitate the development of emerging technologies by mobile telephone manufacturers.

Secondary and primary sources have been used, including interviews with industry participants. Interviews tended to be limited to employees of LM Ericsson and academic sources, though secondary data came from many areas including a number of critical sources emanating from the proponents of competing technologies or critics of the Bluetooth standard for other reasons.

Wireless Networking

The cables connecting the variety of PCs, servers and peripherals that occupy a typical work space are one of the banes of modern office environments. As wireless technology has developed, its potential to remove much of this confusion has become evident. Data services utilised within existing, broadly deployed technologies like GSM, for example, were developed to support voice based services and have tended to be very slow (14.4 kbps) and thus not suited to the routing of large amounts of information able to be handled by cables.

Relatively recent technological developments have created a quantum leap in the amount of data able to be transferred in a wireless mode. The use of digital devices such as data packeting and frequency modulation (time based and code based) has seen data rates of 1 mbps as the norm in many wireless applications, and 54 mbps (approx. 1000 times the data rate that is best achieved by a standard 56 kbps modem) achievable under controlled situations (Johnsson, 2000).

Thus a strong imperative has emerged for the development of both standards and products to deliver wireless solutions to office, industrial and home environments.

The Bluetooth Standard

The Bluetooth communications standard is an interesting technology for many reasons. Bluetooth is a standard for short distance wireless communications, connecting electronic devices such as computers, peripherals and mobile and fixed-line telecommunications devices at speeds up to 1 mbps and distances up to 10 meters. Bluetooth is a technology that exemplifies the potential of the converged information technology and telecommunications industries in delivering innovative and practical network-based solutions for business and personal users.

The technology in its current iteration seeks to remove the need for cabling in office environments, an innovation that will have large benefits for commercial and home users of information technology equipment. Bluetooth in effect creates a piconet around a given user, connecting up to eight compatible appliances. It is vertical in its architectural design in that it employs a master-slave relationship among appliances.

Such an architectural design was a key attraction to the standard's early backer LM Ericsson. By making the mobile telephone the central device in the Bluetooth architecture, (the mobile telephone holds key user details and facilitates access to the PSTN and existing wireless network), value addition could be developed within the core mobile telephony business of that firm. Strong internal competencies in both Bluetooth and mobile telephony will place Ericsson in a strong position to be a lead innovator as 3G systems emerge for mobile telecommunications, where data transfer rates will be far higher than currently experienced and interoperability between devices will be necessary for commercial success.

As a technology that seeks to facilitate wireless connections between computers, peripherals and other high technology devices, Bluetooth is far from unique. The 2.45GHz frequency band has been reserved internationally¹ for unlicensed use for industrial, scientific and medical (ISM) purposes. This frequency of the radio band is well suited for high rate data transmission within a local environment and a number of technologies have emerged that provide peripheral or direct competition for Bluetooth.

Bluetooth's technological nature, though similar to the competing wireless local area network (W-LAN) standards described below, has important differences in its potential uses and market. Bluetooth can best be described as cable replacement technology or Personal Area Network rather than a W-LAN technology. Many of the devices that Bluetooth seeks to interconnect may have very limited computing resources (digital cameras and mobile telephones, for example). This having been said, the W-LAN competitive environment was an important consideration for the Bluetooth consortium throughout the period of its development for a number of reasons.

As Bluetooth's acceptance as a proxy standard develops, similar products will need to ensure that at the physical layer at least (frequency allocation, data transmission rate) that there is a degree of interoperability between future standards and Bluetooth. This will in turn accentuate the value of the component expertise developed by Bluetooth consortium firms relating to aspects of the Bluetooth physical layer. It will potentially also facilitate commercial opportunities for proprietary and complementary additions to Bluetooth and other W-LAN standard that consortium members may have been developing.

Standards Competition

Within this competitive context, other developments in W-LAN technologies are noteworthy. While Bluetooth was never conceived as being able to provide a universal wireless solution for all data exchange needs within an office or commercial environment, potential uses of W-LAN and Bluetooth do intersect. Bluetooth's less ambitious technical requirements have created a more rapid development cycle than has been evident in competing technologies. This rapid cycle has assisted Bluetooth in becoming widely accepted, locking-in vendor commitment and extending the potential for proprietary modular innovations for peripheral uses.

¹ The sole international exception is provided by the French military, which utilises the technology for certain local applications. Negotiations are being undertaken to remedy this problem within European fora.

From a consumer perspective, Bluetooth has a number of potential benefits not shared by the more complex W-LAN technologies. Bluetooth's chipsets will be cheap and relatively simple. Mass production of the devices, it has been estimated by Ericsson, will drive the cost to around USD 5.00 within five years. As such it will be feasible for Bluetooth technology to be incorporated into all electronic products, building significant positive network effects unavailable for the more expensive and complex alternative options detailed below. Bluetooth will also be easy to use. Most user interfaces will occur automatically, with Bluetooth enabled devices automatically recognising and configuring with one another when they come into range.

IEEE 802.11

Among Bluetooth's competitors in the higher end of the local data transmission market (connectivity between PCs and servers, for example) the IEEE 802.11 is the most notable and best established. It was first conceived in 1990, with final drafts of specifications released in 1997. Like all others in the area including Bluetooth, IEEE 802.11 technology uses packet switching to achieve data transmission rates of around 1 Mb/s. As technology has developed, IEEE engineers have developed later iterations of the standard, though at the cost of backward compatibility with earlier versions and appliances.

IEEE 802.11 has suffered most from a lack of market focus. The second version of the standard (IEEE 802.11a) will not be available for use in Japan and Europe due to frequency reservations problems in those regions. While these problems were rectified in the latest technological iteration, such a fundamental market and technological mistake would never have been made by the international Bluetooth consortium.

IEEE 802.11's most serious problem has been lack of strong direction from and backing by commercial vendors. Conversely, this has and continues to be an area of strength for Bluetooth. While IEEE 802.11 has tried to develop solutions within the standard, Bluetooth's rather more parsimonious approach to what is possible technologically in the early stages of release has created the potential for modular innovations later on. This has been attractive to a range of small, medium and large hardware and software vendors.

A variant of the IEEE standard, IEEE 802.15 Personal Area Network is also in development and work is underway by this IEEE group to ensure interoperability between it and Bluetooth. This illustrates the emerging role of Bluetooth as a proxy wireless interconnectivity standard, at least at the physical layer (Palenchar, 2000).

SWAP

The SWAP (Shared Wireless Application Protocol) also targets W-LAN environments. Interestingly from the point of view of this research, the HomeRF consortium that are developing the technology have also developed a consortium approach to encourage diverse participation by hardware and software vendors. This was something of a late decision taken in March 1998 as the technology was becoming increasingly marginalised among its competitors.

The consortium of companies includes Siemens, Compaq, IBM, NTT and Nortel, among others. Membership between Bluetooth and HomeRF is not mutually exclusive. While Nokia and Ericsson are not members of Home

RF, Intel, an early Bluetooth consortium member is.

The SWAP standard is targeted at home users rather than office environments and thus provides peripheral competition to Bluetooth. Products that have been released so far have reflected this focus, and indications seem to show that target users will be users of multiple PCs in a home environment who wish to access single cable modem and other fixed line modem points within domestic environments. The standard builds upon the European DECT cordless standard and it has been developed to allow up to six simultaneous wireless voice lines, a feature that will be of increasing attractiveness as the takeup of Voice over IP and ISDN expands.

Early products released using the SWAP standard have been quite expensive, aimed at higher end users and achieving more complicated tasks than Bluetooth is aiming to satisfy.

Other Standards

There have been a number of other variations developed, though none have achieved the degree of vendor or market support evident for Bluetooth. The European Telecommunications Standards Institute (ETSI) are developing a number of standards called HiperLan, though progress has been slow (Johnsson, 2000).

Bluetooth Processes

The cooperative nature of W-LAN and Bluetooth technological development sits as an exception in the standards setting processes within the broader wireless context. Wireless standards development processes in 3G mobile systems, for example, have been fraught with turf wars and court cases challenging patent and IPR ownership. Notable here was a lengthy conflict between Ericsson and Qualcomm (of the United States) regarding IPRs relating to CDMA technology.

From the point of view of technology development, the process of developing Bluetooth has relied on developing networks between often competing firms. Managing patent claims is always difficult – managing them within a cooperative forum like Bluetooth would be a Herculean task. A solution emerged early in the technology's development due to broad acceptance by all participants to the relative openness of the standard. Such an approach tends to reduce the costs of the overall device by negating the need for royalty payments. It thus also increases the amount of opportunities for peripheral innovators and other late entrants due to the fact that profits tend to emerge from the development of innovative new products and applications rather than from ownership of the relevant protocol IPRs.

The choice of the Bluetooth name, (in memory of Viking King Harald Blåtand who united a few warring Scandinavian tribes, for a short time, at the beginning of the tenth century), illustrates that the development of cooperation among competitors was an early and important element of the standard's development process².

² Historians are divided among the usefulness of Harald as an exemplar of peaceful coexistence. The warring Vikings didn't stay peaceful for too long and soon resorted to their pillaging ways.

The potential for royalties in Bluetooth were always going to be negligible after the product was conceived as a low costs addition to virtually all electronic devices. Early proponents of the technology like Ericsson and Intel viewed the technology as a way of adding value within their core businesses rather than having profit potential in the long-term.

Building a critical mass of vendor support was a key, early challenge for the technology's backers. To assist in this process, the consortium was organised as a cooperative forum. Initially begun with five members, the "Special Interest Group" (SIG) now comprises members from mobile telecommunications, IT hardware and software, media, medical and industrial sectors.

All members of the SIG have access to necessary protocols to facilitate the development of hardware and software for Bluetooth applications. Broader control of central elements of the standard (for example, changes in the protocol) is exercised by a "Promoter Group" (PG), currently comprising 3Com, Ericsson, Intel, IBM, Lucent, Microsoft, Motorola, Nokia and Toshiba.

The cooperative nature of the PG and SIG is the result of an early strategic decision by early developers of the technology – and most notably Ericsson. While this firm was a founder of the Bluetooth consortium with Nokia, IBM, Intel and Toshiba, it was Ericsson that adopted the early technological champion role, undertaking essential early R&D which saw Bluetooth emerge from a competitive environment as the preferred wireless connectivity standard.

Ericsson's view of Bluetooth has been to see its potential to add value to and complement its core businesses of mobile and fixed-line telecommunications infrastructure and terminals. Ownership of the core Bluetooth technology was thus seen to be of secondary importance to the broader objective of Bluetooth's ability to increase demand for Ericsson's core products. The creation of the PG also required a little magnanimity on the part of Ericsson as both Nokia and Intel had similar projects underway, albeit at an earlier stage of development. The decision by these firms to back the Ericsson proposal would not have been possible had an emphasis on royalty payments been made at the early stages of the technology's development.

The entire developmental strategy also had a neat symmetry for Ericsson and Intel, the Bluetooth founders. The cooperative development consortium model, and the decision to make the entire standard openly available to all participants, supported the aims of:

- building installed base within the marketplace and forestalling the growth of a competing, proprietary standard,
- locking in vendor commitment through developing installed base among customers,
- building competencies in and value for complementary technologies within the core businesses of PCs (in the case of Intel) and the mobile phone (in the case of Ericsson),
- developing organisational competencies in key elements of the technology that will facilitate market leadership where interactions occur with their existing products.

While the wireless interactivity market may offer great potential for these firms in the long term, such potential

development will make itself felt within the firms' core markets in the first instance. For Ericsson, the opportunity of engineering a strong role for mobile terminals through the Bluetooth technical architecture was of central importance.

The decision to invite Microsoft to join the PG in mid-1999 (and their decision to accept) can also be seen in this context. Not noted for its commitment to open-source software and open standards, Microsoft's active cooperation within the PG was aimed at ensuring Bluetooth compatibility with their proposed Windows CE operating system rather than developing proprietary value within the Bluetooth consortium. For Microsoft, joining the consortium provided an opportunity to bolster the flagging Windows CE operating system, or at least an opportunity to limit the process of marginalisation of their technology that the introduction of competing operating systems had begun.

The Bluetooth standard's development process can thus be seen as illustrative of the potential of cooperative approaches to standards development. The converged IT&T industries will increasingly require such approaches to develop new knowledge across traditional industry boundaries, thus the success of the Bluetooth cooperative model provides salient lessons for industry and policy makers with interest in the converging IT&T hardware, content and service provision industries.

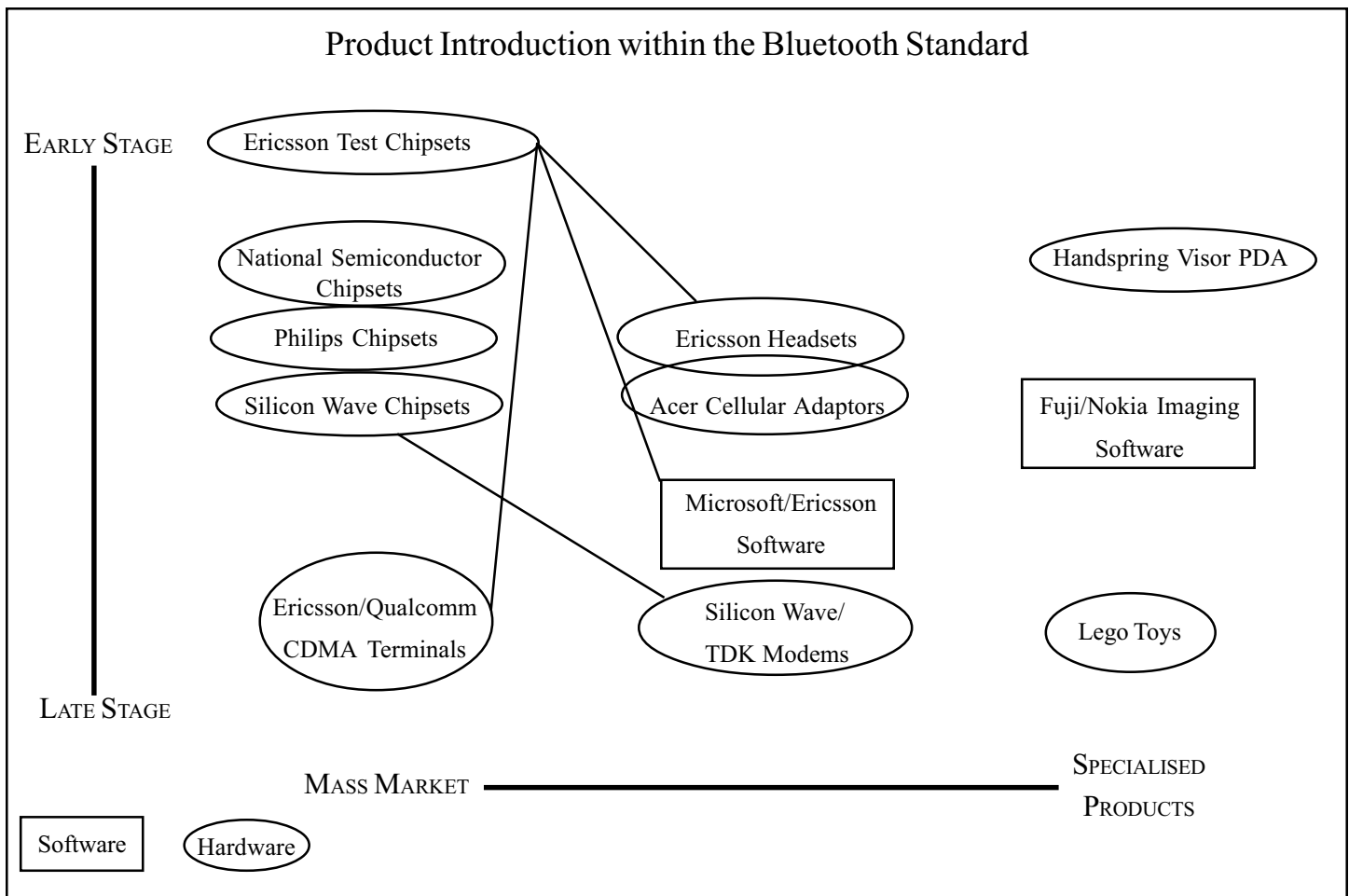
The following graph is illustrative of early developments in Bluetooth hardware and software. It is intended to be illustrative rather than comprehensive in its presentation of new product introduction. Ericsson was the first firm to introduce test chipsets for developers. This indicated their lead role in developing the technology and their advanced position in understanding the issues related to its operation.

In the chipset segment of the Bluetooth market (the basic componentry end), a number of competitors soon entered. Ericsson's depth of competencies, though, gave them a lead position in the development of high value added products like their wireless headsets and also placed them in a strong position to enter alliances with industry leaders like Microsoft and Qualcomm to further develop software and hardware for Bluetooth applications.

The graph also illustrates the entrance of both large and small firms in central and peripheral areas of the market. Both Philips and National Semiconductor leveraged their earlier DECT competencies in the development of Bluetooth chipsets. Nokia has entered into an alliance with Japan's Fuji to develop software for the transmission of digital photographs through wireless means. Handspring was an early adopter of Bluetooth in their Palm compatible PDAs. Acer, the Taiwanese hardware manufacturer, has introduced Bluetooth adaptors for cellular telephones. Lego, the Danish toymaker, have signalled their interest in using Bluetooth to replace the infra-red technology used in some high value toys. (Mayer, 1999; Prophet, 2000; Schneiderman, 1999).

A key element of Ericsson's strategy has focused on the development of firm alliances to leverage their Bluetooth competencies in the development of new and defensible innovations. Illustrative of this have been projects undertaken by Ericsson with Microsoft and Qualcomm to develop software and hardware respectively. Such an approach may lead to patentable innovations within growing markets in the future.

The single-headed arrows in the following graph illustrate the direction of competence leverage in the processes of



product development and alliance formation. Silicon Wave is a relatively small firm based in San Diego. The decision by TDK of Japan to enter into numerous development alliances with them has been based upon the competencies that the small firm had generated in the development of Bluetooth chipsets for various applications early in the technology's development cycle.

Sources: Mayer, 1999; Prophet, 2000; Schneiderman, 1999.

Conclusions

Changing technologies are having far-reaching impacts upon not only the type of products and services that we produce, but also the manner in which production occurs. These changes extend beyond the nature of the productive process to the nature of the economy within which production occurs.

Firms like Ericsson and Intel, Bluetooth's original promoters, viewed the emerging W-LAN technologies as peripheral to their core activities. They did, though, view the technology as being important enough to develop a strategy that would add value in their core businesses through extending overall demand for their products (especially in the case of Ericsson). Both firms also viewed the emergence of a proprietary W-LAN technology with trepidation, due to the potential for either incompatibilities to emerge with their existing products or though royalty payment requirements being created going-forward.

By making the core specifications freely available, the Bluetooth consortium created a strong driver for industry acceptance and innovative-firm takeup. Core competencies that the firms developed in the early stages of the standard's development were not lost as Ericsson, for example, entered into strategic alliances with other major firms to develop patentable technology. Ericsson also used its competency base to be first entrant into consumer markets like wireless headsets for their mobile telephones.

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