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Nokia and MIT's Project Oxygen

Bringing abundant computation and communication, as pervasive and free as air, naturally into people's lives.

—Oxygen Web site

Despite the fact that 2002 was another year of an unremitting telecom industry slump, Pekka Mechelin,[1] a director of strategy at Nokia, remained optimistic about his company's future. In the face of declining sales for mobile infrastructure equipment and difficulty across the mobile industry in rolling out high-bandwidth services, Nokia had announced some interesting new products during the year, had maintained reasonable performance, and was aggressively pursuing a growth strategy. It was still seen as a mobile device powerhouse with market share of more than 50% in Europe, Africa, and the Middle East and in the high 30s in the United States.[2]

On Mechelin's mind on this particular Tuesday, however, was the meeting that he had just attended at Massachusetts Institute of Technology (MIT) in Cambridge, Massachusetts, with a group of cosponsors of the Oxygen project. The Oxygen project was conceived and organized by the late Michael Dertouzos, head of MIT's Laboratory for Computer Science from 1974 to 2001. As described in detail in his book *What Will Be: How the New World of Information Will Change Our Lives*,[3] Dertouzos envisioned a world in which people interacted naturally with computers that were embedded everywhere in the environment around them—computers that provided a rich set of useful services through a human language interface.

While this world was not hard to envision technically—certainly the technology to support it had been under development for decades and was being introduced at an ever-accelerating pace—it was less clear how Dertouzos's world would work economically. What was going to have value? What kind of companies would be best positioned to capture that value? More specifically, thought Mechelin, what were the products and services that Nokia would provide in this new world? Was Nokia's current strategy going to get it there, or would it need a course change on the way?

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[1] Pekka Mechelin is a fictitious character who is named after Leo Mechelin. Mechelin was one of Nokia's founding fathers and was also a leading Finnish parliamentarian who played an important role as advocate for Finland's independence in the 1860s.

[2] "Nokia Plays to Its Strengths," *Wireless Data News*, December 19, 2002, <http://proquest.umi.com>, accessed January 5, 2003.

[3] Michael Dertouzos, *What Will Be: How the New World of Information Will Change Our Lives* (Harper Edge, 1997).

Professor Rebecca Henderson and Research Associate Nancy Confrey prepared this case. HBS cases are developed solely as the basis for class discussion. Cases are not intended to serve as endorsements, sources of primary data, or illustrations of effective or ineffective management.

The Oxygen Project Vision and Technologies

The Oxygen project was a joint endeavor between the MIT Laboratory for Computer Science (LCS), the MIT Artificial Intelligence Laboratory (AI Lab), and a group of corporate partners including NTT, Nokia, Hewlett-Packard, Philips, Acer, and Delta. The project encompassed over 20 loosely coordinated research projects, each of which contributed to the overall vision.

The vision for the Oxygen project was to do nothing short of revolutionizing the interaction of man and computer. Dertouzos observed that in the 40 years since the dawning of the computer age, computation had been centered on machines, not people:

> We have catered to expensive computers, pampering them in air-conditioned rooms or carrying them around with us. Purporting to serve us, they have actually forced us to serve them. They have been difficult to use. They have required us to interact with them on their terms, speaking their languages and manipulating their keyboards or mice. They have not been aware of our needs or even of whether we were in the room with them.
>
> In the future, computation will be human-centered. It will be freely available everywhere, like batteries and power sockets, or oxygen in the air we breathe. It will enter the human world, handling our goals and needs and helping us to do more while doing less. We will not need to carry our own devices around with us. Instead, configurable generic devices, either handheld or embedded in the environment, will bring computation to us, whenever we need it and wherever we might be. . . . We won't have to type, click, or learn new computer jargon. Instead, we'll communicate naturally, using speech and gestures that describe our intent ("send this to Hari" or "print that picture on the nearest color printer") and leave it to the computer to carry out our will.[4]

Oxygen Technologies: Devices, Networks, and the User Interface

A set of technologies defined the central components of the Oxygen world: handheld mobile devices, embedded devices, networks for connecting them, and software applications that could move freely between computing platforms and across networks.

Handheld devices, called H21s, were the mobile access points to the Oxygen world, serving data or communication needs as necessary. Packed into the small space of a mobile device were all the capabilities necessary for it to become whatever was required of it—some combination of mobile telephone, personal digital assistant, pager, camera, and laptop computer—plus entirely new functionality like geographical positioning systems.

An H21 was an "anonymous" device. Sitting on a table it was stateless; however, when picked up, it recognized its user, configured itself to the user's preferences, and attached itself to the applications and data relevant to that user at that time. The H21 could communicate using multiple communications protocols. It reduced the power it consumed by off-loading tasks as possible to the embedded devices around it.

Embedded devices, called E21s, created intelligent spaces in offices, buildings, homes, and vehicles. E21s provided abundant embedded computation, as well as interfaces to cameras and microphone arrays, large-area displays, and other devices. In spaces embedded with E21s, users

[4] From <http://oxygen.lcs.mit.edu/index.html>, accessed January 30, 2003.

could communicate naturally with vision and speech, without having to be aware of where the E21s were located.

Networks in the Oxygen world, called N21s, could support multiple communication protocols for point-to-point, buildingwide, and campuswide communication. Unlike networks in 2003, services provided via N21s could maintain a session between different network types, optimizing network connection quality, speed, and power use. A user, for example, could walk from his or her car to a building while talking to a colleague, and upon the user's entering the building the N21 would reconfigure the network connection to one embedded in the building without the user being aware of the change. N21s would also provide capabilities for naming, location, and secure information access.

The user interface between the computer and any Oxygen device relied on speech and vision rather than keyboards and mice. Speech and vision would work together much as humans communicate, using facial expressions, pointing, gazes, and lip movement to embellish understanding of any interaction. In addition, Oxygen would tailor its communication to a user's situation, relying on speech alone if the user had eyes and hands busy while driving or producing more visual, graphical interactions when the user was sitting in front of screens and cameras.

A Scenario of Life in an Oxygen World

The following scenario was a simple example of how Oxygen's integrated technologies could be used in an everyday situation.[5]

The business conference Hélène calls Ralph in New York from their company's home office in Paris. Ralph's E21, connected to his phone, recognizes Hélène's telephone number; it answers in her native French, reports that Ralph is away on vacation, and asks if her call is urgent. The E21's multilingual speech and automation systems, which Ralph has scripted to handle urgent calls from people such as Hélène, recognize the word "décisif" in Hélène's reply and transfer the call to Ralph's H21 in his hotel. When Ralph speaks with Hélène, he decides to bring George, now at home in London, into the conversation.

All three decide to meet next week in Paris. Conversing via their E21s, they ask their automated calendars to compare their schedules and check the availability of flights from New York and London to Paris. Next Tuesday at 11 a.m. looks good. All three say, "OK," and their automation systems make the necessary reservations.

Ralph and George arrive at Paris headquarters. At the front desk, they pick up H21s, which recognize their faces and connect to their E21s in New York and London. Ralph asks his H21 where they can find Hélène. It tells them she is across the street, and it provides an indoor/outdoor navigation system to guide them to her. George asks his H21 for "last week's technical drawings," which he forgot to bring. The H21 finds and fetches the drawings just as they meet Hélène.

Example Oxygen Projects

Much of the technology described by Oxygen's devices (H21 and E21) and networks (N21) were already feasible in 2003. Some of it was already available in products. Some of the undeveloped technology was being worked on at Oxygen partners' research laboratories. Researchers at LCS and

[5] This scenario is from the Oxygen Project Web site, <http://oxygen.lcs.mit.edu/Overview.html>.

the AI Lab were working on some of the most far-reaching technologies, as described in the two examples below.

Conversational interfaces At the heart of the value of the Oxygen world was the computer that interacted with humans on their own terms, responding not just to human commands but also to human intentions. The conversational interface research being conducted by MIT Professors Jim Glass and Victor Zue focused on creating computer systems that could conduct a goal-oriented dialogue with a human.

Dialogue is an extremely complicated and multifaceted endeavor quite unique to humans. Attempts to produce computerized dialogue fell roughly into three categories. "System-initiative" dialogues were the simplest type, by which the computer directed a set of predetermined questions at the user, who could answer with a restricted set of choices. These types of systems were already available commercially in the interactive voice response systems for call centers in 2002. At the other end of the spectrum were "user-initiative" systems, by which users could say whatever they wanted—relevant or irrelevant to the purpose of interaction with the computer. In between these extremes was "mixed-initiative" dialogue—the topic of Glass and Zue's research—by which the computer and human interacted to jointly solve a goal using a conversational paradigm.[6] Although more constrained than user-initiative systems, mixed-initiative dialogues were still complex in that they required the computer to resolve interruptions, confirmations, clarifications, ellipses, and sentence fragments.

Glass and Zue had designed an architecture that included the many components required of a dialogue system: speech recognition (parsing signals into words and other utterances of speech), language understanding (making sense of words and sentences), semantic frames and discourse context (putting words into context for understanding the full meaning), a dialogue manager (that directs inquiries and responses), language generation (forming new sentences that make sense and accomplish their purpose), and speech synthesis (making the sounds we recognize as speech). Each of these components was an area of research in itself.

Despite the complexity of the task, Glass and Zue believed that a computer with these capabilities was definitely possible, but they estimated that it was still 10–15 years in the future.

RAW RAW was a research project whose aim was to develop a chip appropriate to the embedded, free communications and computing like those envisioned in the Oxygen world.

Rather than using a single microprocessor like Intel's Pentium, the RAW design used a four-by-four grid of tiles that each contained a microprocessor. Each tile also contained communication paths to and from it and holding areas for data and instructions (called caches). Whereas single-processor chips were designed to perform a sequence of instructions over and over very quickly, the RAW chip could perform different functions on different microprocessors at the same time. Like changing a manufacturing line from a sequential process to one based on work cells, this design change could apply more processing power to bottleneck activities, thereby increasing the throughput of the entire system.

The RAW chip also had another fundamental difference from other chip designs. What each microprocessor on the chip did and how information flowed among them was controlled by software rather than being built into the wiring of the chip. This meant that the same chip could be used for different purposes depending on the context. A device equipped with the RAW chip, for example,

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[6] Victor W. Zue and James R. Glass, "Conversational Interfaces: Advances and Challenges," *Proceedings of the IEEE*, Vol. 88, No. 8 (August 2000): 1166–1180.

could be compatible with the GSM transmission protocol at one moment and the CDMA at the next.[7] In the current state of the art, this kind of flexibility was achieved by designing separate chips, each hardwired with one of the functions. In RAW, it was accomplished by writing software that could make the chip behave in alternative ways. There was no limit to the amount of functionality that a RAW chip could be programmed to adopt.

The design of RAW into identical, programmable tiles also meant that it was scalable. Adding more tiles provided more processing capability without requiring changes to wiring—only changes to software.

Nokia's Positioning for an Oxygen Future

Most of the world knew Nokia as a mobile phone and equipment manufacturer that excelled at making fashionable, functional mobile phones. Its competitors and analysts also knew it as a company that could produce phones at lower cost than its competitors. The network operators with which Nokia partnered for the sale and subsidization of its phones knew Nokia as a capable negotiator in striking deals. Despite the popularity of its brand and its strength as a competitor, however, very few people knew much about the Finnish company that in the late 1990s had suddenly become an important part of the global telecommunications market.

Nokia's History of Transformations

The Nokia known by the world in 2003 reflected only a few years of strategic positioning of a 140-year-old company. A recent historian of Nokia organized Nokia's history into five phases.[8] Established in 1865, Nokia's first phase was as a forestry company (paper and pulp manufacturing) that later diversified into electrical power.

The second Nokia, which developed in the early 1900s, was a three-company coalition that came about when The Finnish Rubber Works gained a majority stake in Nokia and The Finnish Cable Works. With Nokia in electricity, The Finnish Cable Works producing the electrical cables, and The Finnish Rubber Works providing the rubber for cable insulation, the three were well-positioned to reap the benefits from the introduction of electricity in the early 1900s. The official merger of the three original companies into the Nokia Corporation occurred in 1967; the Nokia name was used because of the strength of its brand.

Through acquisitions throughout the 1980s, the third Nokia was a European conglomerate that included businesses as diverse as communications, radio phones, information systems, cable, engineering, industrial machinery, paper, rubber, chemicals, and plastics.[9]

It was during this era that Mobira Oy (Nokia Mobile Phones) and Telenokia Oy (Nokia Telecommunications) were founded—the two businesses that would become the heart of the company by 2003. These divisions introduced a number of important innovations; they produced the first fully digitalized local exchange in Europe in 1982, the first portable Nordic mobile telephony

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[7] GSM (Global System for Mobile Communications) was the transmission standard developed for the European mobile wireless market and in 2002 was used in 182 countries. The CDMA standard (code division multiple access) was developed by Qualcomm for the U.S. market and had been adopted by 32 additional countries by 2003.

[8] Dan Steinbock, *The Nokia Revolution* (New York: American Management Association, 2001), pp. 3–28.

[9] Ibid., pp. 85–114.

(NMT) car phone (1984), the first NMT pocket phone (1987), as well as a line of nationwide pagers. Perhaps most importantly, the world's first cell phone call using the GSM protocol—the cellular transmission standard that was to become the standard for all of Europe—was made in Finland using a Nokia phone on a network built with Nokia equipment.

In the early 1990s, the fourth Nokia—one that was still evident in 2003—emerged as a business primarily focused on wireless phone and equipment manufacturing. In this period, Nokia became the first manufacturer to produce phones for all digital systems and expanded globally. By 1999 only 2% of its sales were from Finland, with 52% from Europe, 25% from the Americas, and 21% from Asia-Pacific.[10]

The focus on wireless phones and GSM and the divestiture of the other noncore businesses that occurred during the 1990s (such as cables, machinery, power, and tires) were largely attributed to Jorma Ollila. Ollila was appointed CEO in 1992 after starting at Nokia in 1984 and holding positions as vice president of international operations, chief financial officer, and head of Nokia Mobile Phones. Prior to Nokia, he had held banking positions at Citibank. He was portrayed by the Finnish media as a somewhat eccentric and charismatic character; his public persona had developed during his student years when he had held visible leadership positions in student politics during a very sensitive period in Finland's developing independence.[11]

Once Ollila became CEO of Nokia, he locked on to a strategic vision that was focused on making Nokia a global leader in wireless telecommunications. As this vision looked well in hand at the close of the millennium, Ollila refined the vision further: Nokia's fifth era would be as a global leader in mobile Internet convergence.

Nokia at the Close of 2002

The years 2001 and 2002 were difficult for all companies in the telecom industry, including Nokia. In 2002, Nokia announced sales of $30.7 billion, down 4% from $31.9 billion in 2001. Operating profit rose only 3%, from $5.3 billion to $5.5 billion. (See **Exhibit 1** for Nokia's 2002 financial results.) Some analysts were bullish on Nokia's results, noting that while growth was not as impressive as had been hoped, market share increases had continued in Europe, Africa, and the Middle East.[12]

Clearly one of the factors behind 2002's lackluster performance was Nokia's and the industry's difficulty in implementing 3G[13]—mobile Internet broadband. European mobile operators had spent approximately $120 billion on licenses for the 3G spectrum,[14] while the technology for using the spectrum was still probably several years in the future—a situation that the media was portraying as a crisis.[15]

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[10] Steinbock, p. 151.

[11] Ibid., pp. 116–124.

[12] "Nokia Plays to Its Strengths," *Wireless Data News*, December 19, 2002, <http://proquest.umi.com/>, accessed January 5, 2003.

[13] Called 3G because it represents the third generation of wireless transmission protocols.

[14] Jay Wrolstad, "New Approach Needed for 3G," *Wireless NewsFactor*, December 2, 2002, <http://www.newsfactor.com/perl/story/20118.thml>, accessed January 7, 2003.

[15] Barry Fox, "What happened to 3G?" *Wireless NewsFactor*, January 7, 2003, <http://www.wirelessnewsfactor.com/perl/story/20387.thml>, accessed January 7, 2003.

Nokia, however, was pushing forward producing the equipment that would make 3G a reality. In September 2002, Nokia's Mobile Phones division demonstrated the Nokia 6650 on a live network. The 6650 was a mobile phone that operated using both the GSM (2G) and WCDMA (3G) protocols. It had a large color display and an integrated camera with picture and video capture capabilities, as well as multiple data connectivity options. The Nokia 6650 was the first Nokia phone to include the ability to record video with sound (video clips up to 20 seconds), which users could view and edit, piecing together clips that they could play back like a movie.[16] The device also sported a wireless headset, a microbrowser for browsing Internet content, and the software technology for downloading applications. Because it operated with GSM and WCDMA transmission protocols, the phone was intended to serve the European and Asian markets.[17]

Also in September 2002, Nokia's Network Infrastructure business became the first vendor to announce the beginning of shipments of EDGE hardware. EDGE (enhanced data rates for global evolution) was a data transmission technology that enhanced the bandwidth of current European GSM/GPRS transmission technologies (so was considered "2.5G") without requiring the expensive network infrastructure upgrade required for the full 3G solution. By the end of 2002, Nokia had delivered EDGE-capable equipment to 23 network operators.

In early 2003, Nokia also claimed to have rolled out 25 sites of WCDMA equipment to customers in 14 countries, with 17 more with trials under way. It further claimed to hold 30% market share in 3G in general.[18]

The Vision and Strategy: Leading the Mobile Internet Convergence

At Nokia's Mobile Internet Conference (NMIC) in November 2002, Ollila expressed his conviction that the time was right for working toward the convergence of the mobile industry and the Internet:

> A fundamental shift has begun in the communications industry, one that is as important as the shift from the telegraph to the telephone. This shift is toward IP convergence[19] and will be the next major step in our industry. IP convergence is the bringing together of technologies and services from both the mobile and the Internet domains, bringing together the best of two worlds . . .
>
> Despite the continuing challenging market conditions, we see our vision coming true as our industry is transitioning from mobile voice to applications on the move. And the transition to advanced mobile services is happening right now.[20]

In both public presentations and written company documents—many of them given by or featuring Ollila himself—Nokia reiterated a set of underlying principles it believed had to guide any action toward the vision of IP convergence.

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[16] "Nokia introduces the world's first handset for WCDMA and GSM networks," Nokia press release, September 26, 2002, <http://press.nokia.com/PR/200209/874947_5.html>, accessed January 6, 2003.

[17] Ibid.

[18] Jorma Ollila, "Making the Mobile Promise a Reality," presentation given on November 5, 2002 at the Nokia Mobile Internet Conference in Munich, <http://media.corporate-ir.net/media_files/priv/5395/nokia_nmic.html>, accessed February 4, 2003.

[19] "IP" stands for the Internet Protocol and is the underlying communications protocol of the Internet.

[20] Ollila, NMIC 2002, audiocast on Web site, <nokia.com>.

First, Nokia believed that the source of growth in the industry was dependent on the development of valuable, affordable services to the end user, and that concentrating on developing these new services was in the best interest of all players in the industry. Ollila said:

> What we must focus on now is how to make our new services richer and more valuable while at the same time driving penetration and usage. . . . We all know that services have to be affordable to reach mass-market appeal. We all have a stake in working together to make highly personal services that are genuinely easy to use.[21]
>
> Technology alone is not enough to change the way people communicate. We have to put the consumer to the fore.[22]

Second, these services to the end user had to be built on common platforms and open standards to ensure interoperability among devices, networks, and geographies. Common, open platforms would avoid lock-in to a single provider or the fragmentation that would arise from having multiple different technologies that could not interoperate. "Fragmentation results in reduced mass-market appeal and negatively impacts revenues," Ollila said.[23]

Finally, Nokia claimed that the GSM transmission standard would become the dominant transmission protocol of the future (the "global benchmark"). GSM represented 75% of new mobile subscribers in 2002, and a U.K.-based analyst firm predicted the GSM "family of technologies" would represent 85% of global subscriptions by 2006.[24] "The reality is that the GSM mobile standard is becoming the most important in the world," Ollila said.[25]

In short, Nokia was trying to "make an environment where all players can bring their own individual strength to the market." It wanted an environment that nurtured competition, innovation, and freedom of choice. Further, it believed that "only GSM/EDGE and WCDMA can bring all of this."[26]

Nokia's activities directed toward this strategy were numerous and comprehensive. Its efforts spanned the entire value chain, helping to arrange all the pieces of the giant puzzle that could make the mobile Internet happen. Its primary focus, of course, was on developing mobile devices, mobile infrastructure, and the software required to support these devices. In addition, however, it took leading roles in many of the open-standards efforts across the value chain, it provided extensive assistance and incentives to the community of mobile application developers who would create the new services, and it encouraged network operators to push toward interoperability, such as in the establishment of seamless roaming agreements. It also set up numerous partnerships with the traditional computer hardware and software market, producing products and programs that would

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[21] Jorma Ollila, "Making the Mobile Promise a Reality," presentation given on November 5, 2002 at the Nokia Mobile Internet Conference in Munich, <http://media.corporate-ir.net/media_files/priv/5395/nokia_nmic.html>, accessed February 4, 2003.

[22] "The Year Ahead for Mobile Developers," Forum Nokia, discussion with Ollila, January 2003, <http://www.forum.nokia.com/the_year_ahead>, accessed February 7, 2003.

[23] Jorma Ollila, "Making the Mobile Promise a Reality," presentation given on November 5, 2002 at the Nokia Mobile Internet Conference in Munich, <http://media.corporate-ir.net/media_files/priv/5395/nokia_nmic.html>, accessed February 4, 2003.

[24] "The Year Ahead for Mobile Developers," Forum Nokia, discussion with Ollila, January 2003, <http://www.forum.nokia.com/the_year_ahead>, accessed February 7, 2003.

[25] Jorma Ollila, "Making the Mobile Promise a Reality," presentation given on November 5, 2002 at the Nokia Mobile Internet Conference in Munich, <http://media.corporate-ir.net/media_files/priv/5395/nokia_nmic.html>, accessed February 4, 2003.

[26] Ibid.

extend fixed-wire product sets to mobile uses. (See **Exhibit 2** for examples of Nokia's activities toward mobile Internet convergence.)

Nokia's Research and Development

Nokia attributed its success in global wireless telecommunications in part to its investments in research and development (R&D). In 2002, Nokia's research budget was approximately $3 billion, or 10% of net sales (see **Exhibit 3** for R&D expenditure, 1998–2002). Nokia had carefully structured and funded its R&D efforts to achieve multiple objectives: delivering both research and development to the near-term needs of business units, remaining committed to long-term research, and constantly finding new sources of innovation.

These research objectives were accomplished through three organizational structures: a central R&D group, R&D groups within the business units (Nokia Mobile Phones and Nokia Networks), and the Nokia Ventures organization. At the end of 2002, 38% of all personnel were assigned to one of these units, with the majority of research resources deployed to R&D in the business units (approximately 94%).[27]

Nokia's Role in Fashion and Branding

Nokia was dedicated, both within the company and in its marketing, to portraying the handset as an element of personal fashion and to making the Nokia brand integral to that fashion. "Mobile phones are not consumer electronics," explained one director in R&D, "they are personal, they reflect the individual. You 'wear' a phone, and it needs to be consistent with who you are."[28]

In 1991 Nokia hired Frank Nuovo from 3M,[29] who became vice president of design of Nokia Mobile Phones. His job was to figure out how to make Nokia a household name, and he accomplished the task by extending branding through all of Nokia's activities—product development, sales, and human resources—rather than confining branding to marketing.

When the Nokia 8860 phone was introduced, "Nuovo became a fashionable subject of *Vogue*, which praised him as 'the designer who made wireless technology a fashion statement.'" *Vogue* also listed members of the "8860 club"—people seen carrying the 8860—which included media giants such as Tom Cruise, Steven Spielberg, and Janet Jackson.[30]

Nokia formed "Club Nokia" to reinforce its personalization and branding theme. Club Nokia was an online market for users to download ring tones and user-interface characteristics to customize their phones. Nokia expected personalization to get increasingly interesting and useful when more sophisticated applications could customize the device even further to each individual's needs.

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[27] "Nokia R&D," corporate presentation.

[28] Private conversation with Nokia director, 2002.

[29] Martti Haikio, *Nokia: The Inside Story* (Helsinki: Edita Publishing Ltd., 2001).

[30] Steinbock, p. 273.

Outstanding Questions in 2003

Exhibit 4 provides examples of the activities and major companies in the U.S. markets for the value chains in 2002 that would play some role in an Oxygen future: fixed-wire communications, wireless communications, embedded computing, and Internet content and services.

As Mechelin thought about the future, he wanted to understand:

- What will the business models be?
- Who will own the customer?
- What is the role of chip makers?
- How will embedded networks merge with existing communications and data networks?
- Will the standard stack be open and collectively controlled or privately owned?
- How will end-user markets be defined?

What Will the Business Models Be?

The business models for Oxygen would require mutually beneficial relationships to be established between equipment manufacturers, network operators, and content providers. Equipment includes the infrastructure such as switches, routers, base stations, and network nodes, as well as devices as diverse as mobile handsets, laptops, telephones, and servers. Network operation includes both voice and data communications—functions that in 2003 were split between network operators and Internet service providers (ISPs). Content provision includes operating system and other application platforms, development tools, and applications.

There were reasons to wonder whether the difficulty of establishing these business relationships was going to slow market evolution. Nokia was aware of the difficulties, for example, that network operators and content providers were having in establishing equitable revenue-sharing agreements. There had also been difficulties in establishing roaming agreements to make text messaging possible across networks owned by different operators.

While there was broad agreement that it was new services and applications that would drive market acceptance of the Oxygen paradigm, there were very few models in existence in which services and applications were creating healthy businesses. The revenues from Internet businesses, on which such high expectations had been pinned prior to 2001, were not inspiring; e-mail, games, online shopping, and one online auction site were among the limited set of applications that had healthy subscriber bases. Users paid fixed-fee subscriptions for connection to the Internet, but growth in subscriptions had been uneven recently (see **Exhibit 5** for a history of ISP subscriptions). With subscriber numbers low, advertisers were less enthusiastic about placing ads on Web sites.

In the late 1990s when network bandwidth increased to accommodate Internet use, there had been strong expectations that the locus of computing would move from the individual's personal computer to central servers. New service businesses were expected to develop, called application server providers, or ASPs, that would manage the servers and provide the applications that users wanted, and users would switch to stripped-down computers called thin clients. ASPs would reduce the cost and complexity of maintaining information technology specialists in-house and reduce the cost and complexity of maintaining client machines. The ASP model had failed to catch on by 2003, however, mostly due to concerns about network reliability, speed, and security.

Two interesting business model examples, however—one that had already taken place and one that had future potential—were worth noting: NTT DoCoMo's i-mode service, and massively multi-user persistent worlds (MMPWs).

NTT DoCoMo's i-mode service NTT DoCoMo's i-mode was interesting as a source of insight into business models that might emerge in an Oxygen world. It was simpler than might be needed for an Oxygen world and had not yet proven itself successful outside of the Japanese market. It did, however, at least illustrate a successful orchestration of business, technological, and social factors that attracted a healthy service providing both communication and data connectivity.

When i-mode was launched in February 1999, NTT DoCoMo was Japan's dominant wireless provider with approximately 60% market share.[31] Its i-mode service was provided via low-bandwidth mobile phones with black and white displays. In addition to phone service, i-mode devices could view Internet content that had been customized for viewing on their phones and could perform simple text messaging.

Unexpectedly, i-mode experienced rapid, enthusiastic adoption. It attracted over 31 million subscribers by February of 2002.[32] Revenues from i-mode increased by 37% in FY2000 and by 73% in FY2001.[33] Reasons given for its success included the technical, business, and social design of the service.

I-mode had three particularly strong technical qualities. The first was that NTT developed a packet-switched data network to run in parallel with the voice network so it did not congest existing traffic and could be "always on" from the users' perspective. This enabled a business based on a charge for bits transferred rather than a charge for connect time. Second, NTT engineers developed a subset of HTML, called compactHTML (cHTML), for easily converting existing HTML-based Web sites to i-mode phones,[34] which made it easy to develop content for the phones. Finally, NTT declared that all i-mode devices would run the device operating system TRON—an open standard jointly developed by academia and industrial partners in Japan—so device manufacturers did not have to compete to establish a dominant operating system platform.

The business model for i-mode was based on charging low subscription prices (300 yen, or $3 per month) with the expectation that most revenue would come from the transferring of bits. To encourage lots of content that would drive downloading, DoCoMo established relationships with content providers in which they provided a billing mechanism and listing on the phone interface in return for the relatively low 9% of revenue earned through the service.[35] The billing mechanism was

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[31] Matthew Sandoval and Stephen Bradley, "NTT DoCoMo: The Future of the Wireless Internet?" HBS Case No. 701-013 (Boston: Harvard Business School Publishing, 2000), p. 18.

[32] John Beck and Mitchell Wade, "DoCoMo: Japan's Wireless Tsunami," American Management Association, 2003.

[33] NTT DoCoMo Web site, <http://www.nttdocomo.com>.

[34] The rules for converting a Web site were posted on DoCoMo's Web site, and engineers did not have to learn a new language for developing wireless-access sites as they had to using alternative methods such as the Wireless Application Protocol's (WAP) wireless markup language (WML).

[35] Nine percent was lower than most revenue-sharing agreements, which were typically closer to 20% and sometimes as high as 50%, according to Sonja Hilavuo in the presentation "Practices in Service Tariffing and Revenue Sharing," at the Nokia Mobile Internet Convergence Conference, November 6, 2002, <http://media.corporate-ir.net/media_files/priv/5395/nokia_nmic.html>, accessed January 7, 2003.

not only a convenient service for the content providers, it was also much easier for users, who could accrue small charges across many sites and have all of them presented in one bill.

The social reasons for i-mode's success may have been just as important as the technical or business reasons. The rapid adoption of the device was initially attributed to instant messaging; the i-mode phone turned out to be a convenient way for teenagers to communicate. There was also speculation that the relatively low PC/Internet penetration to Japanese homes drove adoption because despite its limitations, the i-mode device provided access to the Internet at a dramatically lower price than was otherwise available.

Games and massively multiuser persistent worlds It was possible that the real money to be made online would use novel models not yet working in 2003, such as the one envisioned in virtual environments, or "metaverses," also called massively multiuser persistent worlds (MMPWs). Introduced in Neal Stephenson's science fiction novel *Snow Crash*, metaverses were online worlds in which users could "communicate, play games, go on adventures, fall in love, get married, get divorced, start businesses, found religions, wage wars, protest against them, and experiment with self-government."[36] Metaverses were like the popular online interactive games such as "Everquest," "Ultima Online," and "Asheron's Call" except that they did not have defined goals, objectives, or rules of play—they were just places to be. Their graphics were compellingly detailed, with different geographic locations modeled from satellite data

Interactive online games were already a lucrative market. A Korean game called Lineage had more than 2 million subscribers at the end of 2002; Sony's game Everquest had about 450,000 subscribers in the United States.[37] Subscriptions cost approximately $10–$15 per month.

The customers of this market were mostly dedicated computer game player types, many of whom devoted more than 20 hours per week to playing. Approximately 20% of Everquest's inhabitants considered that world their primary residence, and nearly 40% said that if they could earn a living wage playing the game they would give up their real job.[38] Many could see the potential for this world moving to a larger, mass audience; the new site "There.com" and LucasFilm's virtual world modeled after Star Wars had announced plans to do just that.

In addition to increasing subscriptions through mass commercialization, however, makers of virtual worlds had other plans for greatly increasing their revenue from these games. Virtual worlds provided ways for users to earn money and spend it. The thinking was: Why not draw the connection between the "virtual" currency and "real" currency and the ability to use real currency to buy virtual goods? EverQuest players had been known to spend as much as 1,500 "real" dollars for virtual cobalt armor and scepter destruction weapons. Nike and Levi's were undergoing tests to sell virtual versions of their newest clothing lines to array on players' virtual selves.

Many companies were experimenting using games for marketing, customer relationship, and training vehicles. Companies like YaYa, LLC were developing games for clients as diverse as DaimlerChrysler, Burger King, and Siemens. Siemens, for example, built a game for users to create civic structures in cities such as Berlin, Los Angeles, and Shanghai by answering trivia questions—

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36 Michael Benedikt, ed., *Cyberspace: First Steps* (Cambridge, MA: MIT Press, 1991); "The Lessons of Lucasfilm's Habitat," <www.fudco.com/chip/lessons.html>.

37 Robert Gehorsam, "The Coming Revolution in Massively Multiuser Persistent Worlds," *IEEE Computer Magazine*, April 2003..

38 Ibid.

some of them directly related to Siemens's business and some not.[39] These companies found that interacting with potential customers using games engaged their customers many times longer than traditional advertising, resulted in more requests for further information, and led to greater rates of e-mail responsiveness and peer-to-peer marketing than other forms of customer interaction.[40]

Was it possible that games would become a central component of most companies' relationships with their customers or potential customers?

Who Will "Own" the Customer?

Telecommunications' value chains were driven by wired or wireless *network operators*, sometimes called *carriers.*[41] These were the companies that owned the communications infrastructure (the switches, the base stations, the wires, the fiber-optic cable, and the rights to the spectrum)[42] and customer relationships. In 2002, most of these companies were over capacity and in debt, struggling for profitability. During the Internet bubble of the late 1990s they had overinvested in infrastructure (particularly fiber-optic cable and wireless 3G licenses) based on overly optimistic estimates of how quickly Internet commerce would drive capacity and bandwidth needs. In the absence of expected demand, however, prices had dropped precipitously, particularly for long-distance service.

In response to the uncertainties over how the communications infrastructure would develop, many of the large network operators had responded by acquiring cable companies, wireless operators, or ISPs or by consolidating with competitors. The diversified companies that resulted were at an advantage in their ability to place their bets across different types of networks during continued industry uncertainty. Acquisition activity continued in 2002, most notably with Comcast's (a cable television and high-speed Internet access company) purchase of AT&T Broadband (AT&T's cable unit) and Level3's (a wholesale bandwidth provider) purchase of Genuity[43] (an ISP).[44]

Some carriers were capitalizing on this advantage by bundling the services they offered into one package that included fixed wire, wireless, broadband access, and Internet service provision. From the customer's perspective, the bundle would be easier to manage; he or she would receive only one bill and possibly one bundled price for all services. From the carrier's perspective, the convenience of this service would help to create lock-in to customers who might find it harder to switch to other carriers if it would mean disrupting all of their other services at the same time. Verizon, for example, announced in August 2002 that it would offer bundled services to consumers—local, long-distance,

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[39] <http://yaya.com>, accessed May 19, 2003.

[40] Keith Ferrazzi, Jane Chen, and Zhan Li, "Playing Games with Customers," *Harvard Business Review*, April 2003.

[41] Many of the wireless network operators were divisions of the traditional network operators: AT&T Wireless (AT&T) and Verizon Wireless (Verizon) in the United States, DoCoMo (NTT) in Japan, and Orange (France Telecom) in France, for example. There were wireless providers, such as Europe-based Vodafone and Virgin, that had not started as wireline carriers. Vodafone's strategy in 2002 was to buy wireless operations across the globe, building scale and a "global" value proposition to users. Virgin bought wholesale access to other carriers' infrastructure.

[42] Rights to the spectrum for transmitting signals were particularly important in wireless where licenses for the high-bandwidth 3G spectrum had been auctioned for billions of dollars and were one of the widely cited reasons for the delay in investment for the equipment necessary for 3G.

[43] Genuity was originally the ISP division of Bolt Beranek and Newman (BBN), which had been purchased by GTE in the late 1990s. Genuity was spun off as an independent company as a regulatory requirement of the merger of Bell Atlantic and GTE to form Verizon in the late 1990s.

[44] Alex Goldman, "Notes to Top ISPs by Subscriber, Q4 2002," *ISP Planet*, April 3, 2003, <www.isp-planet.com/research/rankings/usa.html >, accessed April 1, 2003.

wireless, and high-speed access service—for one price in one monthly bill.[45] Verizon CEO Ivan Seidenberg predicted that the promotion would add $500 million to $1 billion in annual revenue by 2008.[46]

The network operators' disadvantages, however, were numerous, with many rooted in their highly regulated and monopolistic past. These disadvantages had been painfully evident during the introduction of the Internet when these companies either did not innovate quickly enough or were forced to deal with the constraints of regulation if they were to take advantage of new opportunities.

The role of ISPs ISPs provided customers with a software connection to the Internet, space on computer servers, and usually e-mail services. Larger ISPs such as America On-Line (AOL) and Microsoft's MSN were also "portal" providers; they provided a single, customizable point of entry to the Internet where users could collect and organize information and services such as news, weather, shopping sites, up-to-date stock information, and connections to sports and entertainment sites.

The idea behind portal businesses was to be an Internet "middle man," thereby becoming a platform for value-added services. AOL provided chat rooms and instant messaging that reportedly comprised more than 50% of its subscribers' usage.[47] Microsoft's MSN included deals on Internet connection packages, virus protection, parental controls, and online bill payment as value-added services.

Network operators were not among the largest ISPs. The top five ISPs—AOL (with 26.5 million subscribers), Microsoft's MSN (9 million), Earthlink (5 million), United Online (5 million), and the cable company Comcast (3.6 million)—represented 50% of the market. A further 36% of the ISP market was served by companies with subscriber bases smaller than 100,000.

Wi-Fi and 3G An important development in 2002 was the new popularity of *wireless local area networks* (WLANs) as a potential broadband access network for homes, businesses, and public use. The IEEE standard 802.11 with all its variants had seen a surge in popularity propelled in large part by the Wi-Fi Alliance[48]—an international nonprofit association that conducted a certification program to ensure interoperability of products built to the IEEE 802.11 specification. Since Wi-Fi certification had begun in March of 2000, the alliance had acquired 202 member companies and had certified 580 products.[49]

A number of companies were making significant investments in installing Wi-Fi networks in public places such as coffee shops and airports. Deutsche Telekom's mobile unit T-Mobile invested in providing coverage in Starbucks coffee shops.[50] AT&T, Intel, and IBM Global Services formed the company Cometa, which had aggressive plans to install wireless "hot spots" throughout 50 major urban areas of the United States in the first year and then sell wholesale access to these networks to

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45 Dave Sterman, "Bundle of Joy?" *Multitex Investor's Internet Analyst*, August 16, 2002, <http://tel.multexinvestor.com>, accessed August 23, 2002.

46 Ibid.

47 Robert Gehorsam, "The Coming Revolution in Massively Multiuser Persistent Worlds," *IEEE Computer Magazine*, April 2003, p. 94.

48 Wi-Fi is short for Wireless Fidelity.

49 From the Wi-Fi Alliance Web site, <http://www.weca.net/OpenSection/index.asp>.

50 "Wi-Fi Widens Reach," *IEEE Spectrum*, January 2003.

retail chains, hotels, universities, and cafes.[51] Boingo Wireless was a company started early in 2002 by the founder of the ISP Earthlink that aimed to create the broadband wireless service provider for individual and enterprise access by developing Wi-Fi networks in airports, hotels, and other public places.[52]

Wi-Fi networks were not expected to eliminate the need for 3G networks, but they did represent an interesting challenge to the prevailing assumptions about business models and deployment approaches for high-bandwidth, mobile network capabilities. The wireless carriers' 3G plans required massive up-front investment in spectrum licenses and equipment upgrades that would then be paid back by subscribers over many years. It was a model much like the traditional telephone network and was a reasonable plan assuming that users would be willing to pay for additional broadband services on a level commensurate with the investment made to install it everywhere. Since there was not yet a large set of value-added services that would justify higher prices, however, the plan involved significant risk.

The Wi-Fi network, on the other hand, used unlicensed spectrum and was designed to extend the reach of a current Internet connection a few hundred feet from a base station in a public place, workplace, or campus. Wi-Fi capabilities could be added where and when they were needed. They were a means of providing more value to the "box" (computer)—and were therefore a means of encouraging computer sales. Whereas 3G was going to make money through higher-priced telecommunications services, Wi-Fi would make money by increasing the sales of computing equipment.[53]

Big companies in both computing and telecommunications were making big investments to be part of Wi-Fi's future, but not everyone was optimistic about its ultimate potential. Intel announced new processors with built-in WLAN and dedicated $100 million to WLAN marketing. Cisco purchased the home networking company Linksys for $500 million. Those with low enthusiasm for the technology, however, pointed to the low rates of laptop usage for which Wi-Fi was designed, the poor coverage of Wi-Fi networks, the stress that low cost or free access would place on the back-haul network, and the confusion over which WLAN technology standard would eventually dominate.[54]

What Will the Role of the Semiconductor Manufacturers Be?

The game in semiconductors in 2003 was the race to make faster, more functional chips while decreasing size, power consumption, and heat generation. Intel (the 80% market share holder in chips for computing and telecommunications)[55] introduced its Centrino chip, which was designed to meet all the needs of mobile devices—particularly laptops—including Wi-Fi connectivity, lower power consumption, and longer battery life. Motorola (with 4% of the market) introduced its next generation of chip for embedding in communications equipment (the PowerQUICC™). Texas

[51] "Cometa Networks Formed to Provide National Wireless Internet Access," Cometa Networks press release, December 5, 2002, <http://www.cometanetworks.com/pr.html>, accessed on January 7, 2003.

[52] Brendan I. Koerner, "Sky Dayton's Long Road to Internet Nirvana," *Wired Magazine*, <http://www.wired.com/wired/archive/10.10/boingo_pr.html>, accessed May 16, 2003.

[53] William Lehr and Lee W. McKnight, "Wireless Internet Access: 3G vs. Wi-Fi," Paper 166, August 2002, <http://ebusiness.mit.edu>; and Clay Shirky, "Permanet, Nearlynet, and Wireless Data," <http://shirky.com/writings>.

[54] Lars Godell, "W-LAN Access Won't Be The Next Big Thing," Forrester TechStrategy Brief, March 31, 2003, <http://www.forrester.com/ER/Research/Brief/0,1317,16639,00.html>.

[55] Robert Ristelhueber, "Market Focus: Top Semiconductor Suppliers," *ebn news*, June 10, 2002, <http://www.ebnews.com/showArticle.jhtml?articleID=2915904>, accessed April 16, 2003.

Instruments (1.8% market share) introduced a new chip set and design for cell phones that would connect to Wi-Fi networks, the GSM network, and Bluetooth—the first chip to include all three of these capabilities in one design. Semiconductor manufacturers were assured a healthy business no matter what technology became dominant.

In February 2002, Intel announced a highly ambitious vision for its future called "Radio Free Intel" that aimed to incorporate a tiny radio into every microprocessor the company shipped.[56] Intel planned to make radio-equipped chips so cheap that they could be used everywhere—not just in communications equipment such as cell phones and PDAs but in cars, cameras, clothing, and crops. The "radio inside" would make products with these chips embedded capable of sending and receiving data. The goal was stretching both technical and regulatory realities but was just real enough—and potentially lucrative enough—that it was worth striving for.

Oxygen's RAW chip was a design that might have consequences as far reaching. By moving chip customization to software, it was more flexible in its use and more scalable than existing hardwired chips. The physical chip might have a longer life, since upgrades in both speed and functionality could be accomplished through software. These capabilities might have strong advantages for products requiring complex physical designs, such as military aircraft or robots, which could evolve without the need to change the internal board or chip. Would RAW change the emphasis placed on chip replacement to software?

How Will Embedded Computing Merge with Existing Communications and Data Networks?

Embedded systems were microprocessor or microcontroller-based electronic systems that were used within a product or process. They were playing an increasingly important role in many industries: automotive (in engines and antilock brakes), robotics (in manufacturing and automated control), communications (phones, fax machines), process control (chemicals, food processing), appliances (microwave, dishwasher, thermostats), and avionics (flight management)—just to name a few. The technology used to implement an embedded system varied by application; it could be just a simple microcontroller chip embedded in a product (as in car engines, copiers, or microwaves), a single controller board (as in industrial robots), or complex controller boards that communicated using a computer bus (as in aircraft avionics).

Embedding microprocessors in products and processes was not new, and the industry of embedded processors, controllers, and software supporting it was highly competitive. Processors alone were estimated to be a $15 billion market in 2000.[57] Much of this market was devoted to products with embedded processors that were stand-alone, not yet connected to any remote network.

Will the Standard Stack Be Collectively or Privately Controlled?

As the Oxygen world took shape, the applications, data, and communications capabilities would float across a world of varied infrastructure and computing devices. Implementing this networking miracle was going to involve stacks of new technologies, some already in use, some yet to be defined.

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[56] "In the Chips," *The Wall Street Journal*, September 23, 2002.

[57] "The Information Network," *Electronic Business*, February 2000.

Oxygen researchers intended Oxygen applications to be developed and run on platforms of collectively controlled standards with open interfaces. Competition in the Oxygen world was expected to be based on innovation and quality, not on appropriation.

But the path from 2003 to an Oxygen-standard stack would require many technologies, much competition, and plenty of uncertainty about what had value that could be held privately and what had to be opened to the world.

In early 2002, for example, Nokia, other device manufacturers, and network operators attempted to establish Java 2 Micro Edition (J2ME) as the standard for mobile phone game development software. These companies wanted to stimulate the demand for data-enabled mobile phone service by providing interactive games on phones and wanted to avoid getting into the deeply proprietary world of game console providers such as Sega, Microsoft, and Nintendo.[58] The problem they encountered was that J2ME was slow to get to the market, and many companies did not want to wait for J2ME to have all its bugs fixed and its features developed. Consequently, most of the game software in 2002 was written using proprietary development software. Verizon Wireless, for example, used a technology called BREW developed by Qualcomm—a programming language based on C++ rather than Java. Sony Ericsson was using custom software from a Swedish start-up called Synergenix Interactive AB.[59] Did J2ME still have a chance to become the common platform, or would companies find the switching costs too high once they had already created games—and expertise—in the alternative platforms?

At the start of 2003, another standardization effort called Web Services was facing even greater challenges. The World Wide Web Consortium (W3C)—the organization charged with the development of protocols for the evolution and interoperability of the Internet—was working on an architecture and set of standard interfaces that would enable communication among Internet applications even if they were running on different native platforms or frameworks—a sort of Internet middleware.[60] By the end of 2002, it had succeeded in defining the basic rules for how these services would work along with an initial set of technologies that would be needed (described by acronyms such as XML, SOAP, WSDL, and UDDI). Microsoft, IBM, and BEA were three companies that had played the important role of ensuring that the W3C standards would work with their popular application development platforms.

As a next step, the W3C was working on the standardization of a technology for business transaction choreography (a term that refers to the ordering of events during a set of transactions) that had been submitted by a group of companies, including Sun, SAP, and Oracle. Unfortunately, Microsoft, IBM, and BEA had a competing technology for business transaction choreography that they were building into their product suites but had not submitted to the W3C.

While it could have been possible to negotiate the trade-offs between the two choreography technologies, in a surprise move Microsoft, IBM, and BEA chose to submit the specification of their technology to a standards organization other than the W3C—the Organization for the Advancement of Structured Information Standards (OASIS).[61] What would it mean for different functionality

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[58] David Pringle, "Do You Wanna Talk or Just Play Games?" *The Wall Street Journal*, September 19, 2002.

[59] Ibid.

[60] "Web Services Architecture," W3C working draft, November 14, 2002.

[61] David Berlind, "IBM, MS streamrolling W3C and Web Services?" *ZDNet Tech Update*, <http://techupdate.zdnet.com>, accessed May 16, 2003.

within what should be the tightly coordinated set of technologies that make up Web Services for them to be controlled by different standards organizations?

While these two examples were perhaps expected instances of discord in an understandably difficult process of technology evolution, it was not hard to imagine that somewhere along the way the process would fall prey to a great technology owned by a powerful company. How could companies whose business relied on owning the software platform survive using a different model? Was the alternative attractive enough?

How Will End-User Markets Be Defined?

At the start of 2003, the bottleneck to the future was not the lack of infrastructure or the right new devices, it was defining a new set of services that users really wanted—and for which they would pay. Would there be a new "killer app" like e-mail that all consumers would enthusiastically adopt, or would the services be tailored to the specific needs of specialized groups?

A device manufacturer like Nokia had a strong interest in a single new service appealing to a large percentage of its buyers. The cost of building support for new services in its phones had to be justified by broad user adoption of those services. Multimedia message service (MMS), for example, was a Web service that was an extension of simple text messaging (SMS) that would permit applications by which users could send one another pictures or even short video clips with their text messages. Launched early in 2002, Nokia envisioned that MMS would be the groundwork for a mass-market mobile services platform on which many end-user applications could sit. It would drive new uses of mobile devices and drive mobile-device penetration. Nokia had already launched 15 handset products that were MMS enabled, and it expected that half of its 2003 new products would incorporate MMS.[62]

Not all players in future value chains, however, would require the penetration of mass, global markets to define their success. Vertical markets such as financial services, health care, and insurance had good-sized markets into which to drive service adoption. Most application development and service companies, such as IBM and Accenture, had practices that specialized in the developing needs of vertical industries.

The health care industry, for example, was ready for new applications that provided quick access to patient information, writing or renewing drug prescriptions, tracking the flow of drugs in the hospital to reduce errors, and in-home patient monitoring. Health care was served by some innovative companies, like Minneapolis-based Medtronics, Inc., which had developed a pacemaker that could communicate with physicians by downloading electrocardiograms and other information through the Internet.[63]

At the extreme of vertically defined markets were "mass-customization" efforts. Mass customization, a phrase coined in 1987, referred to the phenomenon in which goods and services are tailored to an individual buyer while their mass-production efficiency is maintained.[64] Archetype Solutions, Inc., for example, was a company founded in 1999 by a former vice president of Levi-

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[62] Seppo Aaltonen, "Web services: New opportunity for stimulating innovation in mobile content," presentation given on November 5, 2002 at the Nokia Mobile Internet Conference in Munich, <http://media.corporate-ir.net/media_files/priv/5395/nokia_nmic.html>, accessed February 4, 2003.

[63] Julie Dunn, "Responsible Party – Dr. Kenneth Riff. A Physician with a Dash of Engineer," *The New York Times*, January 5, 2003.

[64] <http://www.mass-customization.de/news/news03_01.htm#3>, accessed May 19, 2003.

Strauss for the purpose of mass producing custom-tailored apparel.[65] It provided the service by which Lands' End—the catalog and online retailer—could offer custom-fit chinos. For $54 a pair, customers could describe their style, fit preferences, and size and receive custom-made pants two to four weeks later. The logistics for filling the order were complex but relied heavily on technology and efficient production techniques.[66] Would future markets be markets of one?

Summary

As the plane's wheels dropped down and touched the tarmac in Helsinki, Mechelin knew he had generated more questions than answers regarding the economic implications of an Oxygen future. The uncertainties about how this future would unfold were so great that he had difficulty determining which were going to have the greatest economic impact.

- Where would value reside in the new value chains?
- Who would be in a position to capture that value, and how would they do it?
- Would Nokia be in a position to deliver that value?

65 <http://www.archetypesolutions.com/>, accessed May 19, 2003.

66 <http://www.industryweek.com/CurrentArticles/Asp/articles.asp?ArticleId=1314>, accessed May 19, 2003.

Exhibit 1 Nokia Corporation Annual Financial Information

Balance Sheet (excerpt)

Annual Income (000s)

FISCAL YEAR ENDING	12/31/2002	12/31/2001	12/31/2000	12/31/1999	12/31/1998	12/31/1997	12/31/1996	12/31/1995	12/31/1994	12/31/1993
Net Sales	30,016,000	31,191,000	30,376,000	19,772,000	13,326,000	52,612,000	39,321,000	36,810,000	30,177,000	23,697,000
Cost of Goods	18,278,000	19,787,000	19,072,000	12,227,000	8,299,000	33,999,000	28,029,000	25,518,000	20,808,000	17,216,000
Gross Profit	11,738,000	11,404,000	11,304,000	7,545,000	5,027,000	18,613,000	11,292,000	11,292,000	9,369,000	6,481,000
R&D Expenditures	3,052,000	2,985,000	2,584,000	1,755,000	1,150,000	4,560,000	3,514,000	2,531,000	1,937,000	1,472,000
Sell Gen & Admin Exp	3,239,000	3,523,000	2,804,000	1,811,000	1,368,000	5,599,000	3,512,000	3,749,000	3,836,000	3,544,000
Inc Bef Dep & Amort	5,447,000	4,896,000	5,916,000	3,979,000	2,509,000	8,454,000	4,266,000	5,012,000	3,596,000	1,465,000
Depreciation & Amort	206,000	302,000	140,000	71,000	20,000	NA	NA	NA	NA	NA
Non-Operating Inc	-324,000	-1,119,000	86,000	-63,000	-33,000	-83,000	-368,000	-79,000	406,000	28,000
Interest Expense	NA	NA	NA	NA	NA	NA	NA	NA	NA	347,000
Income before Tax	4,917,000	3,475,000	5,862,000	3,845,000	2,456,000	8,371,000	3,898,000	4,933,000	4,002,000	1,146,000
Prov for Inc Taxes	1,484,000	1,192,000	1,784,000	1,189,000	737,000	2,274,000	856,000	769,000	932,000	299,000
Minority Int (INC)	52,000	83,000	140,000	79,000	39,000	99,000	-2,000	77,000	75,000	80,000
Invest Gains/Losses	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Other Income	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Net Inc Bef Ex Items	3,381,000	2,200,000	3,938,000	2,577,000	1,680,000	5,998,000	3,044,000	4,087,000	2,995,000	767,000
Ex Items & Disc Ops	NA	NA	NA	NA	70,000	261,000	219,000	-1,855,000	944,000	-1,917,000
Net Income	3,381,000	2,200,000	3,938,000	2,577,000	1,750,000	6,259,000	3,263,000	2,232,000	3,939,000	-1,150,000
Outstanding Shares	4,787,907	4,736,302	4,696,213	4,652,679	255,000	299,852	299,550	299,550	299,550	41,098

Source: Nokia public documents.

Exhibit 2 Examples of Nokia's Activities Toward Mobile Internet Convergence

Developing the hardware and software to support higher bandwidth and more sophisticated end-user services:	• Helping design the standard and building the equipment for the upgrade of the network infrastructure to broadband (EDGE and WCDMA) • Establishing a company with other handset manufacturers to develop an open-device operating system (Symbian) • Developing and licensing an open-source device software platform on top of the Symbian operating system to aid in software application development on the hand-set (Series 60) • Creating an online source for device customization products such as ring tones and interface options (Club Nokia) • Providing a program for third-party developers to certify operability on specific Nokia devices and use the Nokia brand (Nokia OK)
Driving a market of common, open standards:	• Establishing an alliance with other industry players for developing necessary mobile standards for all aspects of the mobile Internet world (Open Mobile Alliance—OMA) • Establishing standards for device application development platforms such as for multimedia (MMS), messaging (SMS), and gaming (J2ME) • Establishing standards for mobile device-based Internet browsing (WAP) • Establishing standards for device interoperability (Bluetooth)
Providing assistance and incentives to the mobile application developer community:	• Creating an online community for application developers for mobile devices to share tools, development platforms, and applications (Forum Nokia) • Creating a smart phone "Product Creation Community" with companies that could provide assistance in semiconductors, hardware and software integration, and application development • Creating an online business-to-business marketplace for network operators, corporate customers, independent software vendors (ISVs), Internet service providers (ISPs), and ISs to buy and sell mobile products and services (Nokia Tradepoint) • Encouraging the establishment of fair-revenue sharing agreements between network operators and content providers[a] • Giving awards for best content development on mobile devices (Nokia contest)
Encouraging the establishment of seamless roaming agreements (Wireless Village initiative)[b]	
Providing assistance and incentives to the computer hardware and software market to build mobile capabilities	• Partnering with computer manufacturers and software companies (partnerships with IBM, HP, Sun, and Oracle)

Source: Casewriter, collected from various Nokia Web site documents, <http://www.nokia.com>.

[a]"Practices in Tariffing and Revenue Sharing," NMIC, November 6, 2002.

[b]"Migrating to MMS," NMIC, Ollila, and Nokia document.

Exhibit 3 R&D Expenditure, 1998–2002

R&D expenditure of major telecom manufacturers

In million currency unit		1997	Var 1998/1997	1998	Var 1999/1998	1999	Var 2000/1999	2000	Var 2001/2000	2001
Alcatel	(EUR)	2.531	-29%	1.809	17%	2.109	34%	2.828	1%	2.867
Cisco Systems	USD	1.627	29%	2.104	42%	2.984	8%	3.235	21%	3.922
Ericsson	SEK	20.906	20%	25.189	31%	33.123	27%	41.921	11%	46.640
Lucent Technologies	USD	3.023	22%	3.678	22%	4.496	-11%	4.007	-12%	3.520
Motorola	USD	2.748	5%	2.893	19%	3.438	29%	4.437	-3%	4.318
Nokia	USD			1.150	53%	1.755	47%	2.584	16%	2.985
Nortel Networks	USD	2.147	14%	2.453	19%	2.908	38%	4.005	-20%	3.224

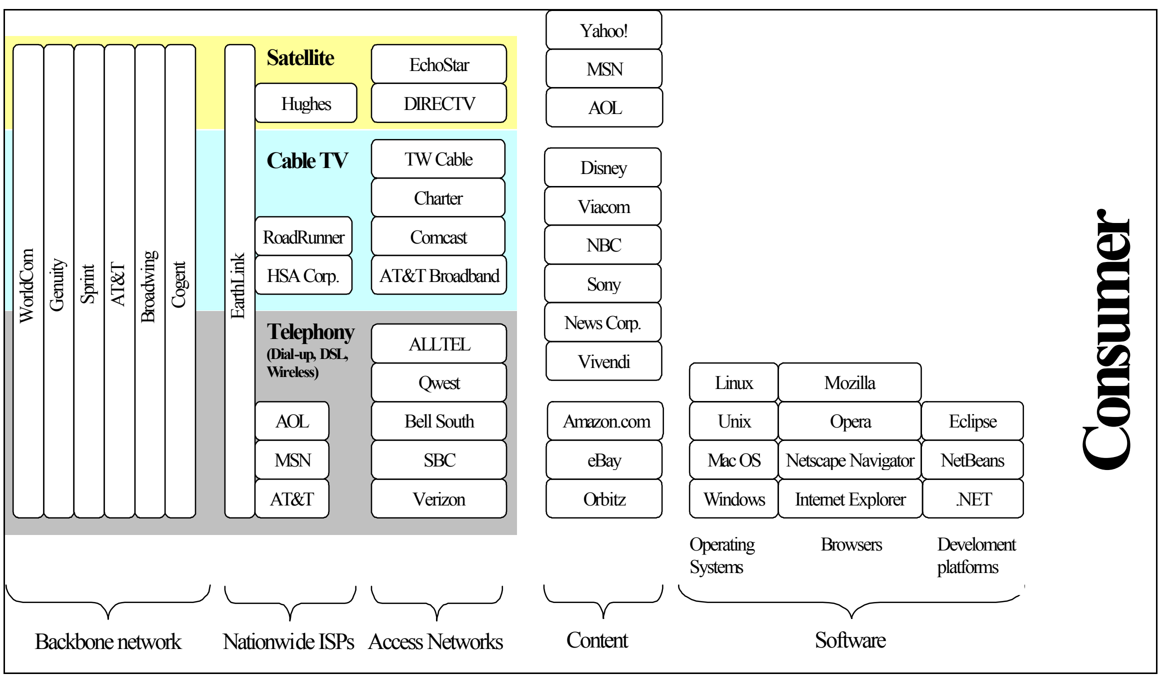
Source : IDATE

NB: Siemens was not included in the table, given that the firm's activities go well beyond the ICT sector.

Source: <http://www.idate.fr/an/lettre/l33/research.pdf>, accessed April 15, 2000.

Exhibit 4a Example of Telecommunications and Computing Value Chains[a]

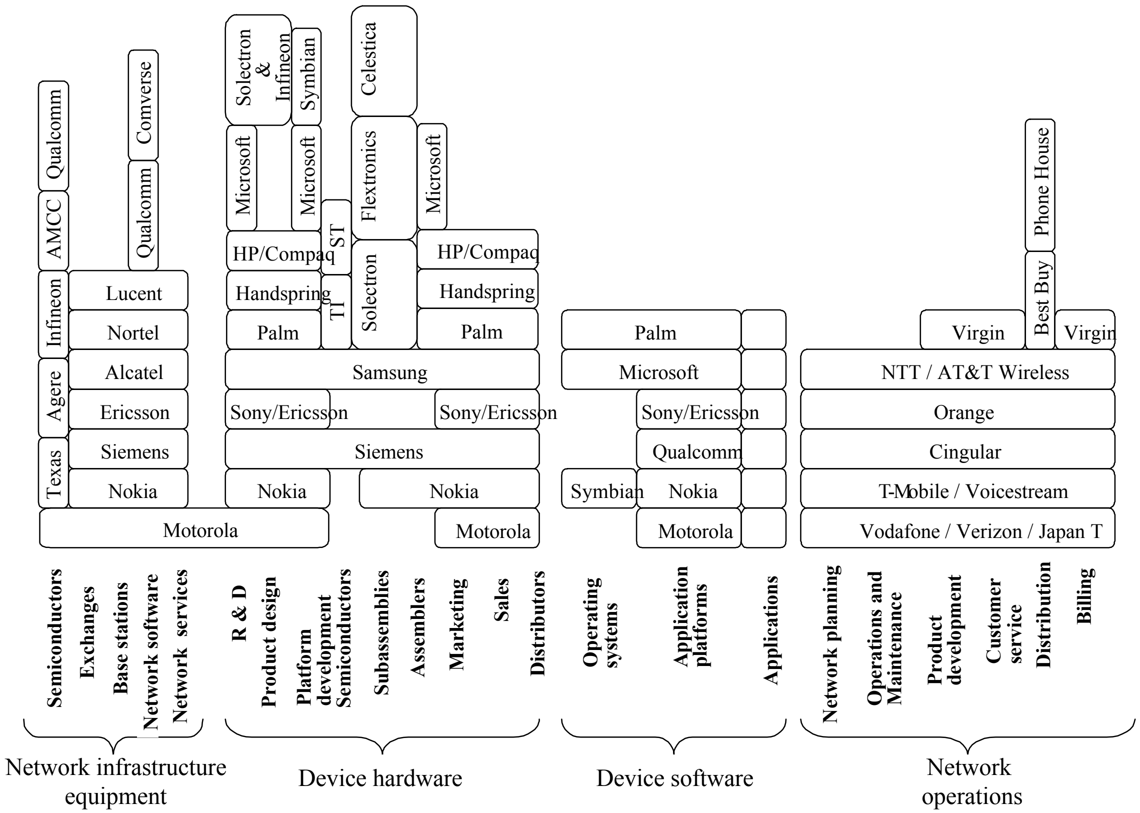
Internet value chain



Source: Casewriter with the assistance of Research Associate Rune Hansen.

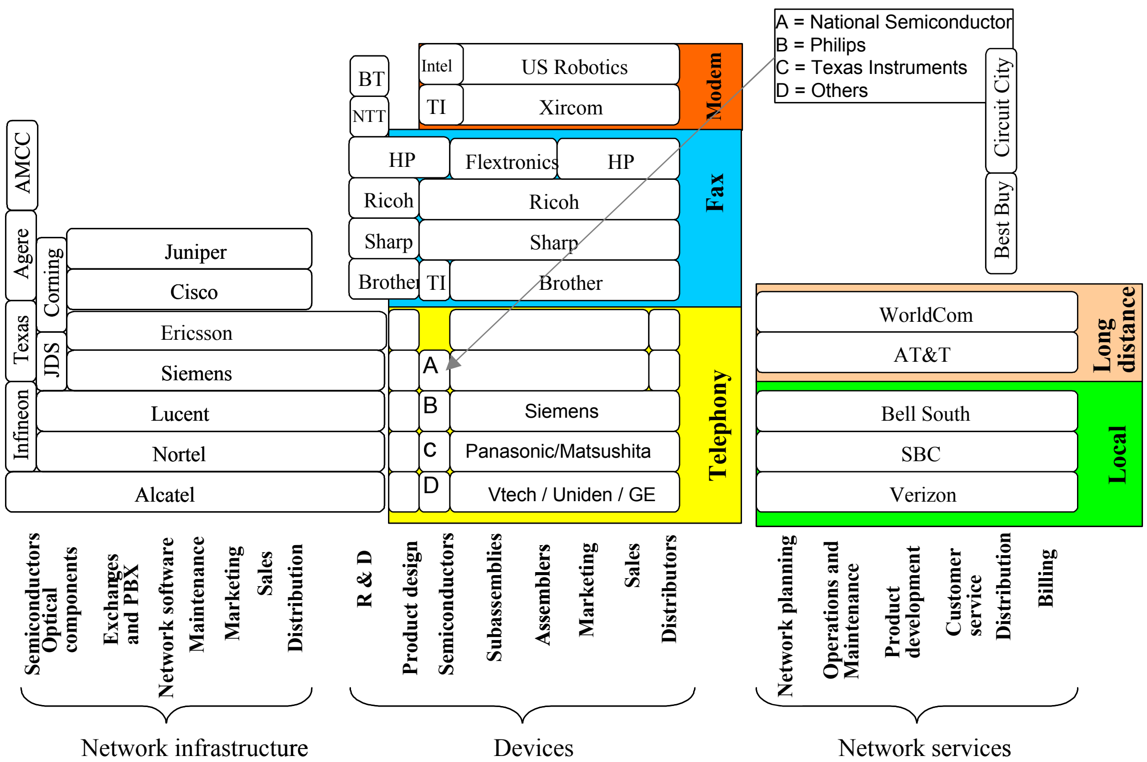
[a]Value chains provided in this exhibit are intended as approximate representations as the basis for class discussion only. No claims are made as to the completeness and accuracy of the presentation.

Exhibit 4b Wireless Value Chain



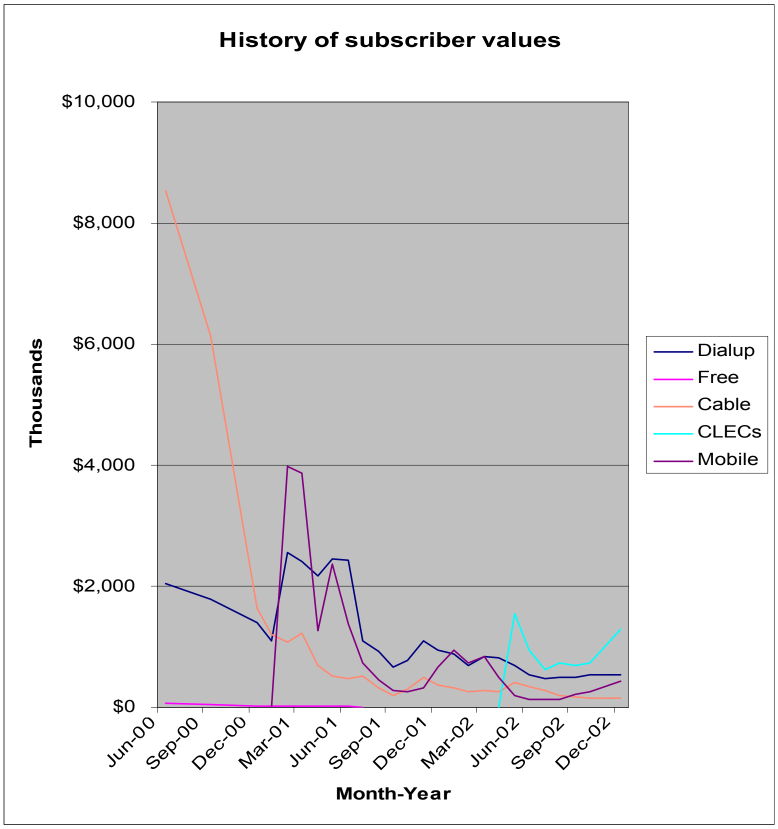
Source: Casewriter with the assistance of Research Associate Rune Hansen.

Exhibit 4c Fixed-Wire Value Chain



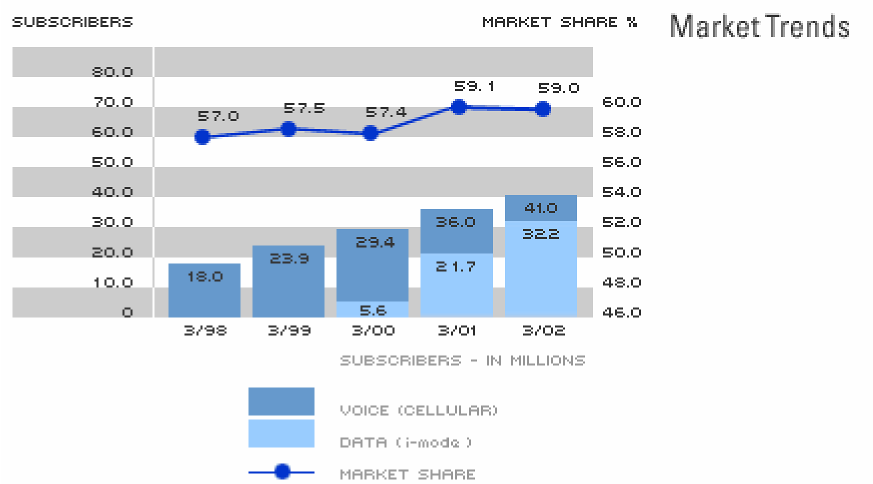
Source: Casewriter with the assistance of Research Associate Rune Hansen.

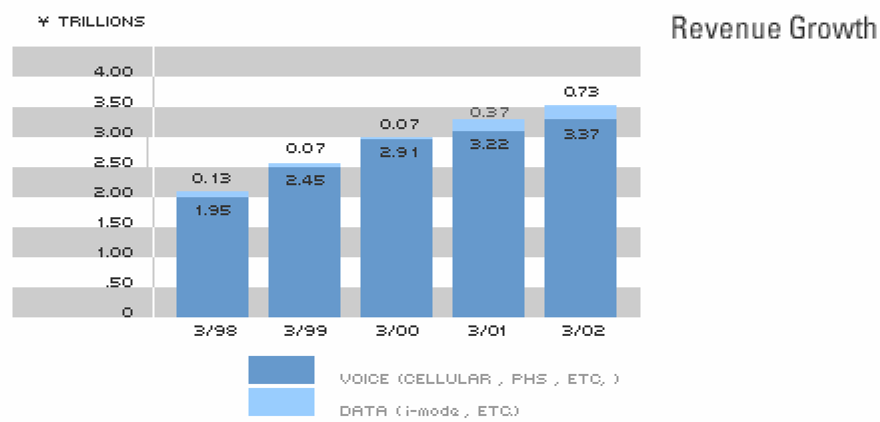
Exhibit 5 History of ISP Subscriptions



Source: ISP Planet Market Research, <http://www.isp-planet.com/research/rankings/usa.html>, accessed April 7, 2003.

Exhibit 6 I-mode Performance





Source: <http://www.nttdocomo.com/investor_relations/corporate_data.html>.