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Developing Tomorrow's Workforce Today

REPORTS

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Wireless Technology Roadmap: 2006-2016

Mapping the Crucial Skills Required to Make Canada a Global Wireless Leader

By Doyletech Corporation and
D.R. Senik and Associates Inc.

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Executive Summary

Technology drives skills. It does so by creating new industries from semiconductors to software and reshaping long established industries from banking to retailing. In a very real sense, *technology is the economy: the prevailing division and organization of labour.*

The tightly interwoven nature of technology and the economy lies at the heart of this Wireless Technology Roadmap for the Information and Communications Technology Council. Technology drives over 80 percent of economic growth. This report is a pioneering effort to apply some of the most recent research findings to model the process of technological evolution. The bottom line is to apply this model to better understand the skills required in the new wireless landscape that will unfold over the coming decade.

Traditional roadmaps have focused on technology. A classic example is The International Technology Roadmap for Semiconductors (ITRS). Its forecast of technology trends serves to guide industry efforts in resolving critical challenges to the performance of integrated circuits.

This roadmap is different. It examines technology in the broader context of its applications. While technology is a powerful change driver, its impact is moderated, indeed constrained, by broad social, political and economic forces. For example, the most immediate is regulation, a legacy from the earlier era of radio broadcasting - shortchanging new spectrum needs in favour of long established ones. Another is investment in advanced network technologies, constrained by the adverse impact on the balance sheets of the large public companies that provide wireless cellular telephony services. A third is the relatively slow evolution of software engineering that is central in providing much of the advanced functionality that is increasingly expected of wireless applications.

To understand the broad sweep of technology developments, we have relied on world data: wireless is a global industry in which Canada represents a small part of world output. However, the specific wireless applications that are the focus of this study were selected by the steering committee on the basis of their expected contribution to Canadian GDP growth, their strategic importance and our national capabilities relative to competition. A series of regional focus groups with over 100 stakeholders from industry, post-secondary education and government examined the selected applications in detail to understand the practical realities and the skills required to exploit the ongoing advances in wireless.

Those skills are much broader than those normally associated with wireless. In particular, software engineering is a powerful theme that cuts across the selected applications of Intelligent Transportation Systems, Wireless Systems Integration and Mobile Multiplayer Gaming. Indeed, software is a major factor in many key developments in wireless. Equally important are skills like business and communications, reflecting profound structural changes driven by globalization – like the predominance of SMEs[1] in Canada's ICT industry and the increasing integration of larger players into multinational networks.

The global wireless industry, dominated by the half-trillion US$ business of wireless cellular telephony has entered a long period of steady single-digit growth that will see increasing emphasis on process (vs. product) innovation and more reliance on inputs like software to drive value creation. This is coupled with the growing role of marketing and distribution as starring actors in the value chain and the related transition of technology to a supporting role. This poses challenges for a Canadian skills response – traditionally strong in S&T and R&D but weaker in marketing and commercialization – the areas that will be at the forefront of the global evolution of wireless over the next two decades.

The technology roadmap model and the skills requirements that it details provide a comprehensive framework to help shape a strategic plan to address the wireless industry's skills needs. Indeed, the work has already begun, with a stakeholders' meeting convened by ICTC on May 15, 2007, validating the roadmap model, the skills identified as central to meeting the challenge along with further discussion of actions to be taken as a result. An effective Canadian response is in the making.

[1] Small and Medium-sized Enterprises.

Chapter 1: Introduction

This section summarizes the major considerations that have shaped this first technology roadmap for the Information and Communications Technology Council (ICTC). It concludes with an outline of the major sections that comprise this document.

1.1 ICTC Mission and Background

In the 1990s, the federal government created Human Resource Councils to help meet the skills needs of major sectors in the Canadian economy. These not-for-profit organizations catalyze collaborative action by business, labour, education and government to help Canadians acquire the skills and knowledge required in the workplace. The ICTC, founded in 1992 as the Software Human Resource Council (SHRC), was originally focused on the software sector.

In 2006, the ICTC mission was expanded to meet the needs of the 'hardware' and emerging technologies sectors. Hardware comprises the manufacturing element of Canada's Information and Communications Technology (ICT) sector. Emerging technologies include new fields, like nanotechnology and quantum computing, that will reshape ICT products and services.

The entire ICT sector generates $60.6 billion of GDP, about 5.6 percent of the Canadian total (2005). ICT manufacturing (hardware) produces about $12.2 billion of GDP. The hardware workforce numbers 104,000 people (2004), of which almost 80 percent require technical skills to do their work.

Hardware is a rapidly evolving business built on the platform technology of electronic systems. Hardware ranges from cell phones and computers to air traffic control radars and MRI[2] scanners.

To help guide its expansion to cover hardware as well as software, the ICTC convened a national conference of leaders from industry, education and government. The purpose of the *ICTC Technology Vision Conference* (March 2006) was to seek consensus on a short list of technologies essential to Canada's continued international competitiveness in the ICT sector. Over sixty participants reviewed developments in seven major fields that impact the platform technology of electronic systems: microelectronics and MEMS[3], software and systems, sensor networks, wireless, photonics, nanotechnology and quantum computing.

Wireless was subsequently selected as the subject of the first ICTC technology roadmap. This roadmap was commissioned to better understand how wireless is reshaping the ICT workplace. **Its overall objective is to provide information for the development of policies and programs to address the changing skills requirements of the ICT workforce.**

1.2 Project Objectives

This project is a pioneering effort to bridge the gap between traditional technology roadmaps and the realities of how the technological evolutions they chart will impact the skills and knowledge needed by tomorrow's workforce. In more detail, the objectives are:

— To define the current state of wireless technology;

— To provide a vision of future technology developments;

— To map how this technology will unfold in the market-place; and

— To forecast the skills requirements to benefit from advances in wireless technology.

1.3 Project Scope and Boundaries

This Wireless Technology Roadmap (WTRM) began with a global industry overview,[4] conducted in autumn 2006. The overview provided a summary of the current state of wireless in order to broadly outline the most important developments shaping this technology and its applications. In particular, it provided data and forecasts for the growth of some twenty significant wireless applications.[5]

Based on the recommendations of a national panel of technical experts,[6] the WTRM Steering Committee selected three of these applications in light of their potential economic impact, their expected contribution to international competitiveness, and Canadian capabilities relative to our competitors. These applications (detailed in Chapter 5) are:

— Intelligent Transportation Systems;

— A Wireless Platform for Systems Integration; and

2 Magnetic Resonance Imaging.
3 Microelectromechanical systems.
4 *"ICTC Wireless Technology Roadmap: Industry Overview,"* Doyletech Corporation and D.R. Senik and Associates (November 2006).
5 See Chapter 9.
6 See Appendix 1.

— A Wireless Platform for Real-Time, Multiplayer Gaming.

The WTRM outlines a vision of the technology developments essential to realize these applications and how they will unfold in the marketplace over the 2006-2016 time frame.

The level of detail in this analysis reflects the results of six one-day consultations with wireless stakeholders on the above applications. These results were combined with current wireless roadmaps by major companies, organizations and governments. The integration of the initial industry overview with the results of these consultations and the broader global picture from contemporary wireless roadmaps provides the foundation for this study's forecast of the resulting skills requirements for the Canadian ICT sector.

1.4 Plan of the Report

The roadmap analysis begins in Chapter 2 with an overview of the concepts and models that apply to technology-driven economic growth, and that have guided our research and analysis. In Chapter 3, we apply this conceptual framework to the global wireless industry. The objective is to understand the major drivers that have shaped the modern industry from its beginnings following World War II to the present.

Chapter 4 outlines the current status of the most important forces that will continue to shape the industry's worldwide evolution over the next decade. In Chapter 5, our attention turns to Canada and the key dimensions of product, market, and technology for the three applications of particular relevance to our domestic industry. Chapter 5 concludes with an analysis of the required product attributes and specific performance levels needed to succeed in the targeted applications. In turn, these performance requirements determine the technologies that will shape the skills of producers and users.

Chapter 6 examines the Canadian situation, and in particular, the broad market drivers that will shape the wireless applications of specific relevance to Canada. This analysis concludes with recommendations for an effective Canadian response to these drivers.

Chapter 7 presents the Technology Roadmap. It outlines a strategy to realize the vision for each of the three selected applications, including key HR issues, external factors and success indicators.

The resulting skills requirements are detailed in Chapter 8. The ninth and concluding chapter summarizes the overall results of the roadmap.

Chapter 2: A Framework for Charting the Wireless Technology Roadmap

This roadmap is built on recent techno-economic models that offer insights into the process of technology-driven economic growth. These models of how wireless technology will unfold over 2006-2016 are based on the work of Branscomb,[7] Freeman & Louca,[8] Perez[9] and Romer.[10] This section begins with a brief outline of key concepts that we have incorporated from these models and others into our framework for charting the WTRM.

2.1 Broad Market Forces

While technology is a potent driver of change, its industrial impact is moderated by interaction with broad market forces, the most important of which are outlined below. The interplay of these forces shapes the overall environment in which technological advances unfold, ultimately rewriting the skills required of industry's workforce. In the context of wireless, these forces include:

— Sociological: e.g., user expectations, privacy and security concerns;

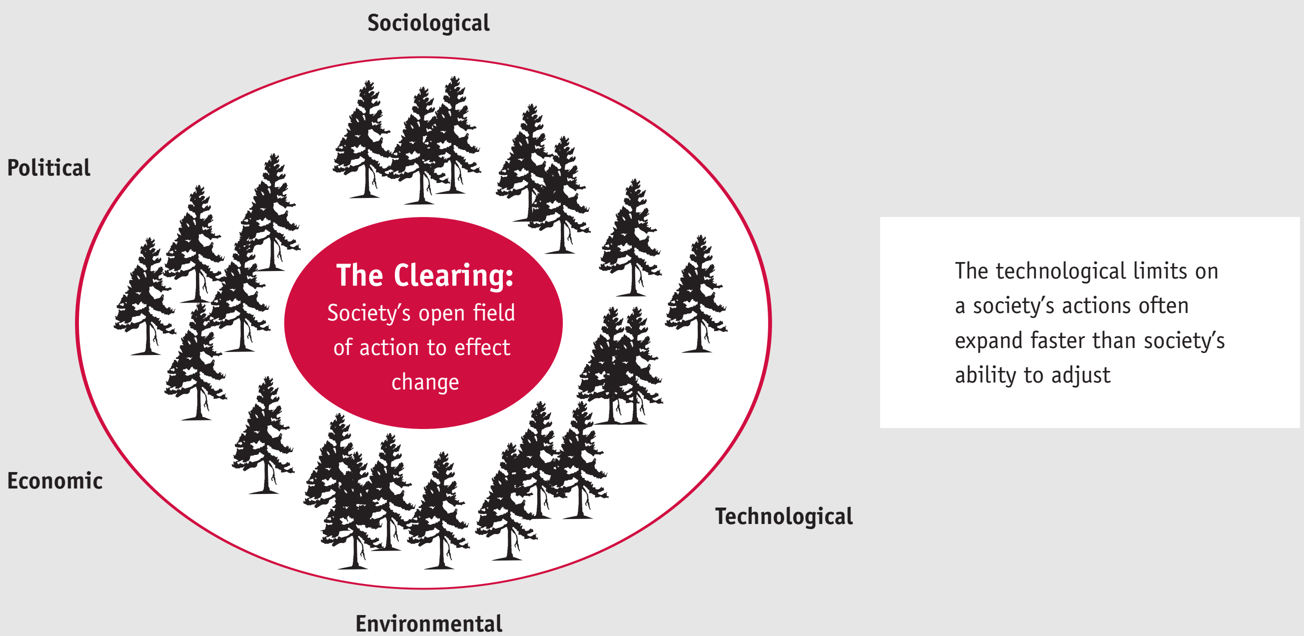
— Political: e.g., spectrum regulation and intellectual property law;

— Economic: e.g., industrial structure, switching costs and sunk asset investments;

— Environmental: e.g., health concerns like increasing electromagnetic (EM) radiation in urban areas, battery and equipment disposal; and

— Technological: e.g., spectrum efficiency, battery life, data transfer rates, coverage, etc.

Figure 1: The Clearing Metaphor



[7] Branscomb, Lewis, *Where do high-tech commercial innovations come from?* Duke University (Feb. 2004).

[8] Freeman, Chris and Louca, Francisco, *As Time Goes By,* Oxford University Press (2002).

[9] Perez, Carlota, *Technological Revolutions and Financial Capital,* Edward Elgar, Cheltenham, U.K. (2002).

[10] "Increasing Returns and Long-run Growth," Paul M. Romer, *Journal of Political Economy,* vol. 94, issue 5, (1986).

Technological Change in the Face of Broad Market Forces

While the focal point of this roadmap analysis is technological change, the reality is that technology only opens the door to new possibilities. These possibilities are then realized to the extent they conform to the constraints imposed by the ever evolving market environment.

Society's capability to incorporate technology-driven change is captured by the metaphor of a clearing in the forest.[11] Here, the surrounding trees represent the constraints imposed by forces like regulation, industrial structure and social norms. If the possibilities offered by technological advance are sufficiently compelling, then society – over time – will adjust in order to expand the clearing. Eras of major technological change, like the Industrial Revolution or the subsequent Age of Rail and Steam take about 50 to 60 years to fully unfold.

It is no coincidence that this lengthy timeframe for society to adjust corresponds to about two working generations. It takes this long for the system, society's tightly interlinked framework of institutions and practices, to change: it is deeply rooted in culture and ideology. Institutions, in particular, are powerful bastions of the status quo. As an astute American politician observed "To get along, you go along".[12]

Culture is the closely woven pattern of everyday life – the way society is; ideology is the powerful set of concepts that express how society *ought to be*. The System, forged by culture and ideology, changes only as new generations slowly replace those who went before them.

This framework[13] of culture and ideology shapes the manner in which institutions like government, corporations, universities and their managers think and act. The bottom line is that technology's incorporation into the mainstream proceeds on society's terms and timetable. Technology drives, but society steers. These concepts will be helpful in identifying the socio-economic factors (Chapter 6) that will influence the product, market and technology drivers that will in turn influence the direction of Canada's wireless industry.

2.2 The Dynamics of Technology-Driven Growth

Technology-driven economic growth is best understood as a sequence of eras. The engine of these eras of change is a small core of closely-interacting technologies and the industries built on them.

The Information Technology (IT) Revolution is a highly relevant example. It is driven by four interlinked core industries: *computers, semiconductors, software and telecommunications*. These industries are built around the technologies of:

- Microelectronics (the design and fabrication of integrated circuits);
- Software (the instruction sets that tell the circuits what to do); and
- Wireless and Photonics (the generation, control and detection of EM radiation, e.g., to transmit and receive signals).

This interconnected cluster generates widespread innovation. It creates new products like Blackberries and new services like GPS location. The trigger for these major eras[14] of technology-driven change is a breakthrough innovation that opens up a whole new frontier of design and product possibilities, sparking the imagination of engineers, entrepreneurs and investors.

For the IT Revolution, the breakthrough was the microprocessor (1971). It combined the essentials of a computer on a single microchip. The new possibilities it created were so compelling that the tiny chip grew into the global US$250 billion (2006) semiconductor industry. Microprocessors are everywhere, from under the hood to inside the human heart, microwave ovens, garage door openers, handheld blood analyzers and laptops. They have been central in creating new industries from software to cell phones and rewriting the rules of long established ones like banking and retailing.

The possibilities opened up by these eras of change are so compelling that they ultimately redefine 'best practice' across much of the economy. However, the full economic impact of these revolutions (measured as percent of GDP) takes about two working generations to be felt. Over the first of those two generations, much effort is devoted to

11 The Clearing Metaphor: A concept coined by contemporary American philosopher Herbert Dreyfus, University of California, Berkeley.

12 Sam Rayburn (Democrat, Texas) longtime Speaker of the House of Representatives.

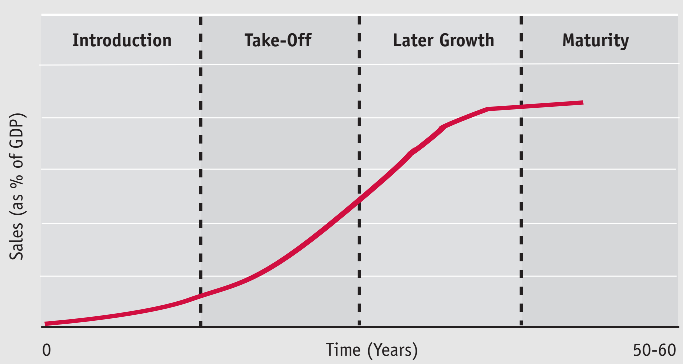
13 Lodge, George C. and Vogel, Ezra F., *Ideology and National Competitiveness,* Harvard Business School (1987).

14 In modern times, beginning with the Industrial Revolution, economists identify four subsequent eras: Steam & Railways; Electricity & Heavy Engineering; Oil & Autos & Mass Production; and, the Information Technology Revolution.

finding the most appropriate applications and refining the technology to better fit into everyday practicalities. *The resulting changes across the economy are as much about modifying mindsets and institutional stances as they are about technical progression.*

Building the necessary infrastructure to support technological innovation takes considerable time as well. For example, the commercial Internet, a major element of the IT Revolution, only arrived in 1995, a quarter century after the microchip. The resulting pattern of economic growth in these eras of change resembles the classic s-curve from biology: slow initially, then accelerating, then flattening out at the end of an era. This is shown in the figure below:

Figure 2: Idealized Growth Curve



Growth unfolds in four major phases: *introduction, take-off, later growth* and *maturity*. The major developments in each of these phases are summarized below.

The Dynamics of Industry Growth

Introduction: Pioneers blaze the trail, gaining production experience through trial and error. Potential users learn what the technology is 'for.' This period of one-to-two decades is capped by a breakthrough development that offers a glimpse of what is to come, e.g.:

- Aviation: The Wright Brothers' first powered flight (1903); and
- Computers: ENIAC (1946).

New technologies are born as 'ugly ducklings,' e.g., ENIAC, the first digital electronic computer, used 18,000 vacuum tubes. Reprogramming meant literally rewiring its logic circuits.

Take-off: The technology is refined to yield a dominant design that combines the right mix of functionality and price, sparking widespread adoption. Growth accelerates to double-digit rates, e.g.:

- Henry Ford's Model-T (1908) settled the basic car design for decades: gasoline engines (vs. steam or electricity) and rear wheel drive. It provided basic transportation at an affordable price; and
- The Apple II (1977), first personal computer available in assembled form, launched the PC revolution.

Later Growth: Industry expansion slips to single-digit rates. Major product innovation is over, replaced by incremental improvements. Process innovation dominates. Marketing and distribution increasingly drive competition, while mergers and acquisitions relentlessly reduce the number of competitors, e.g.:

- Semiconductor technology focuses on improvements in wafer manufacturing: each new generation fits twice the number of transistors in the same area, reducing chip costs by 40 percent.
- Nortel sells its semiconductor manufacturing to ST Microelectronics (2000); Hitachi and Mitsubishi merge to form Renasas (2003); Renasas, Toshiba and NEC enter talks to merge (2006).

Maturity: Inputs increasingly dominate innovation and products/markets become highly segmented, as average growth rates decline toward the overall level of economic expansion, e.g.:

- Aircraft: CFD (Computational Fluid Dynamics), fly-by-wire, composites;
- Computers: Desktops, laptops, notebooks, tablets.

2.3 Technological Systems

This concept captures the practical realities that drive the commercialization of innovation. It describes the user-friendly 'packages' that seamlessly integrate many components to strike the right balance of functionality and price that ignites the rapid market growth that defines the take-off era.

A good example of a technological system is the cell phone. It comprises three tangible elements and two mostly invisible ones as described below:

The Elements of Technological Systems: The Cell Phone

The Major Device*: The transceiver lies at the heart of the functionality provided by this technological system: it generates and receives radio signals to provide mobile personal communications.

Supporting Device: These are sub-systems. They either directly help the major device to do its job, e.g., antenna and power supply; or they facilitate the overall use of the system, e.g., display, memory, embedded software.

Components and Materials: These are the more basic resources from which subsystems are built, e.g., circuit boards, microchips, plastics, liquid crystals.

Two more or less invisible elements are infrastructure and norms and standards:

Infrastructure: This comprises the underlying framework and installations that facilitate the operation of the networks on which cell phones rely, e.g., cell towers, base stations and central call switching centres.

Norms and Standards: These are the established rules, practices and principles that govern the design and operation of technological systems. Most importantly, they standardize relationships between the parts, improving overall systems performance, e.g., transmission power levels for handsets, bandwidth of transmission channels, signal modulation schemes and cell size, application protocols.

** A key aspect of the transceiver is the tight filtering technology and the accurate frequency synchronization to make effective use of the assigned radio spectrum.*

Technological Systems Evolution over the Industry Life Cycle

As eras of change unfold, the capabilities of technological systems evolve, paced by improvements in the above five elements. Over the first half of the 50-60 year life cycle, technological systems advance from ugly ducklings to practical solutions well adapted to the specifics of market applications that have become increasingly clear.

However, the large numbers of new entrants that are key actors in launching innovative technological systems steadily decline as the industry grows and consolidates. The range of divergent design approaches and tentative new applications that characterize the introductory phase narrows as the industry approaches mid-life. The emergence of the dominant design and the resulting double-digit market growth reduce product innovation in favour of process innovation – to increase volume and reduce costs. The huge investments in industry infrastructure (e.g., US$3 billion for a state-of-the-art chip plant) and increasing reliance on proven methodologies and design practices (norms and standards) gradually squeeze radical innovation out of technological systems.

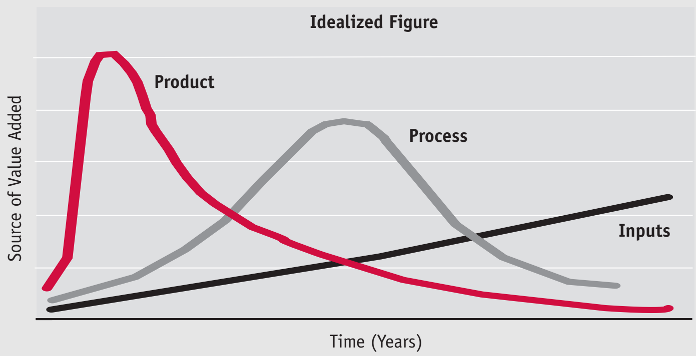
Innovations in the technological system become more incremental and more focused on making the system an effortless convenience for the user. In fact:

"The high-tech innovation sector of the economy is totally negligible and meaningless in the bigger scale of a ten trillion economy…private industry was spending a couple of hundred billion in R&D, but only $16 billion of that, according to a survey done for us by Booz, Allen, Hamilton, was R&D leading to radical innovation." [15]

As an era draws to a close, the only actors free to conduct 'off-the-wall' R&D are located outside of the increasingly tight straight jacket of mainstream industry value chains. Significant innovation ends the last step in its journey from product to process to supplier. This shift in the focus of innovation over the technology lifecycle is shown in Figure 3.

[15] Branscomb, Lewis *Where do high-tech commercial innovations come from?* Duke University (Feb. 2004).

Figure 3: The Focus of Innovation over Industry Lifecycle



2.4 An Applications Focus

In the Canadian context, the conclusions of the *ICTC Technology Vision Conference* (March 2006) stressed that:

> "Applications are the most challenging aspect in the commercialization of technology: understanding the marketplace and the value added that technology creates are critical to success."
>
> *ICTC Technology Vision Conference, 2006*

As a result, our framework for the roadmap is built around future applications. They are the starting point from which we work back to determine the critical path that links the present with desired future outcomes. Consequently, an integral part of our approach was to focus the roadmap analysis on the three applications of importance to Canada's wireless industry:

The Roadmap Focus: **Three Applications**

— Intelligent Transportation Systems

— A Wireless Platform for Systems Integration

— A Wireless Platform for Real-Time, Multiplayer Gaming

These three future applications were used as vehicles of exploration in a series of focus groups with over 100 participants from industry, post-secondary education and government. The objective was to better understand these applications and the developments required to realize them. The discussion sessions addressed four essential questions in understanding how these applications would unfold over the next decade (see Figure 4 below):

— *The market:* Who will be the users?

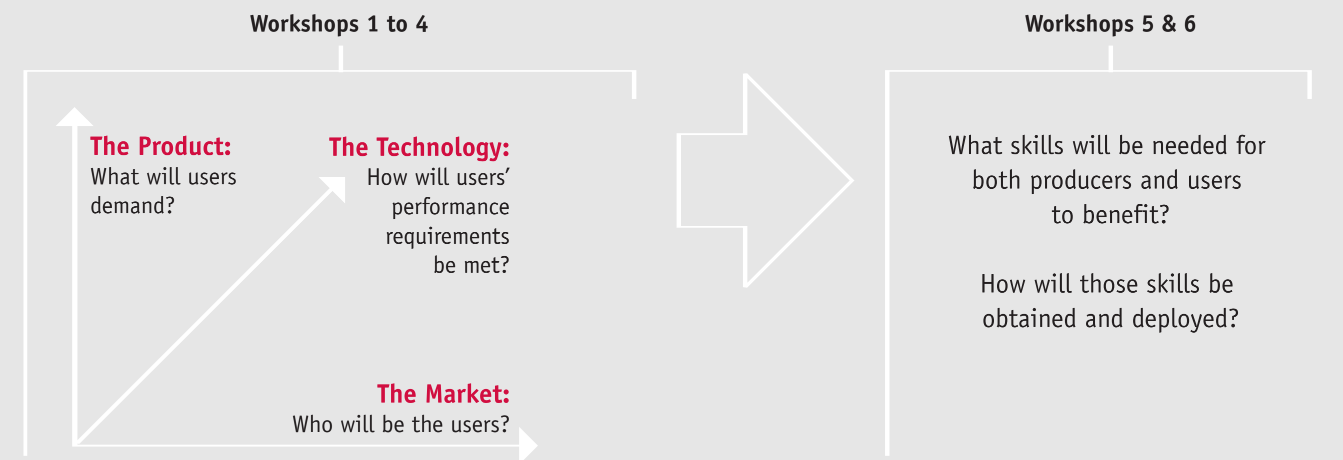
— *The product:* What is the 'package' that users will receive?

— *The technology:* How will the needed product performance be realized?

— *The skills:* What will be required to both create and use these products?

The overall thrust of the focus group discussions and their role in realizing the roadmap objectives is illustrated in the figure below:

Figure 4: The Applications Analysis



The focus groups were guided by the results of our research on wireless. In particular, we addressed the broad framework of market forces and the patterns of industry growth that characterize eras of technology-driven change:

1. *Broad Market Forces:* What are the most important overall social, political, technological, economic and environmental trends that will impose the constraints within which the three selected applications will play out?
2. *The Dynamics of Technology-Driven Growth:* Where is the wireless industry situated in the overall cycle of technology development? How will this impact development in the coming decade?
3. *Technological Systems:* What are the most important gaps in the needed performance of subsystems, devices, components and the related standards and infrastructure on which system performance hinges? What are the current levels of performance and their pace of improvement in meeting key market needs for applications of interest?

Answering the above questions was the starting point for the analysis that underlies the charting of the ICTC Wireless Technology Roadmap (Chapter 7). This analysis is the subject of the next chapter.

Chapter 3: The Wireless Industry

This chapter presents the results of the framework analyses that guided our research toward understanding how wireless applications of particular interest to Canada could evolve over the period 2006-2016.

We begin with an analysis of the first global wireless industry: from Marconi's 'wireless telegraph' in the 1890s through the building of national radio broadcasting networks in the 1920s and 1930s.

3.1 The First Global Wireless Industry: Radio Broadcasting (1896-1956)

The Dynamics of Wireless Growth

Wireless technology has created not one but two major new industries since it emerged in the late 19th century. The first was the radio broadcasting industry, outlined below. The second is wireless cellular telephony, still unfolding since its beginnings after World War II. The four phases of growth for the radio broadcasting industry are shown in the chart below:

The Radio Broadcasting Industry: 1896-1956

The Introductory Period, 1896-1906:

1896: Marconi demonstrates wireless to the British Patent Office.

1900: Marconi International Marine Communication is founded for ship-to-shore radio service.

1901: Marconi sends a first transatlantic radio message. The world takes notice.

1903: Poulsen patents a transmitter that generates continuous radio waves.

1905: Marconi invents the directional antenna.

Take-off, 1906-1929, Radio learns to talk; the world begins to listen:

1906: Fessenden broadcasts voice and music (vs. Morse Code).

1912: "Hams" proliferate, prompting the U.S. to regulate and license transmitters.

1917: The US enters WWI; the military monopolizes radio, outlawing private receivers and transmitters. By 1919, the U.S. government forces the sale ("strategic technology") of American Marconi to GE (forming RCA).

1919: early Westinghouse broadcasts stimulate sales of radios and Westinghouse establishes the first U.S. radio station, KDKA (1920).

1921: AT&T plans a national radio network (1922). RCA and Westinghouse respond with a rival network. AT&T sells out to RCA – creating NBC.

1922-1923: The number of stations jumps from 30 to 556; by 1928, sales of radio equipment have increased from $60 million (1922) to $843 million (1928).

1928: A new rival, CBS, debuts with 16 stations.

Later Growth: 1929-1945

1929-1939: Free entertainment and falling radio costs help steadily expand audiences in a time of economic hardship, the Depression.

1939: Comprehensive national radio coverage; 1,465 U.S. stations and four networks – NBC (2), CBS, and the Mutual Broadcasting System.

Market Maturity: 1945 onward

1945: Market penetration is essentially complete; 95% of all homes have radios.

Laying the Groundwork for Wireless Cellular Telephony

New functionality creates new markets: *Mobility* launched the next wireless revolution. The Detroit Police Department pioneered one-way communication to dispatch patrol cars (1928). Two-way mobile AM radio was the next advance (1933); however, these primitive systems took up most of the trunk and had reception difficulties. FM (improved signal quality and resistance to interference) became the standard for most police systems in the 1940s.

The breakthrough that opened the door to cell phones was AT&T's successful radiotelephony pilot (1946) – the first to connect mobile radio through the public telephone system. However, its adoption – as depicted by the *clearing metaphor* (see Chapter 2) – was blocked by broad market forces, delaying the realization of cell phones as a major market for forty years.

Broad Market Forces Intervene (1946-1987)

Of the five broad forces in the clearing metaphor (see Chapter 2), economics, politics and technology itself were largely responsible for the forty-year hiatus in the commercialization of cell phones:

— **Economics**, industry structure in particular, was the most immediate reason that AT&T shelved the results of its 1946 cell phone pilot. AT&T's lucrative wire line monopoly provided no incentive to incur the significant costs of building wireless networks. (AT&T's market monopoly was a direct result of regulation in the much older telephone market.)

— **Politics**, in the form of spectrum regulation, was the most powerful impediment to the realization of cell phones. It began in earnest with the creation of the Federal Communications Commission (FCC) in 1934, part of Roosevelt's 'New Deal.' Regulation aimed to use radio spectrum, seen as a scarce natural resource, in the broad public interest (e.g., broadcasting, emergency services, government agencies, etc.). Private use like personal two-way radio communication was seen as a misallocation of resources.

Spectrum availability for new applications suffered as a result. For example, in 1947, the frequency allocation for cell phones could support only 23 simultaneous calls per cell. In fact, the very concept of cell phones was a direct consequence of spectrum shortage. In the 1940s, researchers had realized that the limited radio spectrum allocated to mobile telephone service could be 'recycled' again and again by limiting its transmission range to small cells.

— **Technology**: While radio system engineering was up to the task of two-way personal communications, device technology was not. The technological system needed to support truly portable cell phones was missing vital elements. For example, current cell phones depend on the significantly reduced size of advanced microchips. The original cell phone formats reflect this missing element:

— Mobile (permanently installed in vehicles);

— Transportable (briefcase phones); and

— Handheld (original, bulky cell phones).

3.2 The Second Global Wireless Industry: Cellular Telephony (1973-2033[16])

As outlined above, cellular telephony was stillborn in 1946, blocked by the AT&T monopoly and denied more than token bandwidth by the FCC. While mobile two-way radio communication had been a reality since 1933 – based on bulky vehicle-mounted vacuum tube systems – truly portable handheld radiotelephones would have to wait for the creation of the semiconductor industry.

The Elements of the Technological System

It was a quarter-century wait. The transistor (1947) proved the long-anticipated promise[17] of semiconductors, but their high volume application in circuits needed the further inventions of the integrated circuit (1959), CMOS[18] manufacturing technology (1968) and the microprocessor (1971).

Although the needed device, component and material technologies to realize the technological system of the cell phone were then all in place, so was AT&T. Its influence would be felt until its breakup in 1984 by the U.S. Justice Department under antitrust legislation. Important developments in the introductory period leading up to the explosive growth of wireless cellular telephony, beginning in the late 1980s, are outlined in the following table:

Wireless Cellular Telephony: the Introductory Period (1973-1987)

1973: Motorola makes a public demonstration of their cell phone technology in New York City.

1975: The landmark patent for a Radio Telephone System is granted to Motorola.

1976: AT&T reluctantly services the cell phone market (e.g. in New York City soaring demand is met by wait lists and poor service).

1979: The world's first commercial cellular system began operations in Tokyo.

1982: The Federal Communications Commission finally authorizes cellular service.

1983: Ameritech begins service in Chicago.

1987: In the U.S., 1.2 million subscribers outstrip the limited transmission capacity that FCC allocations have allowed.[19]

The subsequent *take off period* of accelerating growth in cellular telephony services was enabled by regulatory compromise. Instead of allocating additional bandwidth to meet the demand for cellular services, the FCC allowed licensees to use competing (i.e., incompatible) transmission

[16] This date is approximate, reflecting about a sixty-year technology lifecycle.

[17] Bell Labs began semiconductor research in the 1930s.

[18] Complementary metal oxide semiconductor.

[19] Cellular was launched in Canada in 1985 by Cantel and affiliates of Mobility Canada.

technologies in the 800 MHz band. Licensees went their separate ways to develop transmission technologies that could maximize capacity with limited bandwidth, e.g.:

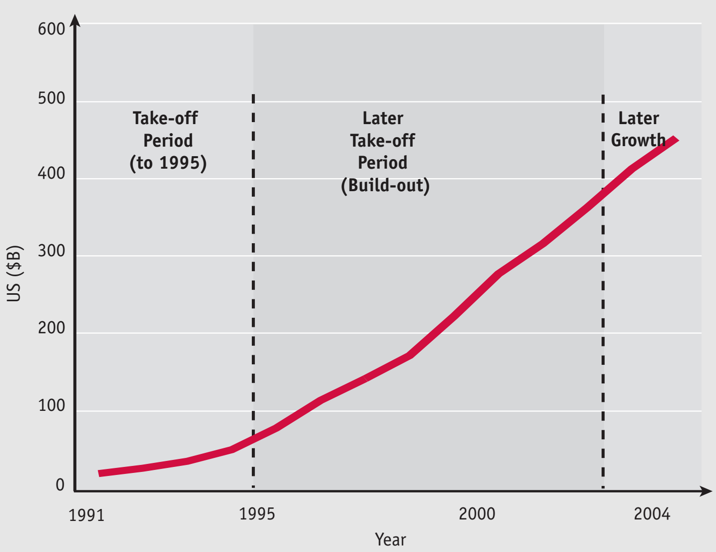
— Verizon, Sprint and Altel developed versions of CDMA;[20]

— AT&T and Cingular developed versions of TDMA.[21]

In contrast, the Europeans (1982) formed a study group called the Groupe Spécial Mobile (GSM) toward developing a pan-European public land mobile system to resolve an undesirable situation: each country had developed its own system, which was incompatible with everyone else's in equipment and operation. The resulting GSM standard first saw commercial service in mid-1991, and by 1993 there were 36 GSM networks in 22 countries.[22]. Today, GSM (aptly standing for 'Global System for Mobile Communications') is the standard in some 170 countries.[23]

"GSM was the first technology that could handle roaming mobile terminals as a global standard. This is very important because this factor alone means that a single technology could be widely deployed anywhere in the world where there is a demand for service.[24]" Standards matter.

Figure 5: Mobile Service Revenue



The Take-off Period (1987-2004)

The classic shape of the first half of the s-curve is seen in the growth of Global Mobile Services Revenue in the data (figure 5) from the International Telecommunications Union.

The FCC decision to allow competing standards rekindled the significant product innovation that is typically most prevalent in the introductory phase. As the above data shows, the rapid double-digit expansion that is a hallmark of the take-off period peaked in 1995 (at 56 percent). As with all technology eras, gradually slowing expansion from peak growth marks the later part of the take-off period. By 2004, sales growth had slipped below 10 percent, signaling the beginning of industry's later growth period, the second-to-last act in technology eras.

The following section focuses on current developments that are shaping the industry's later growth period.

Later Growth (2004-2024)[25]

Wireless technology is entering a period of lower but steady growth that will see its applications fully built out to reach their maximum economic potential, measured as a percent of GDP.

The industry's centre of gravity has begun a major shift toward marketing and distribution as the focus of competition. However, the battle for market share will no longer be decided by product functionality. Major product innovation is over: *technology is now shifting from a starring to a supporting role.*

Product innovation will be increasingly incremental with an emphasis on perfecting the technological system. The objective will be to refine wireless applications to the point where they begin to disappear into the background: a convenience that is taken for granted – like cars, air travel and electricity.

In broad terms, industry research, development and engineering activities will increasingly focus on the following customer objectives:

[20] Code division multiple access.

[21] Time division multiple access.

[22] "A Brief Overview of GSM", John Scourias, University of Waterloo http://www.cs.tu-berlin.de/~jutta/gsm/js-intro.html#1 (May 18, 2007).

[23] Eurotel www.eurotelgsm.com (May 1, 2007).

[24] Mark Pecen, VP Advanced Technology, RIM (May 18, 2007).

[25] This date is approximate.

Key Technological Systems Attributes: Later Growth

Compatibility: does it seamlessly fit the customer's application?

Ease of use: how closely does it approach the ideal of "plug & play"?

Reliability: failures must be few and far between

Serviceability: it has to be easily repaired, replaced or upgraded. It is a given that systems economics and performance are expected to improve:

> *Acquisition cost:* has to go down, to keep competition at bay, and to open up new applications;
>
> *Operating costs:* have to be lowered; and
>
> *Functionality (performance) continues to improve:* it is a "mandatory" requirement.

Because basic functionality (doing the job) is taken for granted, a key issue in choosing between suppliers is how much it costs. Process innovation becomes imperative in achieving cost reduction: it is critical in winning share in existing market applications and opening the door to new ones. However, these new applications are modest relative to the major market: mobile cellular telephony. While this core market is a half trillion dollars (2005), the three next largest applications combined, amount to $47 billion.[26] These new applications are also firmly built on the networks that are the core of the steady build-out that characterizes the later growth phase.

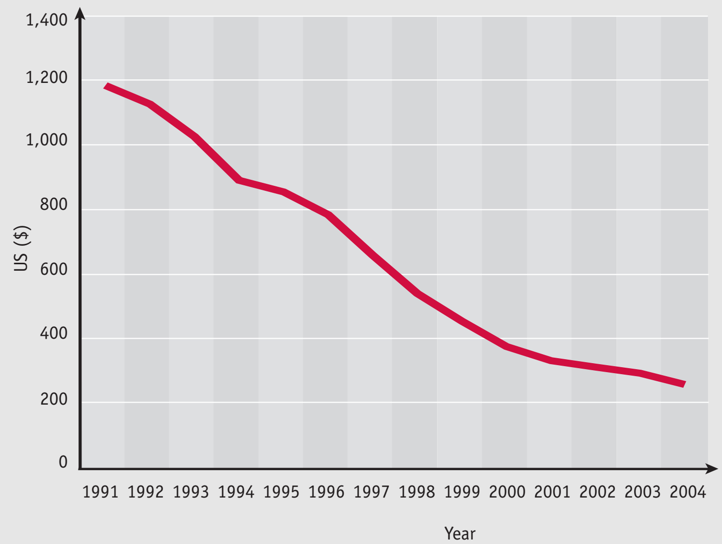
The core market, wireless cellular telephony, exhibits this relentless cost pressure that is a central feature of the later growth stage (figure 6).

These cost pressures translate into mergers and acquisitions as industry consolidates in the face of slowing revenue growth. For example, recent M&A activity among major carriers in both the United States and Canada includes:

— Cingular, in a US$41 billion merger (2004) with AT&T Wireless, created the largest U.S. wireless carrier;

— Verizon merged with MCI in 2005, creating the second-largest carrier: US$90 billion in annual revenues;

Figure 6: Cellular Revenue Per Subscriber



Source: International Telecommunications Union.

— Sprint purchased Nextel for US$35 billion in 2005, creating the third-largest U.S. carrier; and

— Canada: Rogers, the third-largest wireless operator, acquired Microcell Telecommunications Inc., the fourth largest operator in November 2004. This created the largest carrier; Bell and Telus are second and third.

All of this consolidation has spilled over to the supplier level as well. Examples of supplier mergers include Alcatel-Lucent and the combination of the network arms of Nokia and Siemens[27] into Nokia-Siemens Networks; acquisitions include the sale of Nortel's UMTS Access unit to Alcatel.[28]

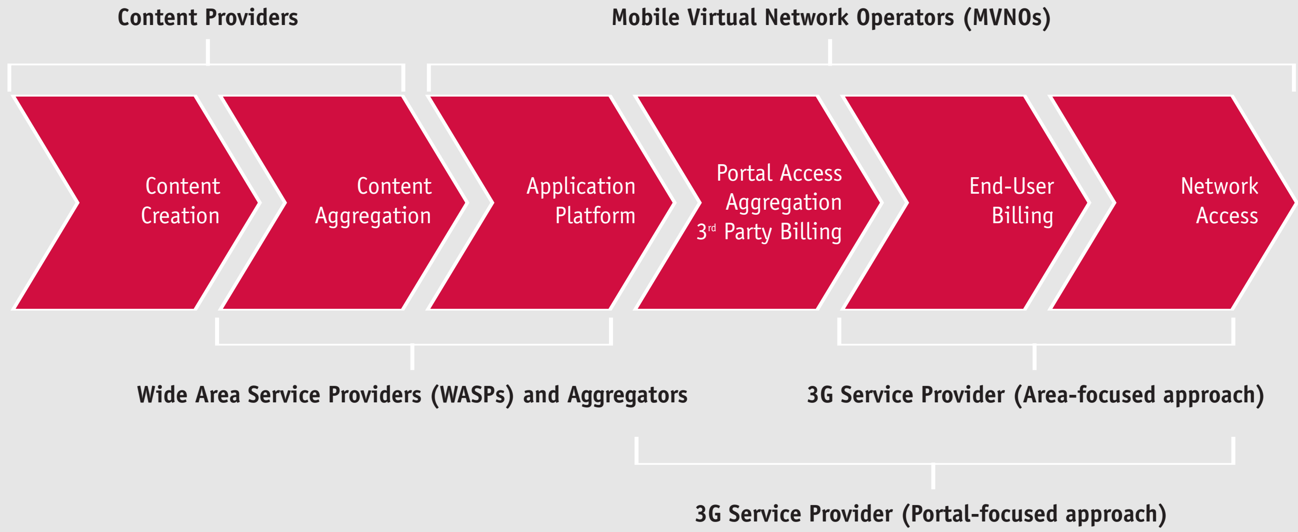
A major difference between the take-off period and the later growth period is the product's transformation – in the consumer's eyes – from technological marvel to basic necessity. This is the driver behind the ascent of marketing and distribution to dominate competition along the industry value chain. The competitive pressure to create customer value reshapes the value chain in support of this critical task. The following figure illustrates the result:

[26] "Mobile Entertainment, Mobile Health Care and Location-based Services," *ICTC Wireless Technology Roadmap Industry Overview* (Nov. 1, 2006).

[27] "Telecom Giants plan $30 Billion Deal" *The New York Times* (June 19, 2006).

[28] "Nortel Selling UMTS Wireless Access Unit to Alcatel for US$320 Million," www.cdc.ca (Sept. 1, 2006).

Figure 7: Specialization and Segmentation of Wireless Service Provision



To better meet the needs of wireless users, suppliers have segmented the industry value chain, regrouping activities around five strategic centres of gravity:

— **Content Creation** (e.g., CNN, Disney): They furnish information and entertainment through mobile Internet portals;

— **Wide-Area Service Providers** (e.g., United Parcel Services, banks): They provide wireless solutions for customers to access corporate databases, applications and intranets;

— **Mobile Virtual Network Operators** (e.g., Financial Times, Virgin): They use their branding and marketing strengths to compete with network operators and content providers;

— **Area-Focused Service Providers** (e.g., Vodafone, Sprint-Nextel): They sell basic wireless network service combined with some service features or content, e.g., roadside assistance, voice-activated dialing, cell phone insurance, etc; and

— **Portal-Focused Service Providers** (e.g., AOL, Yahoo!): They partner with area-focused service providers to supply content and features, e.g., e-mail, stock quotes, weather, etc.

This reconfiguration of the value chain is essentially a shift from vertical integration to horizontal specialists that focus on different levels of the value chain.

Exactly the same shift has been occurring in the *hardware* part of the wireless industry. Here, old vertically-integrated companies (e.g., Motorola and Ericsson) that once started with chip manufacturing and went right up the value chain to make handsets and base stations have increasingly concentrated on systems integration. They outsource their hardware needs to a series of specialists operating at what are now separate levels of the value chain: *chips, software, manufacturing, design* and *branding*.

In the new *horizontal* structure of wireless hardware, chips (e.g., AMD) and software (e.g., Microsoft) can be bought off the shelf. Manufacturing can be outsourced to an electronics-manufacturing firm (e.g., Solectron) or even to an OMD.[29] Such firms, like HDC (Taiwan), design and build handsets for better known firms like Orange (France Telecomm) that apply their own branding. This practice underlines the shift from technology to marketing as the dominant strategic issue.

Content creation is itself experiencing a shift in its centre of gravity. "With the advent of YouTube and other peer-to-peer sharing, the volume of traffic uploaded has shifted dramatically. This challenges previous assumptions which drove asymmetric uplink and downlink designs. Indeed, the nature of this shift in content creation may well challenge the entire ICT structure's ability to deliver what users want."[30]

Maturity (c. 2023-2033)

The final decade in the technology lifecycle of wireless cellular telephony will see the centre of gravity of innovation shift to industry suppliers. Two likely candidates are software and microelectronics.

Software is still more 'black art' than a true engineering discipline (see Chapter 5, *A Software Platform for Systems Integration*). It relies heavily on experience and pragmatic refinements vs. a firm foundation in scientific theory applied through reproducible engineering methodologies. In the next fifteen years considerable progress can be expected.

Microelectronics, now 60 years old,[31] has already seen its successor technology beginning to emerge. *Molecular electronics*, based on quantum (vs. classical) physics, will increasingly replace microelectronics, just as microelectronics began to replace vacuum tubes in the 1950s. A breakthrough development is the first quantum computer demonstrated by D-Wave, a Canadian company, in early 2007.[32]

29 Original design manufacturer: the biggest, all Taiwanese, are BenQ, Arima and Compal.

30 John Visser, P.Eng. International Wireless Standards, Nortel (May 18, 2007).

31 The transistor was invented at Bell Labs in 1947.

32 "Orion's Belter", *The Economist*, Feb. 15, 2007.

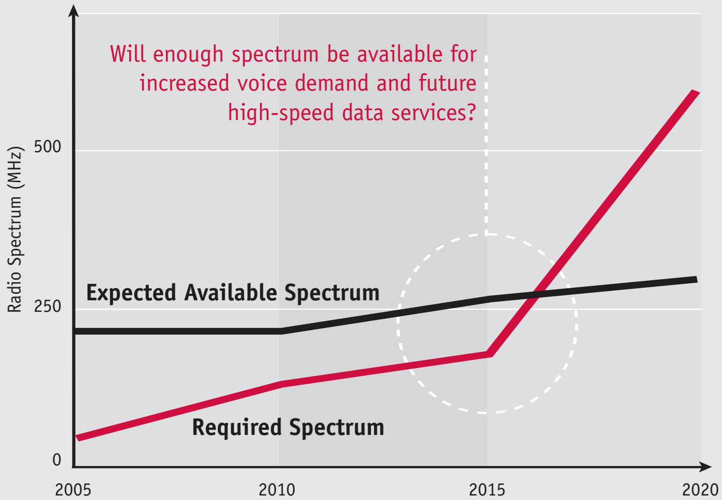
Chapter 4: Market Realities at the Outset of the Later Growth Period

This chapter outlines the broad market forces that will play a critical role in shaping the ongoing later growth period (2004-2024) of the global wireless industry.

4.1 Regulation (Political)

This is a major issue in meeting the growing demand for wireless services: under the current system, spectrum shortages are expected within about a decade.

Figure 8: Spectrum Supply and Demand[33]



The central problem is that the regulatory framework is largely a legacy,[34] *built around the technology of the first global wireless industry,* namely: radio broadcasting. During that era, the only way of avoiding interference was to grant exclusive use of specific frequency bands. As a consequence, radio spectrum has been treated as a scarce resource that "must be allocated by governments or bought and sold like property."[35]

Since the 1930s, governments have decided on the best use of the airwaves. This central planning approach has allocated exclusive free licenses 'in the public interest': from radio and television to local government, the military and educational broadcasters. A market-based approach to spectrum use is still seen as novel. Although governments in both North America and Europe began to auction frequency bands in 1995, central planning still accounts for 98 percent of spectrum use: even now, auctions represent only 2 percent of 'prime spectrum.'

Prime spectrum, the 1 percent of all frequencies below 3 GHz, is worth more than the other 99 percent of radio spectrum between 3 GHz and 300 GHz. The lower frequencies are prized because they are much better at penetrating rain, trees and buildings. However, the legacy of almost a century of regulation has been to vest huge swaths of frequency to underutilized purposes; new uses of desperately-needed prime spectrum are systematically starved as a result.

"Most of the spectrum is empty most of the time. It's absurd."

Dennis Roberson, former CTO, Motorola[36]

For example, TV broadcasters control 15 percent of prime spectrum but serve only 11 million U.S. homes (cable and satellite serve the other 88 percent – using no prime spectrum). Cellular carriers get only half as much spectrum to serve 137 million customers. WiFi serves 20 million customers with only half the spectrum allocated (but rarely used) to distribute video to schools.

"The pregnant question is: what if we took a tiny amount of good spectrum and repurposed it?"

Tren Griffin, Telecom Strategist, Regulation, Microsoft[37]

33 [Source: IST-2003-507581 Winner D6.5 v1.0 *Spectrum Requirements for "Further Developments of IMT-2000 and Systems Beyond IMT-2000"*]

34 U.S. regulation dates from the *Radio Act* of 1912 and the *Communications Act* of 1934. However, Canada has closely followed American practice.

35 "On the same Wavelength," *The Economist*, August 12, 2004.

36 "Dead Air," *Forbes Magazine*, Nov. 25, 2002.

37 Ibid.

The resulting opportunity cost of services and technologies not offered because of legacy allocation of spectrum is estimated at $771 billion in the U.S. (2001).[38]

In summary, the problem of radio interference that long ago led to the current regulatory regime is in fact a technological issue. Moreover, developments in radio technology are obviating the need for central planning.

4.2 Technology

There are five broad developments in wireless technology that effectively increase the ability of users to share spectrum:

— **Spread Spectrum:** This technique distributes a signal across wide bands of frequencies. This is a departure from the old technology of radio broadcasting which concentrates the signal on a single frequency. Spread spectrum's advantage is that it can operate in frequency bands that are already assigned to other uses. One way is for the signal to rapidly 'hop' between unused frequencies in its assigned band – constantly adjusting to noise and interference to make best use of available frequencies. Another way is to spread a low-power signal across a wide band of frequencies, 'underlying' existing uses. Ultra wideband (UWB) applies this approach across a huge range of frequencies. "UWB is an interesting technology, but caution needs to be exercised because it contributes to the RF noise floor, and in so doing can make a previously workable solution for other users of the spectrum unworkable."[39]

— **Software-Defined Radio:** Most radios are 'hard-wired' to transmit and receive one type of signal at one range of frequencies. However, a sufficiently powerful microprocessor can use software to reconfigure a chip's circuitry – within limits[40] – to work with many types of signals and frequency ranges.

— **Cognitive Radio:** Powerful software programs give wireless systems the capability to sense and adapt to the EM environment, e.g., changing transmission characteristics to make best use of available radio spectrum.

— **Smart Antennas:** These systems use multiple antennas both to aim signals in a particular direction and to pick out a specific signal from background noise. Smart antennas can retrieve individual signals that share the same frequencies.

— **Mesh Networks:** This is a recent development that was deliberately designed[41] as a disruptive technology to replace commercial networks with a free, user-based user-owned service. These are random, unplanned networks, self-formed through the co-operation of individual transceivers. Each transceiver in the network acts as a repeater to transmit data from nearby neighbours to distant peers, allowing signals to 'hop' across the network. As with spread spectrum, the advantage is that signals – with only hundreds of metres instead of kilometres to travel – can be sent at low power, allowing reuse of the same spectrum again and again.

Like all technological systems, the performance of wireless depends on developments in supporting devices, components and materials. While a detailed analysis of these areas is beyond the scope of this document, key issues are listed below:

— **Batteries:** These are the *Achilles' Heel* of mobile, handheld devices. They continue to pose a significant constraint on the use of today's features like colour screens. Tomorrow's handsets will include even more power-hungry features like video.

Batteries will also be a factor in the market penetration of newer wireless technologies like WiMax[42] that offer faster network speeds at the expense of higher power consumption.

In summary: "growing processing capabilities and application demands are in conflict with the slow development of battery technology."[43]

— **Chipsets:** Advances in semiconductor technology have been instrumental in making handheld wireless devices possible. They are a critical plank in the platform technology on which electronic systems and their wireless applications rest. Shrinking transistor size has been the key to cost and performance improvements in chipsets. Intel, the world's largest semiconductor manufacturer,

38 "On the same Wavelength," *The Economist*, August 12, 2004.

39 John Visser, P.Eng. International Wireless Standards, Nortel (May 18, 2007).

40 "For example, a radio designed for, say 3.7GHz, cannot be easily adapted to 3.5 GHz because it strays too far from the optimal performance of its RF components governed by the laws of physics" John Visser, P.Eng. International Wireless Standards, Nortel (May 18, 2007).

41 1995, the massive array cellular system (MACS), a Canadian patent.

42 "WhyMax?" *The Economist*, Feb. 24, 2007.

43 "The Future of Wireless" Mark Pecen, VP Advanced Technology, RIM (January 11, 2007).

has been a leader in advancing chip-making technology. For example, at the beginning of 2006, most of Intel's production[44] used 90-nanometer (nm)[45] technology. By year's end, the bulk of Intel's chips were made using a more advanced 65-nm process. Later in 2007, Intel expects to produce the first devices based on its new 45-nm technology.[46]

While chip fabrication technology will run into fundamental barriers imposed by quantum physics as feature sizes decrease, this is not expected to create any significant bottlenecks for the development of wireless applications over the 2006-2016 roadmap timeframe.

— **Photonics:** It addresses transmission capacity,[48] a basic limitation of electronics systems. As chips shrink, the delay in electronic signal transmission from chip to chip and chip to board becomes the performance bottleneck in systems. This is because the huge number of transistors on a chip results in extensive interconnect[49] length. Increasing integration density will result in 20km/cm^2 of interconnect around 2010.[50]

Consequently, photonics connections have increasingly replaced electronic ones where high bandwidth (bits/second) is required. In fact, electronic approaches to deliver 10 Gbps[51] at motherboard level have proven (so far) problematic.[52]

— **Software:** For electronics, software is more and more instrumental in delivering the increased functionality that users expect. This is true from device level (e.g., chips) to systems level (e.g., cell phones).

Initially, chips were very low-level building blocks of electronic systems: a data sheet was sufficient to support their application in systems. Today, advances in fabrication technology have made it possible to shrink entire systems onto a single chip. This is referred to as system-on-chip (SoC) technology. *The result is that where there was once a clear separation between chip and systems design, these two activities are converging.*

For example, it used to be that chip makers supplied the lower-level software and third parties developed the operating systems. Once the wireless system was provided to users, they developed the specialized applications software. However, systems integration presents a whole new challenge: now, software all the way from the chip level to systems to subsequent applications has to work together seamlessly. The result is hardware/software co-design.

4.3 Economic

Economics will place significant limitations on the commercialization of wireless technology. The major factors are outlined below:

— **Globalization:** *This has a major impact on industry structure and on Canada's ability to develop the skills needed to compete internationally.*

The core structural problem is that Canada's ICT sector is fragmented. SMEs[53] dominate: fully 98 percent of the 32,000 ICT firms employ fewer than 100 people. The large, vertically-integrated companies that used to be an effective industry training ground for newly-graduated scientific and engineering talent are gone. They exposed young graduates to the whole range of doing business: taking products from ideas through to market; from R&D to engineering and production prototypes then on into manufacturing and distribution.

In the new global economy, functions like R&D, manufacturing and marketing are each located separately. Head office integrates the results across many countries. Because of Canada's favourable environment for performing R&D, a significant portion of the research is often done here. However, SMEs have to cover the entire range of business activities. Their source for the needed experience (about five years) was the large vertically-integrated companies. Unfortunately, these are gone, bought by global giants and redirected to more specialized missions.

44 "Intel to produce smaller and less power-consumptive chips," www.itworldcanada.com (March 16, 2007).

45 One nanometer is one-billionth of a meter.

46 "Intel UltraMobile PC chip nears release," www.crn.com.au (March 21, 2007).

47 For example "The Red Brick Wall: Computing faces the end of a road," Pile Systems Inc. (2004).

48 Transmission capacity is measured by the product of bit rate (B) x distance (L). B is the transmission speed (bits/sec.) and L is the distance signals can travel without regeneration.

49 Interconnect is the 'wiring' between transistors.

50 "Will Silicon be the Photonic Material of the Third Millennium?" *Journal of Physics: Condensed Matter* 15(2003) R1169-R1196.

51 Gigabits per second (billions of bits per second).

52 "Silicon Photonics Poised to Invade Local Area Networks," *Photonics Spectra*, March 2006.

53 Small and Medium-sized Enterprises.

Even billion-dollar Canadian companies have been bought out. A short list of ICT examples includes Newbridge Networks (by Alcatel), ATI (by Advanced Micro Devices), C-Mac (by Solectron), and Creo (by Kodak).

— **Sunk Assets and Switching Costs:** The established wireless industry is a US$500 billion (c.2005) global giant, dominated by large operators with a huge asset base of existing networks.

Although third-generation (3G) networks are the current industry standard, there are already concerns that 3G networks may fall short of the demands of important new applications:

"3G may not be able to meet the performance required for future multi-media, full motion video and wireless teleconferencing."[54] Others put it more bluntly; "3G isn't good enough to meet wireless broadband demands"[55]

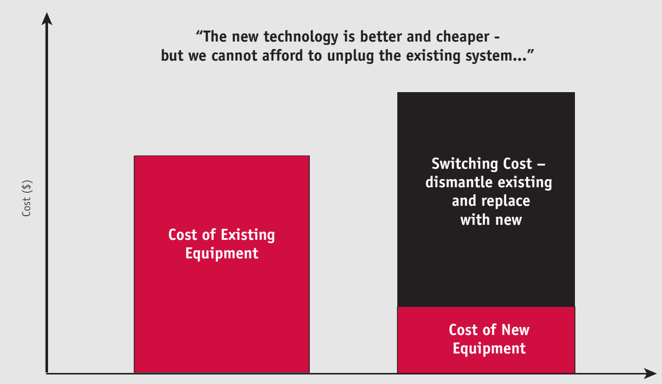
Yet, at the outset of the industry's later growth stage – a time of slowing single-digit market expansion – wireless network operators are caught in the vise of high fixed costs and declining marginal revenues (see Chapter 3). There is a need to invest in technologies beyond 3G, but the switchover costs are prohibitive. As illustrated in Figure 9, the cost of the new equipment may be only one-third the cost of the old equipment, but the cost of switch-over may exceed the cost of the existing equipment.

Moreover, as major public companies, the adverse effects of asset write-downs compel wireless operators – the key customers for large infrastructure investments – to manage with their existing asset base.

Finally, Canada's Competition Bureau found that "there are very high barriers to facilities-based entry, including high capital costs to construct and run a network, regulatory requirements and foreign ownership restrictions."[57]

— **Intellectual Property (IP) Costs:** The fifty-year evolution of the semiconductor industry from vertically-integrated giants to layers of horizontal specialists has seen the rise of IP as a stand-alone business. For example, 'fabless' companies design and market microchips. However, they outsource the complete manufacturing process to merchant wafer foundries, typically Southeast Asian companies that specialize in chip production. Canadian examples of fabless companies include Zarlink and Tundra Semiconductor.

Figure 9: Switching Costs[56]



With the growing complexity of chips, the design business has produced companies that further specialize in particular parts of the chip circuitry. These designs are sold as IP to others that incorporate them into their chips. Canadian examples of these 'chipless' companies include MOSAID Technologies in memory and Elliptic Semiconductor in security and verification.

A related development has been the rise of 'patent trolls' – companies that threaten legal action based on alleged infringement of their designs. With costs and the additional uncertainty that the courts can properly resolve complex technical issues, costly out-of-court settlements are often the result. The dysfunctional result is to increase the cost of innovation. In fact, "Patent trolls and related IPR issues are becoming an increasingly serious and costly problem, and have the potential to entirely stifle innovation."[58]

54 "4G – Beyond 2.5G and 3G Wireless Networks" www.mobileinfo.com (Oct. 2, 2006).
55 "Nortel CEO: 3G can't cut it" http://www.lightreading.com/document.asp?doc_id=117486 (Feb. 15, 2007)
56 "The Future of Wireless" Mark Pecen, VP Advanced Technology, RIM (January 11, 2007).
57 "Competition Bureau's Clearance of Rogers-Microcell Wireless Merger Explained," *The Competitor*, Stikeman Elliott (June 2005).
58 John Visser, P.Eng. International Wireless Standards, Nortel (May 18, 2007).

A recent Canadian example[59] is RIM's $612.5-million payment to patent-holding company NTP to settle a long-running dispute that had threatened to shut down RIM's e-mail service for its three million Blackberry users.

4.4 Social

Wireless access is now taken for granted. Users expect a minimum level of service; a normal development in the technology lifecycle when new products begin to be taken for granted, fading into the background as an everyday convenience.

Privacy concerns over the use of wireless are increasing as the technology makes it easy to intrude to the point of tracking the location of individuals. Security is a major issue as well, in particular as e-commerce grows.

4.5 Environmental

The disposal of obsolete computers and their accessories is becoming a major issue throughout the industrialized world. Many states in the U.S. (e.g., California, Massachusetts, and Minnesota) have outlawed their disposal in landfill sites and incineration operators are apprehensive about placing certain items (particularly batteries) in their plants. As the waste products become smaller and smaller, many small businesses are discarding them in their household garbage because its disposal requirements are generally less stringent. It is estimated that 500 million personal computers were taken out of service between 2000 and 2007.

Waste management companies in the more regulated areas are offering specialized disposal services at costs that are in addition to their normal disposal costs. In less regulated areas, such equipment is finding its way into the hands of junk dealers who dismantle it, making it more difficult for authorities to track its disposal. In keeping with other environmental legislation, the manufacturers of such equipment will face more and more legislation that facilitates the safe disposal of their products. This could result in the application of new technologies (e.g., sensors) at the manufacturing stage in order to monitor compliance.

[59] "Blackberry Maker, NTP Ink $612 Million Settlement," www.money.cnn.com (March 3, 2006).

Chapter 5: The Canadian Context: Three Focal Points

This chapter begins with an outline of the three applications selected by the national WTRM Steering Committee and verified by the regional focus groups as being particularly relevant to Canada's wireless industry:

— Intelligent Transportation Systems (ITS)
— A Wireless Software Platform for Systems Integration
— A Wireless Software Platform for Multiplayer Mobile Gaming

For each of these applications, we present below the findings from the regional focus group discussions. These one-day sessions, with over 100 industry stakeholders in all, were essential in validating and refining the product (including services where appropriate), market and technology dimensions of the selected applications:

— The Product: What customers will receive
— The Market Application: Who the customers are
— The Technology: How their performance needs will be met

ICTC Technology Vision Conference, 2006

This chapter concludes with an overview of the *product drivers* that will fuel customer demand for each of the three applications along with a summary of the specific performance requirements that the applications must meet.

5.1 Intelligent Transportation Systems (ITS)

The Product: Wireless Backhaul for ITS

Intelligent transportation systems comprise integrated networks of sensors, computers, communications and control technologies.[60] Customers use these networks to improve efficiency, safety and productivity in their transportation systems (e.g., urban mass transit).

Backhaul is the task of transporting data traffic from the edge of the network to more centralized points where it is processed into information to support command and control decisions. Examples of backhauled data in transportation systems include:

— Real-time video feeds from police cars and helicopters;
— Bus location and rider load;
— Vehicle detection for adaptive traffic control systems; and
— Trauma centre monitoring of accident victims' vital signs en route to hospital.

The Market: Transportation Systems

Examples of urban transportation systems that comprise the market for ITS include:

— Mass transit (e.g., bus, train, and subway);
— Traffic management in urban areas and access routes;
— Emergency services (e.g., police, fire and ambulance); and
— Collision avoidance systems.

The Technology

The basic performance requirement is well expressed by Motorola's slogan: "Anything, Anywhere." Meeting this prerequisite for range and data volume is just a start. The backhaul technology must also respond to challenging requirements like network security, interoperability and robustness.

Suggested contributing solutions to the need for backhauling large quantities of data over long ranges include:

— Telephone wired and wireless networks: Existing networks could be used to backhaul data for low-capacity sensor nets. Indeed, "Advancing technology has given existing access networks increased capacity (e.g., xDSL) and core networks have much greater capacity (e.g., fibre) than had been the case."[61]
— Dedicated wired networks: Fibre optics and coaxial cables will play an important role in urban areas. In systems like traffic management, surveillance will be largely accomplished by fixed installations (e.g., traffic cameras).

[60] Intelligent Transportation Systems Society of Canada, ITS broadly includes the vehicle, infrastructure and driver.
[61] John Visser, P.Eng. International Wireless Standards, Nortel (May 18, 2007).

— Wireless links with power lines: While this is possible, it is unlikely since bandwidth is limited and the distance between repeaters is relatively small. Dedicated fibre-optic and coaxial cables are far more likely solutions to data transport in urban centres.

— Beam-forming: This allows aiming radio waves at the desired receiver. It minimizes multi-path signal loss. The net result is an increase in spectral efficiency. For example, in cellular systems it allows squeezing two to three times the volume of conversations into the same bandwidth.[62]

— MIMO (multiple input, multiple output): Rather than trying to eliminate the effects of multi-path transmission, MIMO uses an array of antennas at both transmitter and receiver to take advantage of this phenomenon. MIMO[63] can be used in alignment with orthogonal frequency-division multiplexing (OFDM[63]) and is expected to be a part of the *802.11.n standard*.[64] Best suited to the rich scattering environment found in urban areas, it allows increased data rates and low bit error rates. However, it is a complex, high-cost, evolving technology.[65]

— Intelligent radio: This applies significant computing power to allow the transmitter to 'sense' its environment and dynamically adjust parameters such as frequency, modulation, power, etc. to use the most appropriate spectrum. Most RF[66] transmission systems already control transmission power.

— WiFi: Because these systems use 'garbage bands'[67] (frequencies already allocated for other purposes), their potential use in critical applications is limited because of the possibility of significant uncontrollable interference.

— WiMax: This is a wide-area version of WiFi (max. 70 Mbps and 50 km). Because it uses licensed spectrum, it provides better QoS (quality of service). In the U.S., the biggest segment available is around 2.5 GHz. Elsewhere, the most likely bands used will be around 3.5 GHz, 2.3/2.5 GHz or 5 GHz.

— Satellite: Current long-distance telecom networks could be used, especially to cover large areas (e.g., Google Earth). However, satellites will add 0.25-second latency (signal delay).

— Bandwidth management: Controlled use of networks is a standard tool in managing the available data transmission capacity.

— Sensor data fusion: This is the process of putting together information obtained from many heterogeneous sensors, on many platforms, into a composite picture of what the network is measuring. Data fusion at the sensor level will ease the backhaul capacity requirements. It is a young, evolving field less than 20 years old.

— Data compression: This is the process of encoding information using fewer bits than would be required if the data were sent in unencoded form. Data compression performance is a direct function of the nature of the data being compressed.

The important system features and attributes (*product drivers*) that these technologies must provide include:

— Ultra-fast downloading (e.g., for real-time monitoring of hazards, like road spills, accidents, ice formation, etc.);

— Multimodal interfaces (e.g., to variously backhaul data by wire line, fibre or wireless as required);

— Connection to grid-based computing (e.g., to solve complex optimization algorithms in traffic-flow management);

— Embedded applications in robotics and autonomous agent networks (e.g., for the control of flexible manufacturing systems);

— Cognitive system applications (e.g. 'thinking cars' such as those that park themselves or communicate with each other for collision avoidance);

— RF systems-in-package (SiP) devices (e.g., sophisticated sensors capable of transmitting via multiple radio bands and protocols);

— Smart-card technology (e.g., to allow automated fare payment by riders);

[62] "How to create beam-forming smart antennas using FPGAs," *Embedded Systems Design*, www.embedded.com (Feb. 17, 2005).

[63] MIMO and OFDM are also fundamental technologies for WiMax.

[64] 802.11n is better known as WiFi. The Institute of Electrical & Electronics Engineers (IEEE) expects to publish the new 802.11n standard in Oct. 2008. The real data throughput is estimated to reach a theoretical 540 Mbps and should be up to 50 times faster than 802.11b, and up to 10 times faster than 802.11a or 802.11g.

[65] "How to create beam-forming smart antennas using FPGAs," *Embedded Systems Design*, www.embedded.com (Feb. 17, 2005).

[66] Radio frequency.

[67] At 900 MHz, 2.4 GHz and 5.8 GHz.

— Logistical vehicle and real-time operating status management[68] (e.g., remote diagnostics to inform transit maintenance services of mechanical or electronic problems);

— RFID[69] (e.g., for inventory tracking and management in transit fleets); and

— Telemedicine (e.g., for monitoring and care of ambulance patients en route).

5.2 Wireless Software Platform for Systems Integration

The Product: A Systems Integration Process

Systems integration is the process of seamlessly combining multiple, discrete systems to respond to needs that none of the individual systems can meet alone.

Software programs already exist to perform a wide range of separate functions on wireless devices. Examples of financial functions include banking, electronic money and credit cards. However, software developers lack procedures, standards and proven methodologies for combining these programs, e.g., to allow users to manage all of their financial needs from a mobile device.

A rigorous, proven systems integration process could allow multiple software programs to be treated as modules that can be configured in larger architectures to greatly enhance the functionality of wireless devices for users.

The Market: Software Developers for Wireless Applications

An example of a huge market with an unmet need for systems integration is healthcare: for example, the integration of healthcare records to create a comprehensive electronic patient file – a project recently announced by British Columbia "…to store patient medical records and laboratory test results so they can be shared among healthcare professionals across the province."[70]

The Technology

The fundamental challenge is that software design and development has yet to evolve into a true engineering discipline. This evolutionary process and the major stages it comprises are well known.[71] It begins with craft and the designs of talented amateurs, based on intuition. In time, resourceful practitioners evolve established procedures, pragmatic refinements and economic resource use to meet rapidly-expanding market demand. The technology is fully developed when educated professionals, relying on a scientific theory and analysis, proven design solutions and rigorous quality control, can reproduce predictable results within an accurate time and cost framework. It is this final stage of evolution into a true engineering discipline that software design and development has yet to achieve.

The basic product features and attributes (*product drivers*) that a software integration technology must provide include:

— Network computing capability and supporting middleware including:

  — Mobile access and data visualization;

  — Downloading from host servers (e.g., integrated satellite with direct-to-the-home TV equipment for broadcast-oriented data traffic and video-on-demand);

— Full e-commerce capability, including:

  — Consumer mobile transactions (e.g., integration of e-money, credit card payments and bank accounts on handheld devices);

  — Business-to-business transactions (e.g., billing, real-time charges for services, and financial system and stock market operations);

  — Mobile point-of-sales management and service-oriented architectures (e.g., FedEx and UPS handheld terminals);

— Internet protocol storage area networks (e.g., for remote storage and access to data);

— Compliance with legal and governance issues regulating privacy and security of information (e.g., *Personal Information Protection Act*[72]);

68 Telematics.

69 Radio frequency identification.

70 "B.C. government sets $148M EHR project in motion," www.ITWorldCanada.com (April 18, 2007).

71 See for example "Prospects for an Engineering Discipline of Software," Mary M. Shaw, *IEEE Software* (1990).

72 The purpose of PIPA (a province of Alberta act in force as of January 2004) is to govern the means by which private sector organizations handle personal information in a manner that recognizes both the right of an individual to have his or her personal information protected and the need of organizations to collect, use or disclose personal information for purposes that are reasonable.

— System survivability (e.g., net attacks, disaster recovery capability);
— Simple, robust, user-friendly interface with good information display and secure access from anywhere at anytime;
— Geospatial information capability (e.g., GPS); and
— Security, including:
  — Electronic user ID, transportable across platforms (e.g., fingerprint or iris scan via a PC);
  — Secure SQL[73] interfaces to a massive and fully backed-up database; and
  — Control of information access (e.g., VPNs,[74] traceable time-stamped interactions – via a central database with augmented functionality and transaction tracking).

The challenges are daunting and an analysis of the technological solutions to resolve them is far beyond the scope of this document. As a senior official of the U.S. Institute of National Standards and Technology[75] puts it:

> The need to integrate large software systems into complex "systems of systems" is evident in multiple problem domains. Yet industry testimonials describe multi-million-dollar expenditures for unsuccessful software systems integration efforts... Current approaches are costly, time consuming, and frequently yield suboptimal results.
>
> *Steven R. Ray, Ph.D.*
> *Chief, Manufacturing Systems Integration Division*
> *U.S. National Institute of Standards & Technology*

Current approaches are brittle, i.e., they fail when faced with slight perturbations to the information transacted; they are difficult to maintain as the systems are upgraded; they are difficult to scale when the requirements for additional information content or additional constituent systems arise.[76]

5.3 Wireless Platform for Mobile Multiplayer Gaming

The Product: A Technology Platform for Real-Time Multiplayer Games

Mobile multiplayer gaming is a demanding wireless application that will push game design, networks and handheld devices to new levels of performance. For example, the processing capacity of the required game servers must increase exponentially with the number of players. The network transmission capacity must increase significantly as well.

The Canadian gaming industry – a young, vibrant high-growth sector – requires a well engineered *process* to support the development, customization and modification of games for the wireless entertainment market. This process must effectively integrate their five major activity areas of: game design, art, programming, production and quality control (game testing).

The Market

Mobile gaming is still in its embryonic stage. In 2006, it was a US$2.4 billion global business, barely 0.5% of the global market for wireless cellular telephony. The key target is the casual (vs. hardcore) gamer aged 12 to 40 years. Casual players use games to pass the time, e.g., in a doctor's waiting room or ticket queue.

Multiplayer gaming is important because players want the challenge of going against live competitors. Game producers face a demanding clientele: accustomed to a highly sophisticated gaming experience from PCs and the Internet. "The market for massively multiplayer online games in the West reached $1 billion for the first time in 2006."[77]

The Technology

Like systems integration, progress in mobile multiplayer gaming rests largely on advances in software engineering.

Because game design is so interwoven with the closely-related elements of handsets and networks, the *product*

73 Structured query language: used by many programs that manipulate large databases.

74 A virtual private network is a private communication network often used by companies or organizations to communicate confidentially over a public network.

75 "The Future of Software," *Institute for Software Integrated Systems,* Vanderbilt University (April 4, 2007).

76 Ibid.

77 "Analyst report: multiplayer online game market in the West to hit $1.5 billion by 2011," *Digital Media Industry Newsletter,* (March 2007).

drivers in the mobile multiplayer gaming market are best analyzed in the technological systems context (see Chapter 2).

The Major Device: The Game

- Content value: e.g., creativity, cultural, psychological, differentiation from existing games;
- Multilingual gaming interface;
- Geospatial information capability (e.g., to support real-time, location-based interactive gaming);
- Multi-tasking and multi-session gaming (to support simultaneous play with multiple games and players);
- Support for real-time interactive personal area networking (social interaction with other players);
- Data compression algorithms (e.g., game characters' movements are sent over the network rather than the resulting complete picture);
- Maximization of pixel use: this is related only to the presentation of the game on the handheld device, not the transmission over the network; and
- Electronic payment capability (to pay for gaming or game purchase).

The Supporting Device: The Handset

Important needs include:

- Interoperability: from handset to PC. (This is a new requirement that had previously been unimportant since the PC gaming market was separate.) Related capabilities include:
  - Connection to audio-visual systems and home entertainment networks;
- Human Interface design, including features like:
  - Adjustable to suit the user;
  - Wearable (e.g., display glasses, gloves);
  - Voice recognition, touch-screen control;
  - Intuitive operation, user-friendly interface;
  - Design optimized for gaming, not voice;
- Multimedia capability, including:
  - Music downloading;
  - Text messaging;
  - Voice recording, registration and VOIP communications;[78]
  - Mobile, interactive IPTV;
- Low-power electronics;
- High-capacity memory;
- Graphics processing engine;
- RF shielding (re, health concerns about EM radiation);
- Power options (i.e., battery life, recharge time, etc.);
- Lightweight materials; and
- Heat dissipation.

Infrastructure: The Network

- High speed and high capacity: Real-time video is the ideal; however, this is unlikely since high-performance graphics engines reconstitute video based on simpler primitives sent over the network, e.g., character motion, zooming and panning;
- Game response time (i.e., very low latency, real time operation): When geostationary satellites are part of wide-area network coverage this is unattainable since the signal's roundtrip from terminal to orbit takes about 0.25 seconds;[79]
- Universal network access: this refers to inter-modal capabilities such as seamless transfer to fibre and wire line. IP-based protocols should resolve this;
- Protocols (for transporting content as a function of the access interface); and
- Bandwidth management.

While the focus of this particular analysis is on game design and production, the requirements of the other parts of the technological system capture important elements that **mobile gaming** shares with the applications of **systems integration** and **intelligent transportation systems**.

[78] Voice over Internet protocol.

[79] Although EM signals travel at the speed of light, 300,000 km/sec, the 72,000 km roundtrip still takes 0.24 seconds.

5.4 Summary of Product Drivers and Performance Requirements

Product Drivers

The product drivers refer to features and attributes that are likely to have a strong influence on a customer's desire to purchase the product. The term 'product' is assumed to include a service where appropriate. The product drivers are specific to each of the three applications and are outlined in the three previous sections.

Performance Requirements

For each of the three applications, we have defined, below, a *common set of performance requirements that are based on the four fundamental ways that products create value for users.*

The first is *functionality*, the basic job the product is expected to accomplish. While the three applications are different, they all rely on RF transmission to move information.

1. Functionality – *What basic capabilities are needed to get the job done?*
   - Mobile hand-off range and capacity (spatial diversity);
   - Low data transmission latency;
   - High degree of data compression;
   - Degree of security and privacy;
   - Degree of safety: specific absorption rates (SARs) of microwave radiation;
   - RF spectrum efficiency;
   - Power consumption (battery life); and
   - Quality of service.
2. Economics – *How much does it cost?*
   - Acquisition Cost (How much to get it up and running?);
   - Operating Cost (How much to keep it going?);
   - Reliability (How often does it fail?); and
   - Serviceability (How easily is it repaired/replaced?).
3. Compatibility – *How easily does it fit into the user's existing systems?*
   - Network interoperability;
   - Standards-based;
   - Common language based; and
   - Mobile web-based system access.
4. Ease of Use – *Simple & Straightforward?*
   - Reconfigurable input entry;
   - Reconfigurable software radio design;
   - Diverse multimedia capability; and
   - Ergonomic design.

The figures below present the product drivers for each of the three applications. These product drivers were ranked on a scale of 1 to 5 (1 = low importance, 5 = high importance) according to their significance in creating value for users, measured according to the four performance requirements listed above. In the diagrams that follow, only the 4s and 5s are shown, the 4s in red and the 5s in grey so as to highlight the most critical drivers in each application area.

Table 1: Product Drivers for ITS (i.e., product features demanded by the market)

Legend: ■ = 4 moderate importance ■ = 5 high importance

Key Performance-Based Requirements (below)	Ultra-Fast Down-loading	Universal Network Access (i.e., multimodal interfaces)	Connection to Grid-based Computing	Embedded Applications	Cognitive System Applications	RF Systems-in-Package (SiP) Devices	Smart Card Technology	Logistical Vehicle and Real-Time Operating Status Mgmt.	RFID	Tele-medicine
Functionality										
Mobile hand-off range and capacity	4	4	4	4		4	4			5
Low data transmission latency	4	5	5	5						4
High degree of data compression	5		4							4
Degree of security and privacy	4		4					4	5	4
Degree of safety (specific absorption rates of microwave radiation)								4		4
RF spectrum efficiency									4	4
Power consumption	4			4		4	4		4	4
Quality of service	4		4		4				4	4
Economics										
Acquisition cost	4					4		4	5	4
Operating cost	5		4		4	4		4	4	5
Reliability	4	4	5	4	4	4	4	4	5	5
Serviceability	4	4	5		4					5
Compatibility										
Network interoperability	5	5	4		4	4	4	4	4	5
Standards-based	5	5	4		4	4	4	5	4	5
Common language-based	5	5	4		4	4				5
Mobile web-based system access	5	4						4		5
Ease of Use										
Reconfigurable input entry	5							4		
Reconfigurable software radio design						4		4		4
Diverse multimedia capability	4							4		5
Ergonomic design										5

Table 2: Product Drivers for SI (i.e., product features demanded by the market)

Legend: ■ = 4 moderate importance ■ = 5 high importance

Key Performance-Based Requirements (below)	Network Computing Capability and Supporting Middleware	Full e-Commerce Capability	Internet Protocol Storage Area Networks	Compliance with Legal and Governance Issues	System Survivability	Simple, Robust User-Friendly Interface	Geospatial Information Capability
Functionality							
Mobile hand-off range and capacity	5				4	4	
Low data transmission latency	4				5	4	
High degree of data compression	4	4			5	4	
Degree of security and privacy		5		5	5	5	4
Degree of safety (specific absorption rates of microwave radiation)							
RF spectrum efficiency	4				4		
Power consumption					5		
Quality of service	5	4		5	5	4	5
Economics							
Acquisition cost							5
Operating cost	4				4	4	5
Reliability	5	4	5	5	5	5	5
Serviceability	5		4	4	5	4	5
Compatibility							
Network interoperability	5	4	5	4	5	5	4
Standards-based	5	4	5	5	5	4	5
Common language-based	4	4		5	5	4	5
Mobile web-based system access	4	4			4	5	5
Ease of Use							
Reconfigurable input entry					4	5	
Reconfigurable software radio design							
Diverse multimedia capability	4			4	5	5	
Ergonomic design						5	

Table 3: Product Drivers for MMG (i.e., product features demanded by the market)

Legend: ■ = 4 moderate importance ■ = 5 high importance

Key Performance-Based Requirements (below)	Content Value	Multilingual Gaming Interface	Multi-tasking & Multi-session Gaming	Support for Real-Time Interactive Personal Area Networking	Electronic Payment Capability	Human Interface Design	Multimedia Capability	Power Options (i.e., battery life, recharge time)	Game Response Time (i.e., delays, etc.)	Universal Network Access Capabilities
Functionality										
Mobile hand-off range and capacity	4	4		5	4		4		4	4
Low data transmission latency			5	5	4				5	
High degree of data compression	5		4	4			5			5
Degree of security and privacy			4	5	5					4
Degree of safety (specific absorption rates of microwave radiation)										
RF spectrum efficiency	4		4							4
Power consumption	5		5	4		4	4	5		
Quality of service	4		5	5	5	4	5		4	4
Economics										
Acquisition cost	4		4	5		4	4			4
Operating cost				4			4			
Reliability			5	4	5	4	4		4	5
Serviceability			4							4
Compatibility										
Network interoperability	4		4	4	4	4	4		4	5
Standards-based	4	4	5	5	4	5	5			5
Common language-based	4		4							5
Mobile web-based system access	4		4	4	5		4		4	5
Ease of Use										
Reconfigurable input entry		4	5			5				5
Reconfigurable software radio design			4			4				
Diverse multimedia capability	5	5	4	4	4	4	4		4	5
Ergonomic design	4		5			5	4			4

Chapter 6: Canadian Needs and Capabilities

There are many reasons why Canada should be capable of playing a significant role in the global wireless market in general and of being successful in the above applications in particular. The most important reason is that Canada already has a strong wireless industry with considerable momentum. It is made up of clusters of both home-grown firms and affiliates of multinational enterprises (MNEs). Both types of clusters have a role to play in meeting the challenges and realizing the opportunities outlined in this roadmap. The home-grown clusters are the result of either a strong local need or a compelling local pool of technology. For example, the origins of the home-grown Vancouver cluster can be traced to the formation of Glenayre Electronics in the fifties to address some unique communications needs of the logging industry, while the Kitchener-Waterloo cluster (now dominated by RIM) is attributable primarily to the presence of the University of Waterloo.

6.1 Socio-Economic Factors

The drivers that will have an effect on the products, the markets and the technologies associated with each of the application areas will evolve from the following socio-economic factors that can be expected to apply to Canada over the next two decades. These factors are outlined below; their impact is discussed later.

A Greater Emphasis on Economic Diversification

While Canadian policy makers have been concerned about Canada's 'hewers-of-wood-and-drawers-of-water' industrial infrastructure over the years, there is growing evidence that serious attempts will be made in the coming years to diversify the country's economy. Such attempts will be driven by such factors as the dwindling supply of fossil fuels and the vulnerability of our supply of resources in general. The mountain pine beetle problem in Western Canada is an example of that vulnerability. It was the opinion of several workshop attendees that politicians and policy makers are acquiring a better understanding of the forces that will be at play in the diversification of the country's economy in the coming years. For example, they are now aware of technology's central role in that diversification and they are becoming aware of the domestic potential of the market for technology-based goods and services in areas such as healthcare and the environment.

An Emphasis on a Cleaner Environment

There is now a broad consensus that Canada should strive for a cleaner environment and that technology will play a key role in that clean-up.

This environmental element will be related to the economic diversification factor, because the Canadian market for environmental products and services will be sufficiently large to be used as a test bed by companies wishing to expand into foreign markets.

An Emphasis on Security and Safety

Because of its geography and the role that it is playing on the international scene, Canada faces unusual challenges and opportunities in its approach to personal and national security. Its borders are almost impossible to defend against terrorist attacks and its transportation and communications systems are of such a scale that they are vulnerable to attacks that cannot even be planned for. The development of new technologies will be critical in addressing these challenges. There was considerable workshop discussion on the role that sensors will play in our environmental and security initiatives.

A Shift Toward a Service Industry

Canada's economy, like that of most western economies, is now comprised of 70 percent services and only 30 percent products. The services range from research and development (R&D) to post-sales support activities; a large percentage of the latter is now delivered through call centres. The concept of a vertically-integrated company, in which a product is taken from the idea stage to the production stage within the same corporate entity or facility, is now obsolete. This is having a profound effect on the types of communications systems employed in a given company.

Changing Demographics

Canada's population is aging[80] and this is having an impact on everything from school enrollment to the adoption of technologies of all types in industries and establishments. For example, the healthcare industry is very information-intensive, but many older healthcare workers are uncomfortable with advanced ICT systems in general and with wireless systems in particular. On the other hand, the country's younger dentists are adopting

80 2001 census data show that the median age of Canada's population reached an all-time high of 37.6 years, an increase of 2.3 years from 35.3 in 1996. This was the biggest census-to-census increase in a century. Statistics Canada (May 1, 2007).

advanced patient record systems because they recognize the economic payback that can be achieved through the adoption of such technologies.

6.2 The Relationship Between Socio-Economic Factors and Product, Market and Technology Drivers

Figure 10 shows the relationship between the above socio-economic factors and the product, market and technology drivers as they apply to the three applications areas, namely intelligent transportation systems, systems integration, and mobile multiplayer gaming.

The product drivers refer to the product characteristics that are likely to have a strong influence on a customer's desire to purchase the product. The term 'product' is assumed to include a service, where appropriate.

The market drivers refer to a combination of forces that are likely to play a major role in a purchasing decision. As stated in the last chapter, a market is defined by the customers who buy the product. More specifically, it refers to 'a group of people or institutions with a common need and the ability and willingness to fulfill that need.' Since a primary objective of this roadmap project is to outline a vision for the Canadian wireless industry, such markets will refer to foreign as well as domestic customers in the three application areas under discussion.

The technology drivers are the technology-related forces that are likely to be influenced by new developments in related technologies, both in Canada and abroad. Technologies are assumed to be made up of tangible technologies like engineering prototypes, algorithms and intellectual property (e.g., patents) as well as intangible technologies like know-how and show-how.

Figure 10 identifies the product, market and technology drivers that are likely to apply to the three application areas. It also shows an 'other' category of drivers to accommodate factors that do not fit in any of the other three but are specific enough to the wireless industry that they do not qualify as socio-economic factors. The main purpose of Figure 10 is to provide a framework for documenting the major inputs from the various workshops.

Figure 10: Major Socio-Economic Factors and Drivers Impacting the Application Areas

Socio-Economic Factors

Economic Diversification

Cleaner Environment

Security and Safety

Changing Demographics

Service Economy

Product Drivers

— ruggedness, in both hardware and software
— ease of use
— interoperability
— serviceability
— language commonality
— network flexibility
— network latency
— web-based system access
— reliability / availability
— security
— low cost
— brighter/better displays
— multi-tasking

Market Drivers

— aging infrastructure
— security of information
— personal security
— need for real-time information
— higher level of urbanization
— trend toward privatization of public goods
— multimedia capability (MP3, JPEG, etc.)
— high cost of systems upgrades
— high definition movie storage
— IP compatibility
— product waste and disposal

Technology Drivers

— 4G will encompass many more technologies
— standards know-how
— systems know-how
— pool of RF expertise expanding
— software-defined radio
— ability to understand customer requirements
— encryption
— efficient bandwidth utilization
— pixel engineering (includes efficient screen usage)
— power source design (battery improvements not keeping up with demands)
— Moore's Law will apply until about 2020

Other Drivers

— risk capital
— standards / regulations
— globalization
— more bandwidth becoming available
— social attitudes toward technology
— industry maturity

Just as the various drivers will have different levels of importance in the development of this roadmap, the same will be true of the socio-economic factors that influence those drivers. However, it is safe to predict that the increased emphasis on economic diversification will figure more prominently than all the others. The drivers that are related to this factor will have applicability in nearly all of the areas and in the products, markets and technologies. The availability of risk capital is one such example. The way in which Canada's high-technology industries will be financed will likely change dramatically in the next decade.

For example, the country's pool of buyout capital has been expanding in recent years, and this could offer Canadian investors and entrepreneurs more liquidity options than are currently available. The most common option has been to sell the enterprise to a foreign buyer at an early stage. The availability of Canadian pools of buyout capital could mean that more companies will reach maturity with Canadian management teams in place. This would not only provide more opportunities for strategic decision making in Canada but it would offer more receptor capacity for Canadian technology. The emergence of two or three more companies like RIM could have an impact on everything from career decisions on the part of high school graduates to risk taking on the part of entrepreneurs.

6.3 Responding to the Drivers

The roadmap outlined in the next chapter will become a reality only if Canada responds effectively to the drivers identified above. The remainder of this section will discuss some of the key drivers and make recommendations on how the various players should respond to them.

Intelligent Transportation System Drivers

In this application area, all three types of drivers (i.e., product, market and technology) will be important, but the market drivers will dominate. Since most of the customers are likely to be in the public sector, the decision-making process could be slow and the selling costs high. While issues like battery life are not likely to be as important as they are in the gaming applications, latency issues are likely to be just as important. This is also one of the markets where there will be a strong resistance to switching over to new systems because of the costs and delays involved.

The continued urbanization of Canada and its reliance on immigration for population growth will mean that all major cities will rely more and more on public transportation systems. Most immigrants settle in our large urban centres and they rely heavily on mass transit. The emphasis on a cleaner environment will also mean more spending on public transportation systems. The ITS drivers will be heavily influenced by the 'security and safety' and 'changing demographics' socio-economic factors.

Companies wishing to supply products and services into this application area will find many excellent sources of product, market and technology information. For example, the federal government maintains an Intelligent Transportation Systems (ITS) Plan for Canada that gives a balanced perspective on how various technologies are being exploited in Canada's transportation industry and are likely to be exploited in the future. What is striking about the plan is the extensive use that is made of wireless technologies in such areas as toll roads and fare collection systems. A major force in the planning process has been the ITS Society of Canada, a non-profit, incorporated partnership of private and public sector professionals. Its membership includes 200 corporations, individuals, and researchers.

Most of the product, market and technology drivers shown in Figure 10 are self-explanatory and will not be discussed in detail here. What will be more helpful to the suppliers of the physical, financial and human resources necessary to pursue ITS applications is a distillation of those factors (and the identification of others) into information that they can use in their planning processes. The first thing they should understand is that ITS expenditures are driven by what are usually referred to as 'infrastructure' expenditures. Such spending accounts for a very large percentage of budgets at all three levels of government ($15 billion annually at the municipal level), and they are relying more and more on technology to preserve and upgrade their infrastructures. An awareness of infrastructure funding trends and mechanisms would constitute a good response to the ITS market drivers.

Sophisticated sensors of all types are being used to maintain the health of bridges, highways and high-profile structures such as the CN Tower and the Confederation Bridge that links New Brunswick and Prince Edward Island. At the same time, governments are seeking partnerships with the private sector for the development and maintenance of such systems. It is for this reason that the 'availability of risk capital' is shown as an ITS product driver in Figure 10.

GPS is one of the newer technologies that can be applied more extensively to ITS applications. It can be used to provide better information on the movements of public vehicles (fire, police, ambulance, etc.) than is possible with traditional radio communications systems.

Canada has been a leader in the design, manufacture and marketing of mobile data terminals for use in taxis, delivery vehicles and police vehicles. Opportunities exist to introduce a totally new generation of such systems that would provide a wide range of in-car wireless services, not only to the vehicle operators, but in the case of taxis, to customers as well. Television and shopping information are examples of such services. Real-time fleet management is another area in which Canadian companies are enjoying some success. One application involves the downloading of vehicle information to a collection point at the end of a day's operations.

To summarize the discussion on ITS as an application, it is an area that will attract significant amounts of public funding, that lends itself well to the application of wireless technology, that will encourage public/private partnerships and will present new opportunities for investments at all levels of the investment spectrum. Funding is critical for cities. While they are major engines of GDP growth, they already face challenges in maintaining essential infrastructure. The whole issue of funding has yet to be resolved.

Systems Integration Drivers

The focus groups identified the need to develop a systems integration expertise that would allow hardware and software to be treated as modules that could be configured to enhance the adoption of wireless devices. The specific Canadian application area identified for this initiative was healthcare because there is a huge market need to integrate healthcare records to create a comprehensive electronic patient file system. In addition to better administrative systems, there is also a need for software systems that would address the real-time needs of the healthcare system, namely better access to laboratory results (x-ray, biochemistry, etc.), better tracking of medication, and even the use of models for diagnostic work.

As stated previously, Canada's adoption of wireless technologies in the healthcare field has lagged behind that of many other countries, specifically the United States. There are many suggested reasons for the lag, such as the lack of privatization in the Canadian healthcare system and the older demographics of Canada's healthcare professionals that has already been discussed. These factors are changing and the direction of change suggests that we are on the verge of significantly increased spending on electronic patient and wireless systems in our healthcare facilities.

The increasing privatization of public goods was identified earlier as a market driver; its impact is significant in this application area because it means there will be an increased emphasis on efficiency of healthcare delivery. A way to do this is to save/make money and improve patient care through enhanced communication of medical information. Systems integration and electronic patient file systems will do this by reducing medical errors, increasing the accuracy of data, and increasing the efficiency of healthcare personnel. The cost of medical errors to Canada's healthcare system should not be overlooked. Besides the unfortunate impacts on patients, the cost to the system is huge, and if wireless technologies and electronic patient file systems can be combined with medication management systems, the benefits to Canada and Canadians will be enormous.

In the United States, it is estimated that a typical hospital has more than 200 different information system applications, few of which work together. Moreover, about 70 percent of healthcare transactions are paper-based. As Canada's healthcare industry transitions from paper to electronic medical records, healthcare delivery itself will become increasingly mobile through the use of wireless technologies and devices.

The adoption of electronic patient files would allow Canada to play a major role in the new field of pre-hospital electronic patient care reporting. The statutory regulator of pre-hospital emergency care in Ireland has commissioned the deployment of a 'rugged' mobile tablet PC solution. It records and transmits pre-hospital emergency care patient and incident data in real time from point-of-patient-contact to emergency departments. Paramedics are able to communicate patient care data seamlessly to a hospital emergency department after making contact with a casualty. Because they have prior information about incoming patients, healthcare professionals can begin treatment as soon as the patient arrives.

Consider the inefficiency of current Canadian practices when it comes to hand-off of the patient by the ambulance crew. In a traditional paper-based system, carbonized standard forms are used by paramedics to manually record patient details and interventions administered during the care episode. Where possible, this data is written during transit, but it often involves follow-up by paramedics where details are incomplete. Originals of the forms are handed to the emergency department upon patient handover. At the end of the ambulance shift, the copies are returned to the ambulance depot, where they are aggregated for electronic data entry either by scanning or manual input.

Security of information was mentioned as a market driver; it will be a significant one in this application area. The protection of highly confidential patient information in the mobile environment will be demanded by the market and a Canadian capacity in the security area will evolve. As indicated in Figure 10, 'standards/regulations' was identified as an 'other' driver. It is one that becomes very important when a business enters the 'mature' phase of its growth and therefore applies to all three of the applications areas. It is also one that is closely related to the 'security of information' driver that is shown as a market driver, because such security will be heavily dependant on the existence of standards and regulations. This relationship between security of information and standards and regulations will exist in all three application areas but is very obvious in the area of healthcare systems.

With wireless technologies and electronic patient file systems, a variety of healthcare professionals, including administration, stand to benefit from improved access to information at the bedside and other points of patient care.

Mobile Multiplayer Gaming Drivers

There are several market drivers that impact the adoption of multiplayer mobile gaming in Canada. The main ones are the behaviours of the three major market participants in this application area, namely: mobile network operators, mobile gaming consumers, and mobile game developers. The drivers in this application area will be heavily influenced by the 'service economy' socio-economic factor.

Canadian mobile operators (i.e., the wireless carriers) have significant sunk costs in their current technologies and, as has been discussed previously, switching costs are always significant. There has been a reluctance to promote multiplayer content, as it will mean changes to billing plans, and there is the issue of who certifies that the software is 'OK' for the network.

Canadian mobile game consumers are different from at-home gamers. The fundamental difference is that mobile gamers tend to be casual gamers whereas at-home gamers tend to be the hardcore gamers. This greatly impacts the market size and overall market opportunity in Canada.

Canadian mobile game developers face significant development costs. Mobile networked games are much more difficult to develop and hence much more expensive to bring to market. The complexity of the interactions and the sheer number of tests to implement and verify are driving up development and testing costs. Add to that the market of casual users, and it makes viability difficult, at least initially. There are many Canadian companies internationally recognized in the game development industry for the PC or other platforms. However, the large companies are more cautious, and the small ones, which traditionally assume greater risk to bring innovative titles to market, typically have a difficult time convincing mobile operators to deal with them.

What the above discussion reveals is that mobile multiplayer gaming can succeed in Canada when it is tailored to casual users and addresses the concerns of the mobile operators and game developers.

Perhaps the single most important product driver for this application is adequate network performance, which is related to network latency, the time between sending a request and receiving a response. No one wants to see a delay in their game play, which means that the game must allow for latency in both the game design and the software architecture.

Another product driver is screen resolution. While resolution is increasing, it is barely keeping pace with shrinking screen sizes. With more players, more pixels are needed, which means that the whole field of 'pixel engineering' (as some in the workshops referred to it) becomes very important.

The workshops also identified a 'robust user interface' to be a key product driver in this application area. Such a user interface would have to incorporate a touch screen, be configurable and be as user friendly as possible.

Canada's strong capabilities in human factors engineering and user interface design engineering imply that this product driver can be exploited by Canadian researchers/ companies. There are several positive trends which can be leveraged to further develop Canadian capacity in this area. First, there are several small companies in the user interface design field with internationally-recognized capabilities. For example, there are several Ottawa area firms which were created when Nortel made the decision to close its internal human factors engineering (HFE) unit several years ago. Second, Canada has significant research strength in the area of HFE and related fields; several universities are active in this area as are the National Research Council's Institute for Information Technology (NRC-IIT). Precarn has been particularly active in supporting Canada's research activity in this area. Furthermore, Canada's multilingual heritage provides an opportunity to exploit cultural richness in creating unique technologies. This is important because, as stated previously, 98 percent of the wireless market is outside Canada.

Several product drivers can be grouped under the term 'a need for community.' This refers to the fact that many mobile users seek a high degree of community from the games that they play on their devices. Such product features as buddy lists and in-game chat capability will be required. Recommendations from friends are the biggest driver in mobile device and game purchase so these features will be demanded.

The workshops also identified a market driver of 'product waste and disposal.' Increasingly, consumers want products and product packaging incorporating efficient use of materials (even recycled materials in appropriate cases) and seek environmentally benign disposal. For mobile gaming, there is disposal of batteries, displays, plastics, etc. in the handheld products as well as the whole handset itself.

Chapter 7: The Technology Roadmap

This chapter is organized into four major sections. This first section lays out the chapter plan. The second section presents a summary of the major constraints that will dictate the pace and shape of technology developments over the roadmap horizon, 2006-2016. The final sections present the wireless technology roadmap.

This roadmap differs significantly from traditional ones. First, the Steering Committee approached the task from a human resources perspective. The objective was to understand how selected *applications* of wireless technology would unfold in the real-world context of powerful social, political and economic forces that mold technology's *potential* into products, companies and jobs.

Consequently, the roadmap is focused on three specific application areas as opposed to a wireless industry overview (or a portion thereof). Figure 13 refers to the ITS application area, Figure 14 refers to the systems integration application area, and Figure 15 refers to the mobile multiplayer gaming application area.

These three applications roadmaps list the key product, market and technology drivers and the responses that Canada should take to the drivers as a group if it is to achieve the vision outlined in the vision statement. As a result, the issues in this roadmap (see Figures 13, 14 and 15) are not limited to technology; they include HR issues, key external factors and success indicators that will apply to the strategic initiatives that are implied in the roadmaps.

7.1 Major Constraints

Regulation (Politics)

Spectrum shortages are expected by 2016. The fundamental problem (see Chapter 4) is that the regulatory framework is a legacy from the first global wireless industry (1906-1956).

Prime spectrum, the one percent of all frequencies that lie below 3 GHz, is in short supply. These frequencies are prized for their ability to penetrate structures like buildings and trees as well as atmospheric conditions like rain. The bottom line is that legacy allocations of spectrum are entrenched and new uses for prime spectrum are systematically starved as a result.

Canada is constrained from independent action because spectrum regulation is international in character. In particular, most of Canada's population lies within 100 km of the U.S. border – a short distance in radio terms – compelling us to find common solutions with our U.S. neighbours.

Standards (Industry Politics)

Standards are the product of lengthy industry negotiations in which players try to influence the outcome to favour their own technology. The result can be to delay standards and the improvements they bring. For example, efforts to agree on 802.11n, designed to increase WiFi range as much as four times and yield up to a ten-fold increase in theoretical speed by applying MIMO, began in January 2004. While progress has been made on draft 2.0 of the standard, as of April 2, 2007, "there are still 3,000 comments to be addressed."[81]

Industrial Structure (Economics)

The carriers are major players in bringing wireless services to consumers. Industry consolidation has meant fewer, larger public companies. This consolidation has spilled over to suppliers with mergers (e.g., Nokia-Siemens) and acquisitions (e.g., Nortel's sale of its 3G unit to Alcatel). Fewer, larger suppliers lessen innovation. Fewer, larger public companies make it less likely they will take balance sheet write-downs in favour of investments in new network equipment. While 3G networks are expected to be in service for ten percent of the global subscriber base in 2007, there are already concerns that it will "not be able to meet the performance required for future multi-media, full-motion video and wireless teleconferencing."[82]

A related concern is the structural impact of globalization. In the new world of globalization, large vertically-integrated companies are now spread across multiple national borders. The old miniature replica model in which national subsidiaries covered the entire range of business from concept through to commercialization is gone. Subsidiaries now concentrate on a specific function like R&D or production. The large vertically-integrated companies that served as an effective training ground for young graduates are no more. This is problematic for Canada's ICT sector that is overwhelmingly comprised of SMEs. The result: "Everyone is looking for hires with five years of experience."[83]

[81] "Wireless Networking Standard 802.11n Nears Completion," *Design News* (April 2, 2007).

[82] "4G – Beyond 2.5G and 3G Networks," www.mobileinfo.com (Oct. 2, 2006).

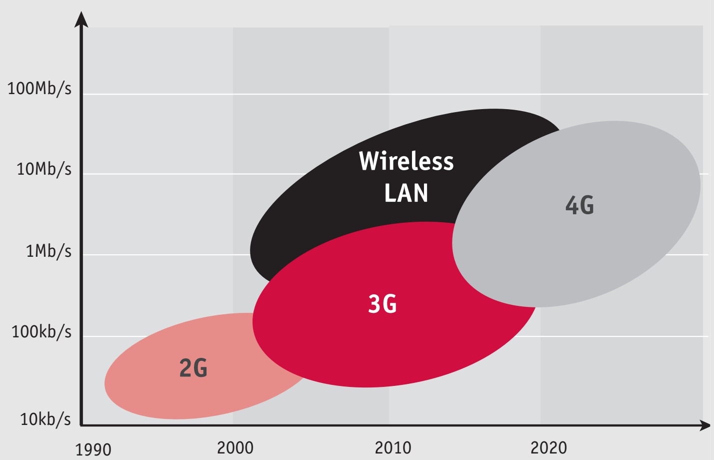
[83] A recurring theme in the focus groups.

Wireless Technology

Integrated Circuits[84], the lowest level of wireless systems, bring potential processing power that is increasing at 58 percent CAGR[85] measured as their increasing complexity (density of logic transistors). However, the engineering productivity to design these circuits (number of transistors/month) is only increasing at 21 percent CAGR, reflecting the inability of software design tools to keep up with Moore's Law.[86]

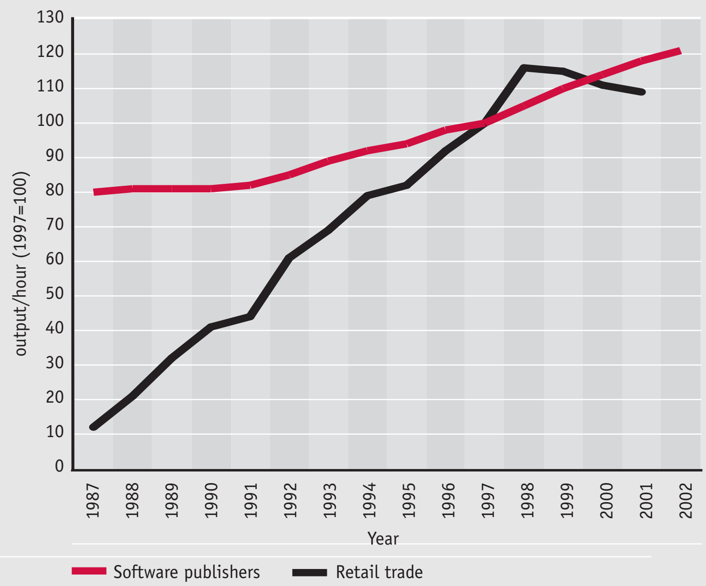
Wireless Networks, the highest level of wireless systems are advancing in data transmission capacity at 46 percent CAGR.

Figure 11: Network Data Rates



However, this projection of network performance is heavily dependent on software. Some of the most promising advances in wireless technology like MIMO, intelligent radio, software-defined radio, sensor data fusion, and spread spectrum rely on software. The problem is that software is struggling with process innovation, a critical element in the third phase of the technology lifecycle (see Chapter 2). This is illustrated in the following figure[87]:

Figure 12: Software Progress vs. a "Slow" Sector (Retail)



Software is the soft underbelly of wireless technology. It delivers more and more of system functionality. Moreover, wireless network data applications – dependent on systems integration – are critical to replace carriers' falling voice revenues if they are to generate the funds necessary to invest in 4G.

In summary, wireless does not present any significant bottleneck over the period 2006-2016. Skilled people, better software process methodologies, carrier economics and regulation are the most imminent problems in realizing the applications objectives of ITS, systems integration, and mobile multiplayer gaming.

7.2 The ITS Roadmap

This application area evolved out of what was referred to as sensor networking. The Steering Committee felt that a focus should be placed on intelligent transportation systems because they rely heavily on sensor networks and because Canada already has some industrial strength in this area.

[84] International Technology Roadmap for Semiconductors.

[85] Compound annual growth rate.

[86] Moore's Law is the empirical observation made in 1965 that the number of transistors on an integrated circuit for minimum component cost doubles every 24 months. It is attributed to Gordon E. Moore (born 1929), a co-founder of Intel. Although it is sometimes quoted as every 18 months, Intel's official Moore's Law page, as well as an interview with Gordon Moore himself, state that it is every two years.

[87] Based on an interpretation of a graph prepared by Mary Poppendieck, (see http://www.noctilucent.org/blog/archives/2004/02/chad_talk_incre.html).

Another reason is that it is likely to be a high growth area. The annual worldwide market for ITS products and services is projected to be $90 billion in 2011, and the total Canadian share of that market is projected to be $4.7 billion. An example of an application in which wireless technology plays a key role is toll roads. Following on the heels of Highway 407 in the Greater Toronto Area (GTA), two toll highways have been built in Atlantic Canada and more can be expected in all of the country's metropolitan areas.

A wireless application that was pioneered in Canada is a smart card fare box collection system that employs contactless proximity cards used by passengers to transfer fares and travel information to an automated database collection system. Because such a card can be used to pay for parking and library fees, it has been renamed the 'combo card.'

Of the drivers listed in Figure 13, software expertise (a technology driver) is the most important. As was stated in Chapter 3, software development is still more of a 'black art' than a true engineering discipline, and the forces of globalization will make it increasingly difficult to manage because the R&D function is typically distant from the production and distribution functions.

7.3 The Systems Integration Roadmap

A fact of life in the Canadian wireless industry is that the average company relies heavily on the supply of hardware and software components that have been developed elsewhere. Such components must be integrated into a system in order to provide a solution to a customer's needs. Like software, the integration process is more of a 'black art' than an engineering discipline and takes on new dimensions when the components are custom engineered as opposed to being off-the-shelf. A technology roadmap for the systems integration application area is shown in Figure 14.

The software-as-a-black-art issue will figure prominently as an impediment to the building of a strong Canadian capability in this application area. A key success indicator will be the emergence of several companies that would be the wireless (or ICT) equivalent of SNC Lavalin. SED Systems of Saskatoon is an example of such a company.

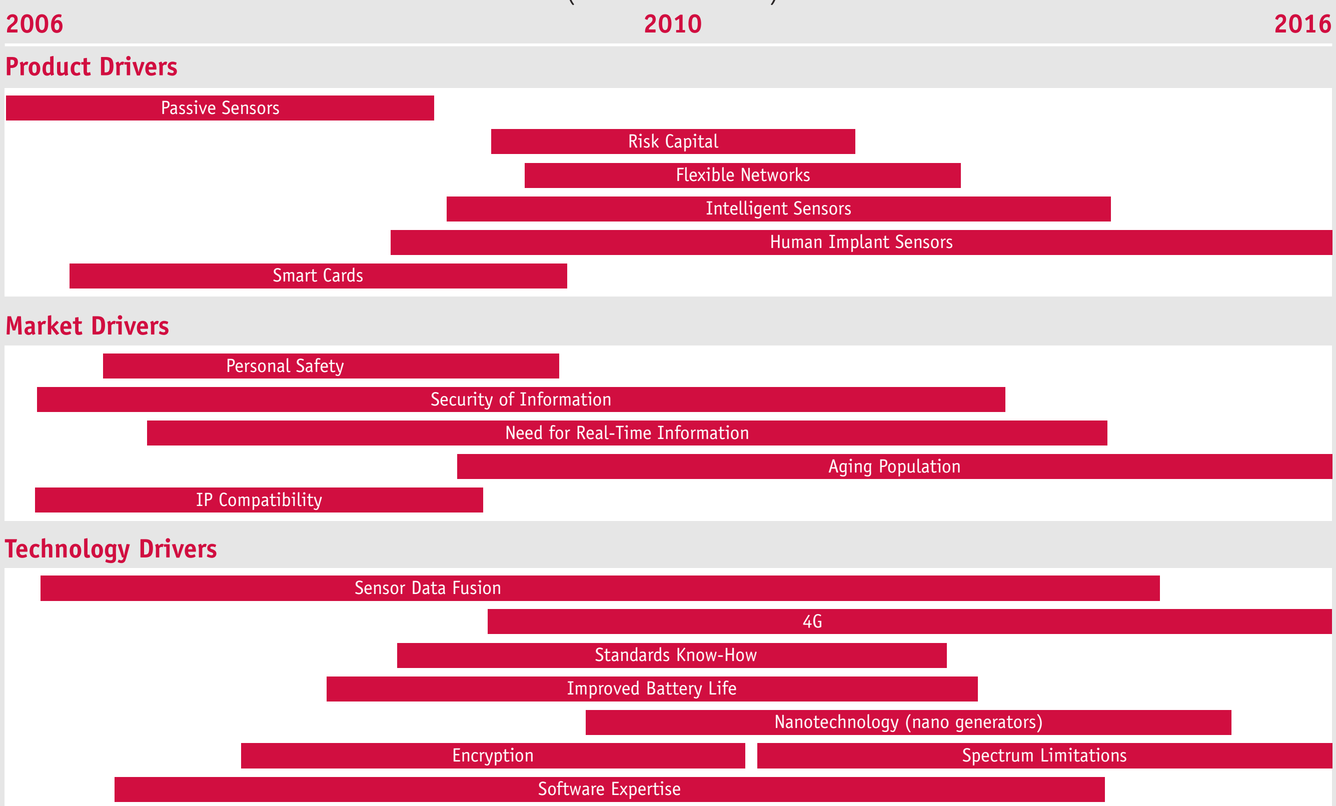
7.4 The Mobile Multiplayer Gaming Roadmap

Figure 15 shows how the various product, market and technology drivers should come together to build a significant mobile multiplayer gaming industry in Canada over the next decade. As was stated in Section 5.3, mobile gaming is still an embryonic industry, but one in which technology advances are playing a major role. The existence of a Canadian presence in this market was one of the surprises of the regional focus groups. Because the industry is so young and because the applicable technologies are changing so dramatically, the timelines shown in Figure 15 are subject to significant change.

Figure 13: The ITS Roadmap[88]

The Vision: Canada becomes a key player in wireless backhaul systems for ITS by 2016. A 5% share of the world market is a reasonable goal. ITS should not be limited to highway systems – for example, Canada has a huge pipeline transportation system.

The Strategy: Development of an integrated HR response to exploit the product, technology and market drivers (see HR issues below).



Response to Drivers

— Encourage the formation of Canadian MNEs in response to globalization. This will require improvements in our financing infrastructure, particularly in the availability of pools of Canadian buyout capital;
— Encourage collaboration between industry groups like ITAC and the ITS; and
— Address software engineering. This is a global issue but Canadian policy makers should be aware of it.

HR Issues

— ICTC monitors skills requirements and alerts industry and academia about impending shortages;
— A greater emphasis on soft skills development is recommended to deal with complex management systems which are in turn related to globalization;
— A greater emphasis on co-op programs to accommodate the shift in corporate infrastructures brought about by globalization (e.g. large companies are not the training grounds they used to be); and
— The processes involved in career selection should be better understood. Guidance counselors play a critical role.

Key External Factors

— Transfer of R&D & Manufacturing offshore; and
— Globalization complicates the management of software development.

Success Indicators

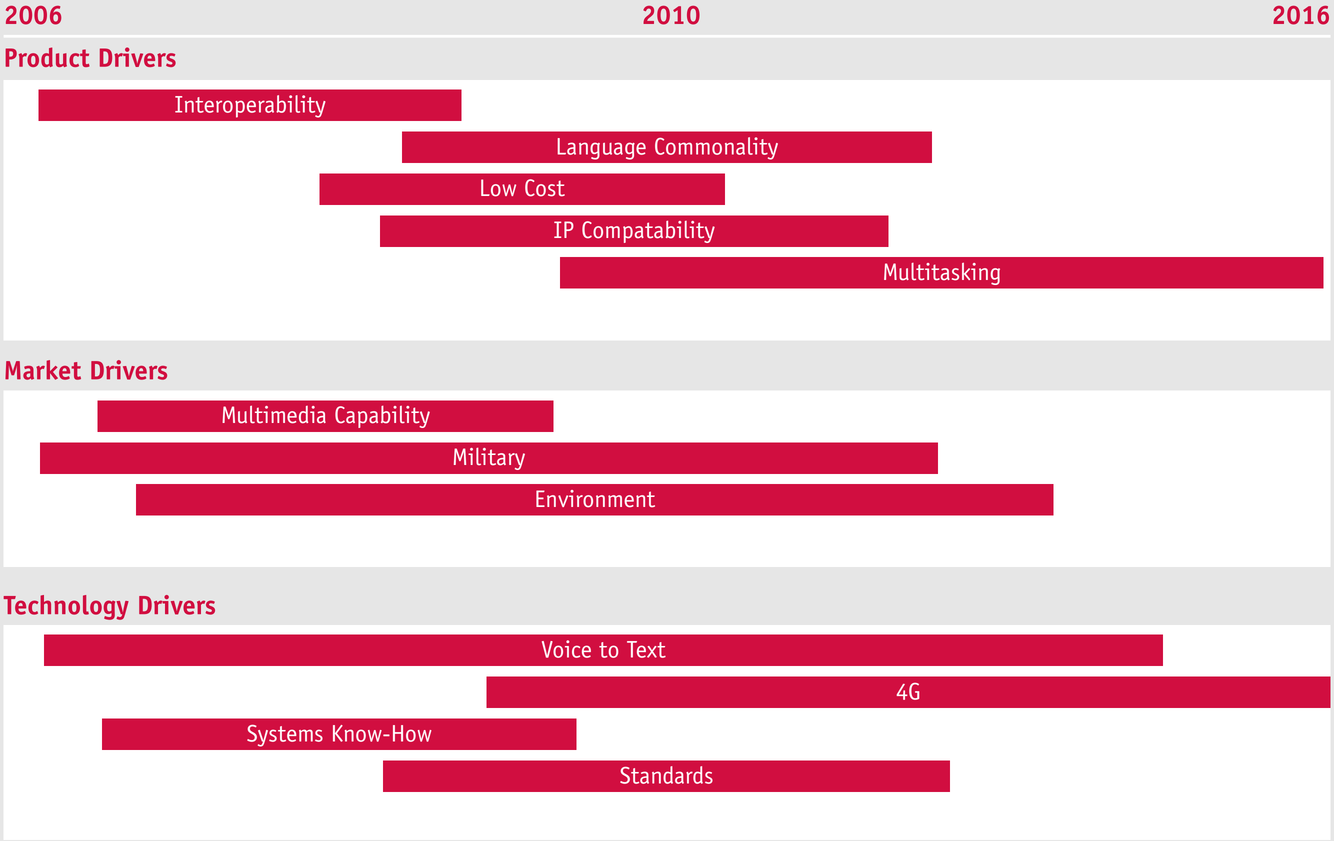
An equivalent to RIM in ITS. An equivalent to Cognos in sensor network software.

[88] The product, market and technology drivers represented by horizontal bars actually vary over time, most in the shape of a bell curve. Some, like software, rise quickly and remain at a high level.

Figure 14: The Systems Integration Roadmap[89]

The Vision: Canada develops a wireless systems integration capability on par with that of Canadian consulting engineering companies like SNC-Lavalin. Another model is the co-operation that exists between Canadian financial institutions and real estate developers (e.g., Canadian companies are large real estate owners around the world).

The Strategy: Canada encourages consortia to undertake large global contracts. This role could be played by Industry Canada, Export Development Canada, and Sustainable Development Technology Canada.



Response to Drivers

— Use government procurement to strengthen Canadian systems integration capabilities.

HR Issues

— Pursue systems integration and project management as skills opportunities.
— Establish systems to track employment in this area and to identify unique skills requirements.
— ICTC to work with Canadian Microelectronics Corporation to identify developments in systems-on-a-chip (SOC) technology. Chips are no longer purely electronic devices but include, for example, mechanical and chemical components.

Key External Factors

— Software systems integration is now being done in traditionally low-wage countries.
— Security clearance is required for both domestic and foreign contracts. Companies must develop the administrative skills to deal with issues like this.

Success Indicators

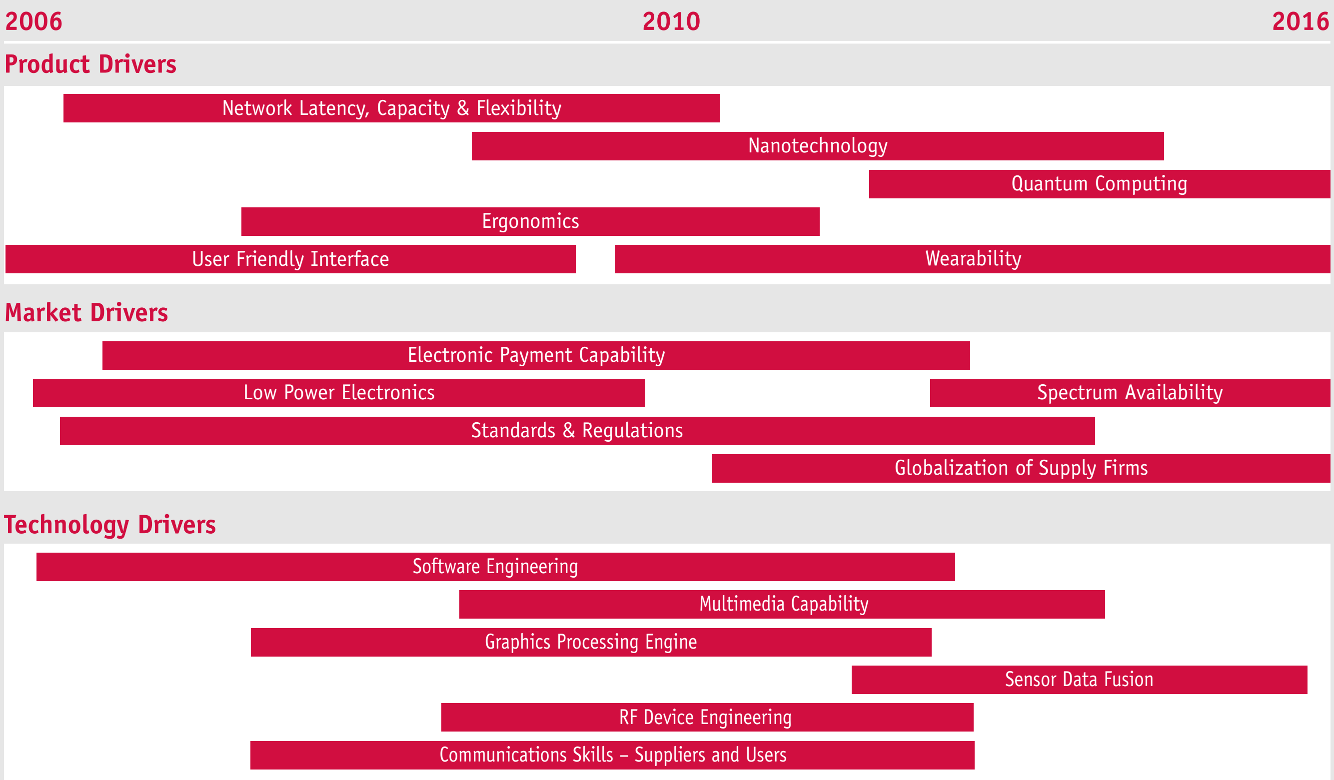
Several Canadian companies are recognized as world-class wireless systems integrators.

89 The product, market and technology drivers represented by horizontal bars actually vary over time, most in the shape of a bell curve. Some, like software, rise quickly and remain at a high level.

Figure 15: The Mobile Multiplayer Gaming Roadmap[90]

The Vision: Canada develops a strong software capability in mobile multiplayer gaming. That capability must extend from development to application to maintenance of software that is unique to the gaming industry.

The Strategy: Encourage more colleges and universities to provide mobile gaming courses, e.g. perhaps as a part of the Network of Centres of Excellence.



Response to Drivers

— An effective response to the image problem, possibly through a trade association, e.g. International Game Developers' Association, Entertainment Software Association, etc.

HR Issues

— Build on current initiatives, e.g. Laurentian University's offering of gaming courses.
— Establish a forum to compare training experiences.
— A forum should be established for the exchange of knowledge between suppliers and potential customers because it is a new field.

Key External Factors

— Globalization will have a key impact on supply chains.
— A limited Systems Engineering skills pool.
— Rapidly increasing development costs.

Success Indicators

A Canadian gaming industry equal to 5 percent of the world industry (Canada's share of high tech markets is typically 3-5 percent).

Emergence of a company that dominates one aspect of the industry (e.g., a fabless semiconductor company specializing in gaming chips).

[90] The product, market and technology drivers represented by horizontal bars actually vary over time, most in the shape of a bell curve. Some, like software, rise quickly and remain at a high level.

Chapter 8: Skills Dimension: The Bottom Line

This chapter begins with a presentation of the results of the six regional focus groups and concludes with an employer-level view of skills developments in the workplace.

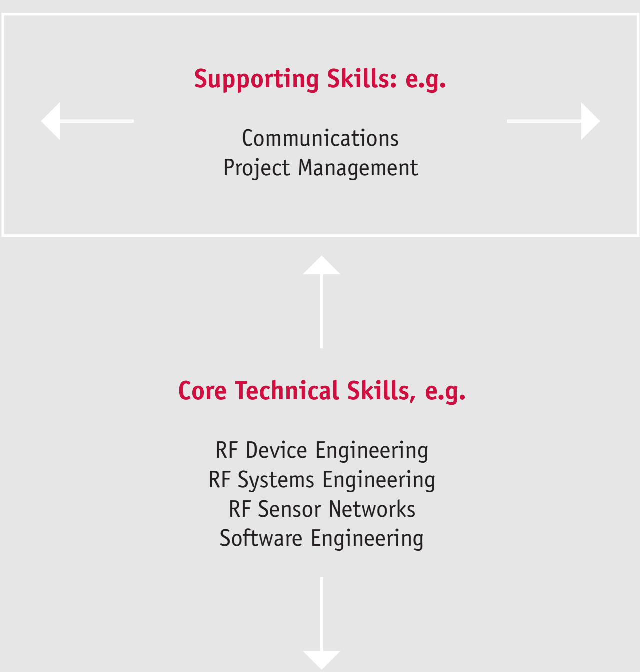
The six focus groups were an integral part of the research effort for the roadmap. All of them considered the skills issues, with the last two sessions dedicated to refining the results of the earlier groups and addressing the issue of how skills requirements could best be met. In all, over 100 industry stakeholders participated in these sessions.

Table 4: Regional Focus Groups

Date	Host	Main Topic	Location
Nov. 8, 2006	ICTC	Product/Market	Ottawa
Dec. 14, 2006	International Institute of Telecommunications	Product/Market	Montreal
Jan. 11, 2007	University of Waterloo, Dept. of Computer & Electrical Engineering	Product/Market	Waterloo
Jan. 26, 2007	British Columbia Technology Industry Association	Product/Market	Vancouver
Feb. 8, 2007	ICTC	Skills	Ottawa
Feb. 22, 2007	International Institute of Telecommunications	Skills	Montreal

The skills required for each of the three applications were grouped according to the 'T' model of skills suggested by participants at the February session in Ottawa:

Figure 16: The 'T' Model of Job Skills



The spine of the T comprises the core technical skills that are required to do the job. The crossbar details the related skills that are necessary to effectively apply the technical skills within the organization.

For each of the applications, the technological systems model (see Chapter 2) was applied to group the necessary technical job skills into four categories: radio frequency device engineering, radio frequency systems engineering, radio frequency sensor networks and software engineering.

RF Device Engineering: These are core skills that focus on the basic components from which RF systems are built: from microchips, antennas and batteries to analytical and design knowledge, like circuit layout and RF propagation needed to determine critical performance requirements. A list of these core skills and their applicability to each of the three projects is presented below.

Table 5: Core Skills Required – RF Device Engineering

Core Skills Required	Project		
	1	2	3
Radio Frequency (RF) Device Engineering			
— Analog Design	■		
— Digital Signal Processing	■		■
— Antennas	■		■
— Circuit Layout	■		■
— Device Fabrication	■		■
— Embedded Computing	■	■	■
— Shielding (e.g., for hospitals)	■	■	■
Design for Manufacturability	■		■
RF Propagation (e.g., coverage, interference, rural vs. urban)	■	■	■
— Field Analysis	■	■	■
Software-Defined Radio (SDR)	■		
Cognitive Radio	■		
Field-Programmable Gate Arrays (FPGA)	■	■	■
Display Engineering			■
— Optimization of Pixel Use			■
Photonic Switching	■		■
Device Platforms like PC, PDAs, Cell Phones, etc.			■
Power Supply	■		■
— Power Management	■		■
— Batteries (e.g., intelligent batteries, capacity, etc.)	■	■	■
Packaging Design	■		■
— Heat Dissipation			■

Note: Project 1: Wireless Backhaul for Intelligent Transportation Systems.
Project 2: Wireless Software Platform for Systems Integration.
Project 3: Wireless Platform for Mobile Multiplayer Gaming.

RF Systems Engineering: These are the core skills that are required to design, build and operate the RF networks that provide the critical infrastructure on which users of RF devices rely. This infrastructure ranges from network base stations to analytical tools like traffic analysis and spectrum issues like planning and regulation. The necessary engineering and technical know-how extend from hands-on practical skills like integration of off-the-shelf chips and prototyping, to standards like transmission control protocols and conceptual frameworks like systems and control theory.

Table 6: Core Skills Required – RF Systems Engineering

Core Skills Required	Project		
	1	2	3
RF Systems Engineering			
Base Stations	■		
Terminals	■		
Amplification	■		
Transmission	■		
Traffic Analysis & Engineering	■		■
— Bandwidth Management (e.g., spectrum efficiency)	■	■	■
Network Operations and Management	■	■	■
— Quality Assurance	■	■	■
— Risk Management	■	■	
Wireless Security	■	■	
Spectrum Planning & Regulation	■	■	■
Network Architecture, Integration & Interoperability			
— Inter-modal Interfaces	■	■	
— Transmission Control Protocols (e.g., for error prevention, detection and correction)	■	■	■
— Internet Protocols	■	■	■
— Network Access	■	■	■
— User Interfaces	■	■	■
Process Methodologies			
— System Design	■	■	
— Integration of Off-the-Shelf Chips	■		■
— Prototyping	■	■	■
— Implementation	■	■	■
— Engineering Test	■	■	■
Systems Theory			
— Process Models		■	
— Systems Dynamics & Engineering		■	
— Control Theory		■	

Note: Project 1: Wireless Backhaul for Intelligent Transportation Systems.
Project 2: Wireless Software Platform for Systems Integration.
Project 3: Wireless Platform for Mobile Multiplayer Gaming.

RF Sensor Networks: This is the newest and most specialized area of know-how. It relates almost exclusively to Intelligent Transportation Systems. There are two elements: the sensors themselves and the data treatment techniques that are essential to reducing the volume of data transmission while retaining critical information. These skills are listed below:

Table 7: Core Skills Required – RF Sensor Networks

Core Skills Required	Project		
	1	2	3
RF Sensor Networks			
Signals & Signal Theory	■		
Data Treatment Techniques			
— Data Compression	■		
— Data Fusion	■		
— Data Routing	■		
— Data Mining (e.g., pattern recognition)	■		
— Data Visualization	■		
— Data Reliability	■		
— Predictive Modeling	■		
— Encryption	■		
— Distributed Data Compression Algorithms	■		■
Sensors			
— Devices (e.g., optical, transducers)	■		
— Embedded Software	■		
— Robotics	■		
— Packaging	■		
— Design & Control	■		
— Networking & Protocols	■		
— Standardization / Interoperability	■		

Note: *Project 1: Wireless Backhaul for Intelligent Transportation Systems.*
Project 2: Wireless Software Platform for Systems Integration.
Project 3: Wireless Platform for Mobile Multiplayer Gaming.

Software Engineering: This is an area of know-how that will increase in importance over the roadmap timeframe. Across the entire platform technology of electronic systems, it has become an integral part of delivering the sophisticated functionality that end-users rely on. Its impact on skills is so great that hardware design is no longer a stand-alone activity. Systems are now developed through a process of *hardware-software co-design*.

Table 8: Core Skills Required – Software Engineering

Core Skills Required	Project		
	1	2	3
Software Engineering			
Process Methodologies			
— Design	■	■	■
— Coding & Documentation	■	■	■
— Prototyping	■	■	■
— Testing	■	■	■
— Implementation	■	■	
Java Programming	■	■	
Web-Based Systems	■	■	
Network Programming	■	■	
Databases (e.g., concurrent access)		■	
Data Packet Design	■		
Graphics Processing Engines			■
Platforms, e.g., Mobile Integrated Device Profile (MIDP)		■	■

Note: *Project 1: Wireless Backhaul for Intelligent Transportation Systems.*
Project 2: Wireless Software Platform for Systems Integration.
Project 3: Wireless Platform for Mobile Multiplayer Gaming.

Supporting Skills: These skills are no longer polishing touches on the rough diamond of technical talent: they are essential ingredients in Canada's ICT industry. A powerful theme that ran through all of the focus groups was the need for generalists whose understanding extends far beyond the specialty knowledge of a narrow technical area.

As the table below shows, management skills cut across all three applications areas. Gaming requires an even more impressive CV, drawing heavily on the arts and social sciences as well.

> "Planning a mobile game requires attention to detail and an understanding of various issues – technical, legal, social, psychological, cultural and economic – each of which affects the viability of the game."
>
> *Planning a Game Application: Forum Nokia*

Table 9: Core Skills Required – Supporting Skills

Core Skills Required	Project		
	1	2	3
Project Management	■	■	■
— Team Building (e.g., Leadership)	■	■	■
— Business/Strategic Analysis (e.g., problem-solving)	■	■	■
— Scheduling	■	■	■
— Industry Standards	■	■	■
— Environmental Standards & Laws	■	■	■
Communications (e.g., technical writing, story-telling ability, creative writing)	■	■	■
Basic Communications Law	■	■	■
Cultural Studies (e.g., differences between markets)			■
Languages			■
History			■
Visual Arts			■
Game Design			■
Cognitive Engineering (e.g., data presentation)	■		
Ergonomics			■
Industrial Design	■		■
Consumer Marketing			■

Note: *Project 1: Wireless Backhaul for Intelligent Transportation Systems.*
Project 2: Wireless Software Platform for Systems Integration.
Project 3: Wireless Platform for Mobile Multiplayer Gaming.

8.1 In Summary: The Skills Requirements

Breadth of Skills: The large range of skills required to succeed in the wireless domain is driven by important factors in the economic, technological and political environments (see Chapter 2, *The Clearing Metaphor*).

Economics, globalization in particular, is a major factor. As outlined in Chapters 4 and 6, globalization has resulted in the break-up of vertically-integrated companies into more specialized operating units like R&D, manufacturing and marketing that are located separately. Head office integrates the results across many countries.

In the old model, Canadian subsidiaries were organized as miniature replicas of the foreign (often U.S.) parent to supply the domestic market from within. While this resulted in a 'truncated pyramid,' with strategic decisions made at head office, such firms covered the entire range of operations: from product concept through to research, development, commercialization, manufacturing, distribution and marketing. This type of firm served as an effective industry training ground where young scientific and technical talent could learn the big picture.

In the new model, even billion-dollar Canadian ICT firms have been bought out and redirected into the global framework. The Canadian ICT industry is dominated by SMEs: 98 percent of the sector's 32,000 firms employ fewer than 100 people. All these firms rely heavily on experienced engineers and technicians vs. new hires. There is little room for 'green' graduates to learn about the broader value chain in their first years on the job.

Technology *itself* is the second most important factor contributing to breadth of skills. Wireless devices bridge the gap between the real (analog) world and the digital domain of integrated circuits and computers. At the level of devices, mixed-signal design (the capability to process both analog and digital signals and transform from one to the other) is a basic requirement. Moreover, interference is a given in the wireless operating environment, complicating the design task.

By way of comparison, automotive engineers do not have to worry about designing for rocks in the middle of the road. They also need not concern themselves with the details of infrastructure like road design and construction. Wireless engineers do. The specifics of wireless networks have an important bearing on device performance and design. Furthermore, fuel capacity and fuel consumption are not limiting factors for automotive engineers, whereas battery storage and power consumption are critical issues for wireless engineers. Such constraints are amplified by the personal portability that is taken for granted in the biggest global market: wireless cellular telephony.

Finally, wireless designers are faced with very different signal propagation environments in urban, suburban and rural areas. In contrast, automotive designers face no such complication with modern roads.

Politics *(spectrum regulation)* is the third most important issue in adding to the complexity of the wireless environment. As outlined in Chapter 4, looming spectrum shortages are the legacy of regulatory frameworks conceived eighty years ago when technology was significantly less advanced. Knowledge of spectrum issues is critical in planning and designing for wireless markets.

Needed Changes at the Entry Level: Participants noted many skills shortcomings that could be effectively addressed at the level of post-secondary education.

First and foremost, globalization is a reality that must be faced. The fact that more projects span multiple countries and organizations requires knowledge of other cultures. One way is language training. For example, science graduates are often required to have taken courses to acquire reading proficiency in a second language relevant to their field of studies. In another example, human resource professionals in ICT companies[91] now take cultural courses to better understand the work ethics and habits of engineers from countries like India.

The most important skill in a broader world is the ability to effectively communicate and interact with others. In particular, writing is a basic skill that technical employees need to improve. They also need to have a much better understanding of business and the realities of organizational life, from an appreciation of basic functions like finance and marketing, to leadership issues like the ability to cut to the core of complex problems and to look ahead.

More of engineering education needs to focus on foundation stones like the scientific method and basic electrical engineering. There is too much emphasis on subjects like advanced software and not enough on more fundamental knowledge that provides an understanding of the limitations of modern tools like simulations.

Knowledge at the level of a four-year engineering degree needs to focus on covering the *extent of modern value chains*: i.e., breadth vs. depth. For example, software

[91] "Cultural Training Essential in Business," *Canwest News Service* (March 31, 2007).

engineers need to understand the essentials of circuit fabrication as well as the market application. Sensor networks are a good example of the need for *systemic knowledge* that goes beyond narrow areas of specialization; such know-how stretches from wireless transmission to electronics design and from the mechanical engineering of sensors to the software engineering of algorithms for data compression. To top it off are the very different issues in systems operation vs. design and the human engineering factors of getting the right information to the right person in timely fashion. Finally, the most important shortfall in engineering education is an overemphasis on theory vs. hands-on practical work.

Many companies address the needed breadth of skills through interdisciplinary groups (e.g., RIM). Such teams further underline the need for project management skills to effectively integrate the contributions of large numbers of specialists.

8.2 Relative Importance of Specific Skills

Particular skills stood out because they cut across all three applications. These essential technical skills, as well as important supporting skills, are outlined below.

RF Device Engineering

Of the 22 skills identified by stakeholders, four were common to ITS, systems integration and mobile multiplayer gaming:

— Embedded computing;

— RF propagation and field analysis;

— FPGAs (field programmable gate arrays); and

— Power supply, batteries in particular.

The importance of software to the entire wireless sector is underlined by its recurrence in many different forms. Both embedded computing and FPGAs are critical elements in obtaining the desired functionality at the device level.

Power supply is the Achilles Heel of mobile handheld devices, with little dramatic improvement foreseen for batteries, a 200-year-old technology. RF propagation, especially the hands-on knowledge of the realities of signal transmission in dense urban environments is a foundation stone of wireless network operations.

RF Systems Engineering

Twenty-four specific skills were identified in four broad categories: network facilities; network architecture, integration and interoperability; process methodologies; and systems theory.

In the facilities category, network operations, bandwidth management and quality assurance were essential in all the applications addressed in this study. Transmission control protocols and Internet protocols were common factors in network architectural knowledge. Prototyping, implementation and engineering test were shared requirements in process methodologies.

Networks are an integral part of wireless applications and their steady build-out is a central factor in the ongoing growth of mobile wireless in the middle age of its product lifecycle.

RF Sensor Networks

This skills requirement is exclusive to intelligent transportation systems. However, sensor nets are a new and evolving field that can be expected to find broader application as they move into the early growth stage of their technology lifecycle.

Software Engineering

This is a key bottleneck in the overall advancement of wireless technologies. This is because so much of systems performance now hinges on the software. In fact, software and hardware design are no longer separate: they have merged into *hardware-software co-design*.

The process technologies of design, coding and documentation, prototyping and testing are common to all three applications areas. They directly address the vital role that software increasingly plays in all systems.

Software is a critical part of networks. The OSI model was developed by the International Standards Organization in 1984 to describe networks and network applications. In this seven layer model, the highest layer describes applications while the lowest layers describe the physical hardware: "It is essential that low level software have a long half life, since it pervades the ICT world and needs to be stable in order to support information exchange for its users. At the top end of the OSI model, application software has a short half life as it must constantly evolve to meet the changing demands of users."[92]

[92] John Visser, P.Eng., International Wireless Standards, Nortel (May 18, 2007)

Supporting Skills

Because wireless demands such a broad range of skills sets, project teams are extensively used to cover these skills requirements. Consequently, a comprehensive set of project management and communications skills – including basic knowledge of communications law – are now essential for wireless technical employees.

8.3 The Situation in the Applications Areas

The following section focuses on the specific skills challenges faced in each of the three applications areas. It is drawn from the regional focus group sessions and follow-up interviews with companies active in these areas.

The View from Intelligent Transportation Systems

Intelligent transportation systems cover a vast field in which wireless sensor networks will play a central role in addressing the transportation challenges of a highly urbanized and interconnected society. Public policy will be critical in facilitating the development of ITS technology.

Intelligent transportation systems span both the public and private domains. Road networks, mass transit, emergency vehicles and traffic management are public issues. Commuting and car ownership are private matters in which public policy will have to lead.

For example, equipping all vehicles with wireless systems is essential to implementing many of the benefits that ITS can bring. Such systems include automated crash notification, traffic management, incident management and collision avoidance.

GM's 'On-Star' system is an example of the first. This 'Mayday' system automatically connects with a call centre when drivers press a button or an airbag deploys. More sophisticated systems could transmit crash information such as collision force and angle of impact to assist emergency responders in determining what type of help to send and where to transport the injured. Already, telemedicine systems inside ambulances and medical helicopters allow physicians to direct victim care en route to trauma centres.

The solution to congestion and commuting as fixtures of everyday life will most likely be addressed by advanced traffic management systems that employ detectors, cameras and communications systems to monitor traffic, optimize signal timings on major arteries and improve the flow of traffic. For example, floating car data (FCD) utilizes the transmissions that cell phones routinely make – even when there is no voice connection – to compile an accurate picture of overall traffic flow. This leverages the existing cellular network to provide vital information to help resolve congestion.

Incident management systems allow police to quickly respond to accidents, hazardous spills and other emergencies. An integrated network and decision support software links traffic operations centres, emergency vehicles and support services to efficiently and adaptively cope with situations.

Collision avoidance systems promise to reduce the number of accidents in the first place. Intersection collision avoidance systems monitor the speed and position of nearby vehicles, alerting drivers to take appropriate action when a collision threatens. Rear-end collision avoidance systems sense the presence and speed of vehicles ahead to warn drivers of dangerous situations. Road departure avoidance systems track the lane or road edge and suggest safe speeds. More advanced systems will include adaptive cruise control linked to GPS navigation and road surface sensors (ice, water) to adjust vehicle speed.

Already, for over 100 million Americans in 28 states (as of February 2006), 511 service[93] brings ITS, traffic and incident management, public transportation and weather information together in a single access point. The goal for 2010[94] is for 511 to be operating throughout the U.S. Information on major road systems and metro areas will include travel time, construction, incidents, special events, congestion and weather. Transit information will be available on most systems: typically schedules, fares and service disruptions, along with call transfers and website links to transit agencies. Individual systems will be linked together into an integrated, seamless network. This will be public-sector supported with funds for enhancement and growth.

A related initiative is the U.S. Advanced Transportation Weather Information System (ATWIS). "It has merged technologies from meteorology, computer science, wireless communication, road weather monitoring and forecasting, and transportation into a single decision support system that can respond, adapt and disseminate information on short notice within a recurring cycle."[95] It responds to the fact that many fatal crashes occur on remote (non-interstate) highways in severe weather.

93 "ITS Technologies," www.itsa.org (April 2, 2007).

94 "American Travel Information Number, Implementation and Operational Guidelines for 511 Services," U.S. Dept. of Transportation, Federal Highway Administration (September 2005).

95 "Final Report of the Operation and Demonstration Test of Short-Range Weather Forecasting Decision Support within an Advanced Transportation Weather Information System," U.S. Dept. of Transportation, Federal Highway Administration (April 2006).

In summary, networks and standards will be an integral part of building out and integrating elements of the ITS possibilities that have already begun to emerge. As discussed at the outset of this chapter, sensors are an additional element that enters into the broad technical skills requirements that stretch from RF device engineering through RF systems, software engineering and systems integration.

The View from Software Integration

Software integration is part of the larger domain of software engineering. It is the foundation stone for the development of new software-based products and services.

Software engineering comprises "the processes, methods and tools to develop software-intensive systems in a timely and economic manner."[96] Today, these systems are rarely developed from scratch; typically they involve the extension of existing systems and their integration with legacy infrastructure. COTS (commercial off-the-shelf software) is now widely used to build systems. As a result, software development efforts are focused on configuration and interoperability.

The overall situation "is characterized on the one hand by increasing business dependence on the reliability of software infrastructure, and on the other hand, by rapid change and reconfiguration is a of business services – necessitating fast software development and frequent changes to software infrastructure."[97] It is a huge challenge to develop solutions that can be easily adopted. Moreover, 'simple' integration problems are often complex when dealing with very large amounts of data: scalability is a must.

While the challenges are clear, the solutions are not. The U.K. Foresight exercise enumerated the following challenges (among some twenty in all) that are expected to be the focus of software engineering efforts over the next 15 to 20 years:

Challenges for the Next 15-20 Years

Software Processes: Tools are needed that give a clear view of the overall development process.

Requirements Engineering: More formal specification, modeling & analysis techniques to capture the specifics of the problem domain.

Reverse Engineering: Investigation of infrastructure, methods and tools to improve the entire development process.

Testing: Development of tools & techniques to help users integrate and test components with applications.

Software Maintenance & Evolution: Improved software design to facilitate maintenance.

Software Architecture: To support dynamic combinations of software services and identify design principles to explicitly make trade-offs between factors like resource consumption and reliability.

Middleware: To support Internet-scale distribution and adaptive systems.

Security: Develop architectures and designs to integrate security and functionality requirements.

Software Economics: Develop models to analyze benefits and opportunities, costs and risks in software development.

Software Metrics: To support management decision-making during the software lifecycle.

The above is just a sampling of the themes that will drive efforts to make software design and development a true engineering discipline. Others include, object-oriented modeling, software analysis (checking conformance of code to design), software reliability and dependability, formalization of performance measurements, real-time software, databases and formal methods for safety critical systems.

In Canada, the National Research Council has led a research program into software development practices since 1994. Specific research projects address many of the issues listed above. For example, *Process Measurement and Awareness* aims to increase development efficiency by extracting software process knowledge from real-time software development efforts. The *Human and Social Aspects of Software Development* investigates both individual and group development efforts in order to improve tools and processes in software engineering.

The Council's *Integration and Interoperability* program aims to understand the techniques and processes of constructing systems from pre-built software elements. Currently, there are three projects:

Software for Science is developing techniques to integrate the software and information systems used in scientific

[96] "Information, Communications & Media (ICM) Panel," U.K. Foresight Program (2002).

[97] Ibid.

research for the generation, analysis and reporting of results for experiments. These techniques will support the integration of IT resources to provide proper design, configuration management, testing and maintenance – for use by non-software professionals.

Systems Acquisition deals with the process of writing requirements, evaluating proposed software and its integration architecture – for purchasing software intensive systems that are built by integration.

The *Business Rules Recovery Project* addresses how to move business rules from legacy systems to COTS-based systems. In fact, the problem is difficult and largely unresolved.

Moreover, NRC is working with the U.S. Carnegie-Mellon Software Engineering Institute (SEI). The SEI was founded in 1984 to advance the practice of software engineering. It most recently received a US$411-million contract to continue its long-standing efforts in software R&D to support national defense needs. It is best known in the software development community for its *Capability Maturity Model*.[98] This defines five levels of proficiency in software engineering based on a TQM[99] approach. The overall state of software engineering is best illustrated by the fact that most organizations are at the two lowest levels of proficiency.

The NRC Institute for Information Technology (IIT) also works with *The Consortium for Software Engineering Research* (CSER). The CSER was founded in 1996 and is supported by NSERC and the software engineering sector. CSER university investigators are heavily involved in the creation and advancement of software engineering programs. To date, more than 20 courses have been created or significantly modified as a result of CSER experience.[100]

Currently, formal university Software Engineering Programs "require expertise in data management, design and algorithm paradigms, programming languages, human-computer interfaces and digital hardware system. It also demands an understanding of and appreciation for systematic design processes, non-functional system properties (e.g., economy and time-to-market) and large integrated systems."[101]

The View from Game Development

Looking Back

Five years ago, the Canadian industry was just beginning. The focus was on getting a basic product out the door. From concept to launch, the whole process for a typical casual game took three or four months. Development teams were small, anywhere from three to ten people, many of them focused on optimizing the game to live within the constraints imposed by the handsets and networks of the day.

The fact that games are not stand-alone products has meant that developers have always needed to understand the technical details of handsets, networks and interfaces – and to design their products accordingly. For example, the limited memory of cell phones has meant that games are small: currently 250 to 300 kb is tops. The network transmission capacity keeps game size down as well; a rule of thumb is that customers expect to download games in no more than a minute.

Handset makers have understood the value of games in enhancing their products. As a result, they have begun to facilitate game development, offering their own interfaces and multiplayer technologies. For example, Nokia's *Snap Mobile* team supports multiplayer gaming. They provide developers with a wide variety of time-saving tools and documentation, including technical support. The objective is to allow developers to focus on game play vs. communications technology issues. As the gaming market evolves to become an important segment, cell phones specifically designed for gaming have appeared, e.g., *Nokia's N-Gage*. In fact, gaming is already (2006) a US$2.4-billion global market with over a 25% compound annual growth rate (CAGR).

> "Mobile gaming is still in its embryonic stage."
>
> *Kamar Shaw, Head of Industry Marketing, Nokia*[102]

Cell phone makers clearly understand the promise of mobile gaming. However, their enthusiastic participation has meant a huge increase in the number of devices that game developers must support: from about 50 to 100 devices five years ago to 600 to 700 devices now. The

[98] Since upgraded to the CMMI (Capability Maturity Model Integration).

[99] Total quality management.

[100] www.cser.ca (April 2, 2007).

[101] "Software Engineering," University of Waterloo, www.math.uwaterloo.ca (April 2, 2007).

[102] http://www.spillgroup.com/news/2006/09/6046.html (Oct. 27, 2006).

game developers must also offer their products in 5 to 10 languages: for example, about 98 percent of the market for Canadian game developers is export.

One advantage for Canadian developers is our limited number of national carriers: three. Otherwise, supporting this growing market is daunting: "There are too many standards, carriers and devices."[103] The good news is that game developers find that communications with Canadian carriers have improved in recent years. Game developers are also interested in partnering with handset makers to benefit from their innovative ideas.

Looking Forward

As older handsets are replaced, the dramatic increase in the number of devices that game developers must support will slow significantly. The ongoing consolidation of both carriers and their suppliers will also help moderate the number of standards.

However, the sophistication of game developers' products will continue to rise, fueled by expectations of more powerful and more realistic games – led in part by the example of PC-based games. In fact, game developers judge that PCs are about five years ahead of cell phones in terms of computing power. A look at what *PlayStation* or *MP3* games can do today foreshadows what handset games should easily achieve by 2010-2012. The game developers point out that their games have accomplished in the past two years what PC games took five years to do: mobile technology is moving rapidly.

Now, 3-D graphics and writing the software to support it is an important issue for game developers. The handset hardware is evolving to allow the processing of game data in real time and further supports 'physics' programs that capture the realistic behaviour of moving objects. These games will be bigger, too: 3-5 mb vs. 250-300 kb currently.

The result is that the product development cycle is longer, about six to nine months from concept to launch, double what it was five years ago. A common theme is bigger development teams with more animators and artists and stronger game design. By way of comparison, the development team for a PC-based game is now 20 to 35: a glimpse of what is coming. The five main job categories are: production, design, arts, programming and testing, with programmers (20:1) and artists (10:1) outnumbering game designers and producers. Like all software products, the testing requirement will increase significantly with the size of the game.

Overall, the game developers see wireless handsets becoming a central point in users' daily lives for communications and the need for light diversion with casual games. The early adoption period is over; their sights are now clearly set on the mass market. A recent survey (June 2006)[104] agrees:

> "45% of the people who play games on their mobile phones are playing online multiplayer games at least once a month. And 20% of gamers play online every week."
>
> *Neilson Entertainment*

[103] Montreal Regional Focus Group, February 22, 2007.

[104] A global study of 1,800 mobile game players in the United States, China, India, Spain, and Thailand http://snapmobile.nokia.com/core/en/developers.html (April 3, 2007).

Chapter 9: Conclusion

We begin by summarizing the major findings of the ICTC Wireless Technology Roadmap. This is followed by our recommendations on how the results of this first of a new kind of roadmap, can best be utilized to meet the human resource needs of industry. We conclude with a summary of the results of the stakeholders' meeting (May 15, 2007), organized by ICTC to validate this report and begin the work of building the wireless skills needed in the coming decade.

9.1 The Roadmap in Summary

Wireless technology is entering middle age. Almost four decades have passed since Motorola first demonstrated its landmark wireless cell phone technology in New York City. Mobile cellular service is still the dominant application, in 2007 it represented a worldwide market of over a half-trillion US$. To put cellular into perspective, the next three applications combined represent less than 10 percent of this market. The remaining applications, all told, represent less than 5 percent.

Table 10: World Wireless Applications in Perspective[105]

World Wireless Markets

Application	Most Recent	
	Year	$10^9
World Mobile Services	2004	454.00
World Telecom Equipment	2003	300.00
Mobile Entertainment	2005	17.60
Mobile Healthcare	2006	16.40[106]
Location-Based Services	2003	13.00
Machine-to-Machine Comm.	2005	6.00
Satellite Communications	2004	2.70
Fixed-Mobile Convergence	2006	2.50
Mobile Gaming	2006	2.40
Mobile Internet Access	2005	2.40
Communicators	2006	1.75
Fixed Wireless Broadband	2006	1.50
NFC	2006	0.75
RFID	2006	0.55
Mobile Device Management	2004	0.50
Smart Dust	2006	0.25
Smart Cards	2002	0.15
IPTV	2005	0.05
IP Multimedia Subsystems	2006	0.00

In this phase of the technology lifecycle of the second global wireless industry (2004-2024, see Chapter 3), innovation has significantly shifted from product to process innovation. In this later growth stage, the dominance of process innovation is driven by the relentless pressure of serving mass markets at increasingly competitive prices in the context of single-digit growth. Sustained double-digit growth has shifted to developing markets.

In the advanced economies, the tightening straightjacket of established practices, reflected in the importance of standards and regulation all anchored by the existing infrastructure of large public companies, further steer innovation in the direction of incremental product improvements. The technological systems needed to fully exploit wireless applications are dependent on *process innovation and increasingly on critical inputs from younger areas like software*. In the later growth phase, the bottom line is that the industry's greatest economic potential lies more in the modification and tailoring of existing products and services than in the introduction of disruptive technologies. This is a period of modest but steady growth as dominant applications are fully built out to reach maximum market penetration. The spillover of declining costs opens up new applications that can expand rapidly, but are relatively small compared to the dominant market.

Of the applications selected for this roadmap, *systems integration* squarely addresses the dominant mobile cellular telephony market. As operators' voice revenues continue to decline (see Chapter 3), data applications will become ever more important in filling this gap. The ability to seamlessly integrate multiple applications on mobile devices is critical in serving the fast growing data market:

> "The mobile phone is fast becoming the nucleus of digital convergence… It combines the best of many areas: wireless communications, computers, software, consumer electronics, watches, fashion and more… As services increasingly move onto information networks, access must be possible from more and more places at any time."[107]

Mobile multiplayer gaming also addresses a vibrant market in which Canada has a significant concentration of companies, in both Vancouver and Montreal. It, too, promises to help carriers fill the void left by the decline in voice revenues.

[105] "Industry Overview, ICTC Wireless Roadmap" (Nov. 1, 2006).

[106] Based on $7 billion+ in the U.S.

[107] "Information, Communications & Media (ICM) Panel," U.K. Foresight Program (2002).

The third application, mobile backhaul for *intelligent transportation systems* (ITS) recognizes Canada's need for wide-area sensor networks to improve urban transportation: we are one of the world's most urbanized societies. It is significant that of the three applications selected by the steering committee, only this one centres on product innovation. Both *systems integration* and *mobile multiplayer gaming* focus on process innovation.

Software engineering and systems integration are major process technologies that will play a significant role in enabling the build-out of wireless applications over the next two decades.

The maturity phase of wireless (2024-2033), will be marked by a slow decline of growth toward that of the overall economy. It lies well beyond the ten-year time horizon of this report. However, the young technologies that will eclipse the slowing growth of wireless with revolutions of their own have already been born. These *disruptive technologies* will find their way into wireless as enabling inputs in its declining years. Two such technologies are *nanotechnologies* and *quantum computing*.

Nanotechnologies will play a central role in recasting microelectronics as *molecular electronics* where small numbers of atoms will replace classic circuit elements like transistors, resistors and capacitors. In quantum computing, the first primitive quantum computer is already a reality (see Chapter 3). Such developments will shape new computing paradigms that will continue the progress associated with Moore's Law. Future versions of this roadmap should pay close attention to such developments, since such inputs will be a primary force for innovation in the coming maturity stage of the second global wireless industry.

9.2 Using the Roadmap

A technology roadmap can take many different forms and serve many different purposes. When written by a corporation, it is usually intended to document the R&D programs that will support the corporation's product migration strategy (usually over a five-year horizon). When written by a consortium of companies, it typically forecasts technology developments that are likely to become available for exploitation by industry.

Over the years, Canada's high-technology industry, with the help of governments and trade associations, has prepared technology roadmaps for sectors like aerospace and microelectronics. Such roadmaps were built around technology but emphasized other topics that were of major concern to the industry, like regulations, financing mechanisms and government incentives.

This wireless technology roadmap is a direct result of the ICTC *Technology Vision Conference* (TVC) of March 2006. It reached consensus on the central importance of human resources in building a world-class wireless industry. Canada represents a small part of world wireless activity, a global reality. The issue is how best to use it.

The key question that should be addressed is: "Who can make use of this roadmap, and what should that use be?" In answering that question, it is helpful to refer to Canada's microelectronics industry which is world-class, even though Canada does not have its own cutting-edge fabrication facilities.

Microelectronics is an industry in which government, academia and corporations have worked closely together over the years through initiatives such as the CMC Microsystems,[108] the Strategic Microelectronics Consortium (taken over by the Information Technology Association of Canada in 2002), and several strategy documents, some of which were really technology roadmaps. One of the reasons that collaboration has worked so well is that most of the initiatives were related in one way or another to industry's human resource requirements.

Microelectronics is the only industry in Canada that has a university post-graduate program (supported through CMC Microsystems) dedicated specifically to its human resource needs. CMC presently involves over 2,300 faculty and graduate students at 42 universities and one college. It provides Microsystems researchers with industry-calibre design resources, access to state-of-the-art manufacturing technologies and support services. CMC has won international acclaim for its achievements in developing Canada's capabilities in microelectronics. The lesson that should be taken from the microelectronics experience is that such collaboration works well when it is heavily focused on any industry's most important ingredient, namely, the human resources available to it.

It is expected that the focus on the three selected wireless application areas will be helpful to entrepreneurs wishing to launch such companies, to investors wishing to finance them and above all to the human resource managers in existing companies. This document should be particularly helpful to educators because a number of skills were

[108] Originally launched in 1984 through a university, industry and Natural Sciences and Engineering Research Council of Canada (NSERC) initiative as the Canadian Microelectronics Corporation.

identified that are 'off the beaten path' but very important. For example, it was pointed out that increased globalization results in many projects that span multiple countries and cultures - requiring human interaction skills that are not given much priority in our education systems. It was also pointed out that the industry is dominated by SMEs that have limited skills development resources.

There was a broad consensus among members of the ICTC Wireless Technology Roadmap Steering Committee and workshop attendees that the roadmap should be updated at regular intervals in the future (i.e. it should be a 'living document'). They also recommended that it be distributed to several trade associations: the skills in all three applications extend well beyond traditional high-technology skills pools.

The roadmap should assist ICT-related organizations in government, industry and academia in their own strategic planning initiatives. An important message that has been delivered is that wireless is approaching maturity, with critical implications for innovation, the skills required to realize it and supporting technologies like software. Most importantly, the roadmap provides a comprehensive model to pinpoint essential skills and relate them to the specifics of the Canadian wireless industry.

9.3 WTRM Validation Meeting

A WTRM Validation Meeting was held on May 15th, 2007 to solicit final comments on the roadmap and to confirm the ideas and recommendations that had been articulated throughout the 6 focus groups. Approximately thirty participants attended, including representatives from industry, academia, trade associations, government departments, wireless and spectrum consultants, and the project's funding partners. Its main purpose was to solicit feedback from key stakeholders on the relevancy and appropriateness of the roadmap content and to share project ideas, in relation to the development of wireless skills. The meeting also provided an opportunity to emphasize particular points or add depth where it was felt to be needed. The results of those discussions have been incorporated into the roadmap under the relevant headings.

The stakeholders validated the model of wireless industry developments and the skills required to successfully adapt to them. The following are projects for further exploration that will assist in moving the wireless sector in Canada forward, and advance the skills that have been deemed necessary throughout this report.

Penetrate Early Educational Levels with the 'Wireless Message'

Greater efforts are needed to reach into the early levels of the Canadian education system (elementary and secondary schools) in order to educate young students on the wireless industry and the opportunities it may present. There is a particularly strong need to attract more females to the technical fields in general and to the wireless field in particular.

Encourage Cross Disciplinary Projects in the Curriculae

Formal curriculae at all levels of education should involve cross disciplinary projects where students have the opportunity to develop and mesh their technical and wireless skills with business and management skills. Examples were provided – Algonquin College is looking at integrating their wireless program with their business program while the University of Waterloo has developed a program in Entrepreneurship for IT graduates.

Work with Guidance Counsellors

Guidance counsellors have a unique role to play. They can help change perceptions, thereby encouraging more young people to consider careers in the wireless and technical fields. Moreover, several felt that workshops are needed to train and educate Canadian guidance counsellors. ICTC should also work with universities and colleges to help them implement and roll out their wireless programs.

Help Canadian SMEs develop and improve their Management and Wireless Skills

Since SMEs make up the majority of Canada's wireless industry, special efforts should be made to help SMEs develop the wireless skills of their employees, especially since these skills are becoming increasingly multi-disciplinary, and more difficult to find, even in Canada's larger firms (due to the globalization factors that have been discussed throughout this report).

Specific case studies on SMEs should be considered to determine how those skills can be improved. Such case studies should also examine SME management skills because new business models and globalization factors mean that team building and project management skills are now critical to the growth of most Canadian SMEs.

Encourage Interaction between Industry and Academia

Participants felt that there has to be even more interaction between industry (particularly SMEs) and the universities and colleges. One proposal was to encourage Canadian SMEs to use their facilities to expose students to the project management and other skills they require. Canada should also continue to develop co-op programs as they expose students to the rapid shifts in the technology and skills requirements.

Other ways that industry and academia can interact is through science fairs (which increase student awareness of the technology), *joint projects* (where students assist with actual industry projects), and *joint marketing campaigns* (where industry and academia develop campaigns to encourage enrollment in technical fields). Industry and academia also need to work together to demonstrate to young people that mathematical and technical skills are very important to their future and they need to work together to inform the Canadian media of the value of technical skills. They can also work together in the area of job profiling, which is the identification of the skills needed to deliver their products and services.

Encourage Certification

Participants felt that there is a general lack of understanding of how other countries' skills can fit with the needs of Canadian industry. This situation reinforces the need for certification in the trades and the professions. The ability to perform the job was viewed as much more important than the number of years of experience. The retraining of Internationally Educated Professionals (IEPs) and misplaced workers should be based on company needs.

Supply and Demand of Wireless Skills

This report defines the major wireless skills that will enhance Canada as a wireless leader in the global market, and provides a timeline of when various skills will be most relevant. Further analysis, to narrow in on the number of trained workers that will be required for each of the identified skills in the report, and to explore the potential supply that will be available, would help to ensure there is no gap and that supply can meet demand.

Appropriately Training the Wireless Workforce

It is important that industry, education and government come together to create programs that promote the necessary skills that are needed in the IT sector, specifically wireless, and assist in training and retraining employees. Partnership programs such as Vitesse have been successful at this goal; with a mandate to meet the constantly evolving needs of high tech industry, Vitesse (Re-Skilling) retrains and re-skills science and engineering graduates to take advantage of current and emerging opportunities in a variety of IT related fields. The program was created in 1996 through a partnership between NRC, the University of Ottawa, Carleton University and knowledge-sector employers. A program such as this would be very beneficial when applied to the wireless sector and the skills articulated in the roadmap.

In Summary

Technology drives skills – through the creation of new industries and the reshaping of long established ones. The forces that drive this process and the recurring patterns that characterize it are increasingly well understood. It is up to us to act.

Appendix 1: WTRM Technical Focus Group, Ottawa (November 8th, 2006)

Attendees:

Name	Title	Organization
Abielmona, Rami	Chief Engineer	Larus Technologies Corporation
Barake, Omar	Senior Research Architech	Research In Motion (RIM)
Boch, Eric	Founder, CTO & VP Engineering	DragonWave Inc.
Boucher, Pierre	Director for Research and Innovation	Ericcson Research Canada
Crawhall, Robert	President & CEO	National Capital Institute of Telecommunications (NCIT)
Gagnon, Francois	École de technologie supérieure	Prompt Quebec (Montreal)
Khandani, Amir	Professor, Tier 1 Canada Research Chair and NSERC-Nortel Networks Industrial Research Chair	University of Waterloo
Knudsen, Neil	President	The Ottawa Wireless Cluster
Reid, Doug	Professor Wireless & Telecom	Algonquin College
Thomas, Terry	President	Terry Thomas Consulting (X-Nortel & Chrysalis)
Visser, John	Sr. Mgr., International Wireless Standards	Nortel Networks
Yee, Jung	CTO	WiLan
Wittenburg, Richard	Sr. Practice Leader for IT	IBM

The Information and Communications Technology Council (ICTC) is a non-profit sectoral council dedicated to creating a strong, prepared and highly educated Canadian ICT industry and workforce. ICTC is a catalyst for change, pushing for innovations that will provide labour market intelligence, life-long professional development and quality education and training for the Canadian ICT industry, educators, governments and the ICT workforce. We forge partnerships that help develop the quantity and quality of ICT professionals needed to improve Canada's position as a leader in the global marketplace.

To achieve its goals, ICTC focuses on four areas that are proven building blocks of a healthy, forward-looking sector:

- **Skills Definition** – defining the skills required to be a professional in the ICT sector.
- **Labour Market Intelligence** – providing up-to-date statistics and analyses of human resource developments in the ICT sector.
- **Career Awareness** – providing programs and tools to explore the career possibilities in Canada's ICT sector.
- **Professional Development** – dedicated to continuous learning for ICT workers so they can maintain and improve their skills sets and increase their opportunities within the sector.

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