As discussions about the commoditization of technology pervade corporate America, a monumental trend is gathering steam. That trend is pervasive computing. One way to think about pervasive computing is to position the Internet and the World Wide Web (WWW) as a prototype, which is really what it was in the 1990s. The speculation around the new digital economy was valid, on the one hand, because it was based on a vision that was essentially accurate. But on the other hand, speculation was based not on an evolutionary march toward ubiquitous seamless connectivity but rather a revolutionary prerequisite that the prototype Internet simply could not provide. At the same time, “Internet” opportunities are still ahead of, rather than behind, us, and these opportunities are likely to be wrapped in pervasive computing.

The vision persists and will evolve into a suite of architectures and applications that will revolutionize business-to-business (B2B), business-to-consumer (B2C), business-to-employee (B2E), and business-to-government (B2G). In fact, it will be impossible to perform the following tasks without relying on pervasive computing technology:

- Buy and sell
- Negotiate and partner
- Advertise and market
- Manufacture
In the midst of all of the hype, all of the technology and all of new ways we are expected to communicate and compute, there is precious little insight into how it all ties together. If the world becomes “virtual” through Internet ubiquity, how will it impact us? What can we expect?

This analysis identifies and describes the technology trends that will determine how we will work with personal digital agents who will do our bidding over the Web, how we will learn new things through virtual reality-based simulations distributed around the world, how social referenda will occur in real-time, how we will buy the dress of an academy award nominee while watching the awards ceremony, how we will walk down the 16th hole at Augusta National Golf Club chatting with a virtual Tiger Woods about club selection, how we will manufacture from our computer consoles, and how we will treat all varieties of illnesses remotely and compassionately.

This analysis identifies and describes technology trends that when taken together define the macro trend, pervasive computing, a trend that will enable all sorts of activities that today are discrete, disconnected transactions. Pervasive computing will make transactions continuous and seamless.

The analysis describes the macro trend through the multiple trends lens of software, services, and communications, the major drivers of computing and communications applications, architectures, and infrastructure. What we have done here is identify and describe the trends most likely to impact the transaction processing future wrapped under the pervasive computing mantra.

But just as importantly, the analysis outlines an action plan that will help companies prepare themselves for the inevitable connectivity that will change the way we all do business.

It is important to stand back and assess what we have done with technology over time. If you are a large insurer, retailer, or manufacturer you have probably still got a lot of legacy applications that service major parts of your back-office business.

You also probably have some first generation client/server applications that you deployed in the early to mid-1990s that you are supporting—and no doubt you have added some Internet applications, rounding out your back/front/virtual office applications suite. You have also probably “kluged” them together with some integration tools and tricks.
The challenge now is to reassess your computing and communications environment once again, this time with reference to the pervasive computing “wave.” Figure 1 describes the various computing eras in some detail (with some additional details about pervasive computing in the bullets that follow Figure 1).

There are vertical industry implications to all of this: some industries have been slower to move along the continuum than others while others have embraced the newer technologies enthusiastically. When we overlay vertical industries on to company age and size, a picture emerges that describes where most companies live. For example, if a company is over 50 years old, is in the insurance or financial services industry and has revenues over $5 billion, it is probably stuck between Eras 2 and 3.

All of this leads to a vision of the future that is measurably unlike anything we have experienced before. In other words, the future, defined in terms of a 3 to 5 year window, will not represent the steady extrapolation from well understood events but rather a revolutionary change that will impact every aspect of our personal and professional lives. Unlike other “revolutions,” however, this one is based upon extrapolative infrastructure trends: the revolutionary explosion will come when automated, always-on applications get deployed.

This is the vision with which we all must become familiar. What will it mean when our applications are automated? Continuous? Integrated? How will your busi-

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Figure 1. Major computing eras and pervasive computing

<table>
<thead>
<tr>
<th>Year</th>
<th>Era 1</th>
<th>Era 2</th>
<th>Era 3</th>
<th>Era 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980 -</td>
<td>1G</td>
<td>1G Automation</td>
<td>1G Distributed Computing</td>
<td>1G Internet Connectivity</td>
</tr>
<tr>
<td>1985 -</td>
<td>2 Tier</td>
<td>3/N Tier</td>
<td>3/N Tier</td>
<td>3/N Tier</td>
</tr>
<tr>
<td>1990 -</td>
<td>Fat Clients</td>
<td>Architecture</td>
<td>Architecture</td>
<td>Architecture</td>
</tr>
<tr>
<td>1995 -</td>
<td>Skinny Servers</td>
<td>1G Supply Chain Connectivity</td>
<td>1G Disintermediation</td>
<td>1G Security</td>
</tr>
<tr>
<td>2000 -</td>
<td>Fat Servers</td>
<td>1G Security</td>
<td>1G Security</td>
<td>1G Security</td>
</tr>
</tbody>
</table>

1G = First Generation

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Figure 1. continued

1. **Adaptive Architectures**
   Computing & communications architectures & infrastructures capable of adapting to heterogeneous environments; architectures that integrate & interoperate across platforms ...

2. **Always On Connectivity**
   Via combinations of narrow and broadband connectivity, continuous personal & professional transactions; ability to continuously access and transact ...

3. **IP Ubiquity**
   IP addresses proliferate across the physical & virtual worlds: cars, homes, buildings, clothing, appliances, etc.; real-time ability to locate all entities ...

4. **Automation**
   Continuous transaction processing via (all) client, server & network-based cooperating intelligent agents; full customization & personalization; the rise of "exception processing" ...

5. **Rich Content**
   Voice/text/video interactive multimedia content; immersable content ...

6. **Security**
   Total security solutions (authentication, authorization, administration ...) ...

7. **Supply Chain Integration**
   Full supply chain integration; real-time inspection of supply chain processes; emergence of personal & professional supply chains ...

8. **Convergence**
   Convergence occurring simultaneously in multiple sectors, including:
   - Devices
     *Convergence of access & transaction processing devices, including especially telephones, PDAs, pagers, PCs, embedded processors ...
   - Business Models
     *Convergence of personal, professional & hybrid transactions & workflow/collaboration processes ...
   - Communications
     *Convergence of all forms & content of communications; integration of off-line & on-line communications ...
   - Personal & Professional Processes ...
     Integration of non-stop, seamless transaction processing across all personal & professional domains ...
ness models and processes adapt to ubiquity? Will your internal processes support continuous transaction processing? These are just a few of the questions we will all need to answer.

The trends that we will examine here include:

- **Software trends**
  - Enterprise/Internet application integration (EAI/IAI) integration
  - Transaction platform development
  - Supply chain connectivity
  - Personalization and customization/business intelligence
  - Automation
  - Rich content aggregation/management
  - Personal and professional portals
  - Architectures: Embedded applications and peer-to-peer computing
  - Voice recognition/natural interfaces
  - Web services/service oriented architectures

- **Services trends**
  - Outsourced service providers
  - Application integration service providers
  - Rich content management service providers
  - Development services
  - Infrastructure engineering services → solutions

- **Communications trends**
  - Wireless applications
  - Network security solutions
  - Bandwidth management and optimization
  - Telecom
  - Broadband
  - Network applications and services
  - Optical networking
  - Touch technologies

These are the computing and communications trends we believe will exert the most impact on pervasive computing. They are also the trends we believe investors in technology—whether they be CIOs, vendors, or VCs—should track.
PERVASIVE COMPUTING TECHNOLOGY TRENDS

There are three broad trends that will enable and extend pervasive computing:

- Software trends
- Services trends
- Communications trends

Software Trends

The software trends we will explore include:

- EAI/IAI/exchange integration
- Transaction platform development
- Supply chain connectivity
- Personalization and customization/business intelligence
- Automation
- Rich content aggregation/management
- Personal and professional portals
- Architectures: embedded applications and peer-to-peer computing
- Voice recognition/natural interfaces
- Web services/service oriented architectures

These trends define the first leg of pervasive computing enabling technology, trends companies should track as indicators of the breadth and depth of pervasive computing’s impact on business. The above list is significant because of its simultaneous arrival and because of the combinatorial effect of the technologies on the list: individually they are all important but together they enable a whole new future.

EAI/IAI/Exchange Integration

There are at least three pieces here. But according to industry analysts, no single vendor has all of the integration pieces in place—yet:

1. "Federated Database" EAI (Applications Integration Through Access to Multiple Data Bases ... eg, Cohera & Information Builders, Inc.)
2. "Process Automation" EAI (Applications Integration by Building Workflow/Process Layers on Top of Existing ERPs & Enterprise Processes ... eg, Vitria)
3. "Brokering" EAI (Products that Integrate Applications by Brokering Information ... eg, New Era of Networks & Active Software)

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The trends here suggest that there will be software to create new applications as well as platforms that integrate the capabilities of many of the leading vendors. BEA Systems, IBM, Oracle, TIBCO, Vitria, and WebMethods have good capabilities in scalability, universal connectivity, business process tools, and standards compliance. What if a vendor platformed the best of the best? The integration of disparate exchanges and exchange processes (alternative auction forms, for example) is beginning to emerge. Once companies conquer their internal/external integration problems they will move to address their real-time transaction processing integration problems.

What all this means to technologists and technology and business managers is that integration will be a major driver of pervasive computing and that progress here is faster and better than expected. It is important to track this trend because applications integration—when it is truly seamless—will catapult our ability to integrate processes and transactions among customers, suppliers, and employees. A pilot or two here makes sense, especially since everyone has a smattering of disparate applications that need to get integrated. EAI tools and techniques will extend business models and processes, making them ubiquitous, always on, and intelligent.

The assumption here is that while we will certainly get to the next level of connectivity, it is just as likely that we will not throw too much away. Instead, EAI tools and techniques will be used to link applications that will ride on the pervasive computing infrastructure.

The trends analyses indicate that the collapsing of supply chains continues at an incredible pace aided by a variety of software tools and “platforms.” Industry analysts predict that the major transaction engines will survive, but that other vendors will not survive the inevitable Darwinian shake-out in the space. Our trends analysis indicates no less than twenty transaction processing engines are working today—and that it will be impossible for them all to own meaningful market share. Track the five market share leaders; ignore the others.

Market makers-in-a-box are also emerging, like from IBM (Websphere Commerce Suite). The ability to integrate different market maker software will continue to be highly valued since these engines are not natively interoperable. It is this space that companies like WebMethods have targeted. It is also an integral component of the pervasive computing revolution.

EAI tools and techniques will morph into Internet application integration (IAI) tools and techniques, and both will facilitate the integration of transaction exchange engines. First generation Internet applications are already disconnected from each other and the myriad legacy systems on which they often depend.
So what are the key application technologies and standards you need to track? With apologies right up front for the following techno-speak, you need to track the major application development and integration technologies offered by the major vendors and their henchmen, which include: XML (extensible mark-up language) and its extensions, Java (the generic programming language) and its extensions, and Microsoft’s .net technology (designed to integrate data and applications). Tracking these macro trends will pay dividends downstream.

Let us talk about Web services, which exhibits all of the characteristics of a trend that may or may not have long-term legs. The idea is simple: get the industry to adopt a set of common technology standards to make applications (and data) integrate and interoperate. Wouldn’t that be nice? There are at least three XML-based standards that define Web services: Simple object access protocol (SOAP), Web services description language (WSDL), and universal description, discovery, and integration (UDDI). Sorry, here we go again. SOAP permits applications to talk to each other; WSDL is a kind of self-description of a process that allows other applications to use it; and UDDI is like the Yellow Pages where services can be listed. The simplest understanding of Web services is a collection of capabilities that allow primarily newer applications to work with each other over the Internet. Because of the relative agreement about the standards that define Web services there is potential efficiency in their adoption. Conventional glue, for example, may consist of middleware, EAI technology and portals, where Web services—because it is standards-based—can reduce the number of data and transaction hops by reducing the number of necessary protocols and interfaces. Eventually, the plan is to extend Web services to your entire collaborative world, your suppliers, partners, customers, and employees. As you may have already inferred, Web services—theoretically at least—reduces the need for conventional integration technology.

So what should you do about Web Services, what some call the industry’s newest silver bullet?

Web services is fueling the development of service-oriented architectures (SOAs), the organization of software functions and activities that cooperate within an application or even over the Internet. SOAs will change the way we think about software dramatically over the next 5 years.

Platform development, another key software trend, is closely related to the applications integration trend. As platforms become more “standardized,” integration problems will decrease. One of the prerequisites to pervasive computing is applications that work together. But note that perfect seamless integration is not necessary for pervasive computing. What is necessary is predictable, reliable integration and evolving proprietary and nonproprietary platforms will also help a lot.
Transaction Platform Development

In spite of the mindshare penetration of Ariba, CommerceOne and other trading/exchange platforms, the “killer app” in e-procurement is an adaptive, real-time platform that dynamically supports “perfect” exchanges, that is, exchanges that involve multiple buyers and sellers in a dynamic pricing environment. Real-time is the killer characteristic of perfect market-making platforms. Trading platforms perform additional tasks, such as organizing buyers and sellers into cooperative trading parties, but the field is still lacking the killer app in the space. At the same time, the major players are evolving their business models in this direction. Part of the problem for these vendors is the complexity of the technology necessary to move from their respective models to a true exchange, since perfect exchanges require fundamentally different software architectures than exchanges based on supplier-only, seller-only, or multiple buyer or seller aggregation. But clearly their strategic plans will move in this direction—and fast (arguably, had the dot.com’s not crashed, we would be there already). Pay close attention to this trend: it is a key component to supply chain connectivity (which is enabled by pervasive connectivity).

Online payment options are growing in number and complexity. While consumer preference remains with credit card purchasing (over e-cash or debiting), trends indicate that online billing will be integrated with other billing methods, tools, and techniques. Vendors are improving tools to permit buyers to register and then pay without credit cards. While credit card payment for B2C transactions rules today, it will not tomorrow. Estimates are that within 3 to 5 years, e-cash and related alternatives to credit cards will account for more than 70% of all payments. The engines to support these payment processes represent key enablers of the digital economy and pervasive computing. Exchange and payment platforms will permit seamless, automated, and “frictionless” B2B transactions.

Storage area management (and it is cousin, content management) are huge pervasive computing requirements trends. This area will continue to explode over the next couple of years. In a sense, Akamai represents an architectural response to frequently-requested content management. Akamai precaches the most frequently requested content in servers located strategically along the Internet. The Akamai effect will repeat itself on sites all over and storage and content management will be necessary to keep Web sites humming. Products and services in this area will be in great demand; a killer app here would generate enormous productivity and efficiency—and would have to distinguish itself from piecemeal solutions.

If you look at the discussions about e-CRM, supply chain management, sales force automation, automated marketing, and the evolution of the modern e-call center (which requires an IP backbone), there is an opportunity to build an integrated platform that would combine all of this functionality in a single application. The
underlying technology here would have to involve some EAI/IAI/Web services/SOA tools, some telecommunications services, middleware, and lots of communications technology; the integrated application would ultimately evolve to a "whole customer management" platform. This does not exist today and the trends analyses suggest there would be a huge market for it almost immediately, especially if the rollout of broadband communications continues to keep pace with recent commercial deployment. Watch for the integration of what we today call customer relationship management (CRM), customization, personalization, and content management platforms, among others.

Supply Chain Connectivity

As we move toward continuous, connected commerce, supply chain software (and services) will rise dramatically in importance. Unlike the EAI/IAI space, there is not an endless list of players; rather a few dominant ones (i2, Manugistics, and the supply chain modules offered by the major ERP vendors).

The functionality of supply chain management and planning (SCM/SCP) software is rising dramatically. Next generation tools will integrate supply chains across vertical industries and SCM/SCP software platforms.

Supply chain connectivity will occur because of the efficiencies that integrated supply chains yield. When suppliers know that wholesalers and retailers are selling—and for what price—they are in a position to adaptively organize their production processes and schedules. Collaborative forecasting and planning, when it is fully integrated, will fundamentally change the way businesses produce and distribute goods and services.

Supply chain applications will continue to evolve and converge, as ERP vendors, SCM/SCP specific vendors and systems integrators all continue to offer tools to connect producers, distributors, wholesalers, retailers, and customers.

Personalization and Customization/Business Intelligence

Pervasive computing will breathe even more life into mass customization and personalization (and the data mining it requires):

- **Customer, Supplier & Employee “G2” & “Manipulation”**
  - New Models for Identifying, Profiling & Interacting with eCommerce Customers, Suppliers & Employees
  - Distributed Data Mining for Customer/Marketing Personalization
  - Vertical Cross-Selling Inference Models
  - Models of the “Extended Customer”
  - Infomediaion Tools ...

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Personalization and customization will converge at customer/supplier/ employee touch points which will require the integration of CRM, eCRM, SFA, customer self-service, telesales, campaign management, interactive marketing, and other applications.

There are also opportunities to integrate CRM platforms into networking and call center service models yielding a people-facing solution. Applications, platforms and service models that recognize this trend are bell weathers of pervasive computing progress. The general data mining world will also be resurrected by customization and personalization trends—and the pull for pervasive computing (built upon the major CRM platforms).

There is lots of noise about business and competitor intelligence. This assumes access to data/information/knowledge/content in ways that support all kinds of analyses. Cognos and MicroStrategy represent two successful software vendors in this space. In some respects, this trend represents the intersection of data integration, knowledge management, and enterprise information portal technology. But there is a deeper implication here: all data/information/knowledge/content can be integrated into a platform that would—essentially (and pervasively)—be a flexible distributed data warehouse that supports whatever data users want.

The trends here reveal that all applications that interact with people—customer relationship management, supply chain, sales force automation, customization, personalization, and business intelligence software—will collapse into integrated suites. There are tons of applications that do essentially the same thing as well as market leaders with large market shares (like Siebel Systems). The hottest action is in the broadly defined personalization area, which combines CRM, customization, one-to-one marketing, permission marketing, relationship marketing, and multiple touch point software. But the personalization space is crowded. As is usually the case, about 10% of the companies own 90% of the market share. But remember that a long list of vendors in a space also validates opportunities: if the trend were not valid there would not be so many vendors trying to occupy it.

When we turn to CRM and e-CRM applications, we see a similarly large number of vendors. There is still room for the development of behavioral models that correlate demographic and (online, real-time, and off-line legacy) data into informed CRM, SFA, up-selling, cross-selling, promotional and other inference models (though privacy concerns will continue to rise). All of these applications require integration. Front office CRM and e-CRM applications must be linked with operational customer information data bases, back office core processing applications, business intelligence (BI) software, and customer data warehouse(s)—and then delivered via the Web through wired and wireless connections.

There is room for a technology that would link disparate CRM/customization applications. This is a technology that will catapult pervasive computing applications integration and extensibility.
Automation

There is perhaps no more important technology for pervasive computing than intelligent systems technology (we will talk much more about this in the next section of this chapter). The trends here continue to indicate that the Web will become increasingly automated and that intelligent agents will drive this trend.

Intelligent agents will play a major role in pervasive computing-based transaction processing. There are several levels of functionality here. One is the development of horizontal agent technologies and architectures applicable to multiple computing and communications infrastructures. Another is the deployment of vertical agents with deep domain knowledge about specific industries.

The general capabilities appear below:

- **Intelligent Agents**
  - Software Agents Capable of Autonomous, Self-initiated, "Social" Able to Communicate with Users (& Other Agents), Reactive, Dynamic, Asynchronous (Actions Independent of Linear/Linked Events), Event-Driven (Can Proact & React to Events), Self-Executing (Can Run Themselves) & Self-Contained (Have What They Need to Run Themselves)
  - Focused on Specific B-to-B & B-to-C Problems

Agents are already powering applications. In the network monitoring area, Computer Associates (CA) and IBM are applications using predictive analysis tools. There are tons of automation opportunities. Some major capabilities will be spun around automation, intelligent systems technology and cooperating intelligent agents. Pervasive computing will be about continuous computing and continuous computing will be about automation. Agents can be applied to security, shopping, manufacturing, e-mail, content management, and countless other application areas.

There are a number of opportunities in the automation area. Trends analysis reveals an increase in attention paid to the resurrection of artificial intelligence (AI). While CA continues to tout their "neugents"—applied principally to network and systems management—other vendors are exploring how to leverage intelligent systems technology in a variety of applications. CA has announced its intention to extend neugents into their entire suite of applications. RightNow Technologies integrates intelligence into customer service applications through e-mail and related applications.

Many companies would benefit from the application of some form of intelligence to their applications and services. The market would reward a killer app here, since
there is currently no single company (or even group of companies) that can claim market leadership or market share in the space.

Artificial intelligence (AI) will return with a vengeance. Why? Because Web-based automation is inevitable—it is cheaper, faster, and more efficient than human-computer interaction. The initial trends here have been task-based. “Bots”—like MySimon—assist shoppers and collaborative filtering agents actively assisting Internet searches. This is just the beginning. Watch for the vertical spread of intelligent processing followed by the widespread horizontal application of intelligent technology.

Trends analyses suggest that now that raw data is available and beginning to integrate, the need for better behavior inference models is rising dramatically. Why? Because mass customization, impulse buying, and collaborative forecasting and replenishment (CFAR) all require insight into the buying patterns of individuals and organizations. Some of these models are based on complex psychological models of human behavior, while others are based on simpler extrapolative models of organizational buying patterns. Now that we are close to enterprise data integration, the need for robust intelligent models will rise.

Rich Content Aggregation/Management

- Converged, Rich Content & Content Management
  - Industry-Specific (Vertical) & Generic (Horizontal) Content Creation, Integration & Aggregation
  - Distributed Content Synchronization & Management
  - Enabled Content
  - Content Repositories & Repository Management Services
  - Universal Content Access

This area continues to expand—especially as bandwidth increases and the richness of applications rises:

Companies like RealNetworks are well positioned in the streaming media area with tools that synchronize and stream rich media. Validation of the space comes from Cisco’s (and other vendors’) commitment to develop rich content management solutions.

Tools and services that span content creation (tools + repositories), content management (development, QA + deployment), and content delivery (Web servers, application servers + eCommerce analysis/metrics tools) will be required to support pervasive computing.

Content management and distribution is also becoming complex. In fact, it is impossible to separate technologies like load balancing and caching from content
management and distribution. Ultimately, this takes us to performance enhancement and quality of service (QoS) capabilities as distributed business models get deployed.

Significantly, some of the largest technology players—like Cisco—are moving aggressively into the content management and distribution space. Last Year, Cisco announced a suite of content networking products. IBM, EMC, and other large vendors have also announced hardware, software, and services capabilities in the space.

Some of the niche vendors in the space include:

**For document content management:**
- EMC/Documentum
- Hummingbird communications
- Open text

**For electronic publishing:**
- Interleaf
- Inso
- Arbortext

**For software configuration management:**
- IBM/Rational software
- Continuous software

**For Web content management:**
- Allaire
- Broadvision
- Eprise
- Interwoven
- Vignette
- IntraNet Solutions

The ability to exploit and optimize these and other vendors’ technologies and tools will become increasingly important as the vendors themselves add services to their repertoires.

The new content delivery business model assumes multiple touch and access points, including wireless, Web site-based, interactive TV, and data interchange through different communications mechanisms, including e-mail, call centers, and data warehouses.
The space is morphing into integrated tools, technologies, services and solutions—all necessary to support pervasively distributed data, information, content, and knowledge.

**Personal and Professional Portals**

Always on, continuous computing will be facilitated by personal and professional portals. Yahoo! Will—like all of the other general purpose portals—continue to evolve into professional and personal portals. There will also be lots of additional portals that support a variety of transactions.

The portal landscape is evolving quickly but like many other software areas lacks integration. The major corporate portals (like Plumtree, Hummingbird, SAP AG, and Oracle), the commercial portals (like My Yahoo! and Netscape), the publishing portals and the personal portals are all point solutions to disembodied processes. As pervasive computing takes hold, there will be a need for cross-portal integration. (There will also be a need for portals with greater functionality and integration capabilities than the current products on the market today have.)

Enterprise information portals (EIP) are growing rapidly as a delivery solution to disparate data bases, applications, remote access, and other problems that demand the integration of function, access, and processing. In fact, EIPs are emerging as a meta-application that umbrella all applications within and beyond a company’s firewall.

Portal’s come in various shapes and sizes, including corporate, consumer, vertical, and commerce portals. The emphasis here is not on the creation of business models that are portals but on the processes by which portals are designed, developed, hosted, and supported. Opportunities for the application of off-the-shelf portal software are growing rapidly. When well conceived, they represent the ultimate in applications integration, or the interface to all varieties of inside and outside the firewall applications and data bases.

Portal software is offered by:

**For ERP portals:**
- SAP
- Oracle/PeopleSoft

**For collaboration:**
- IBM/Lotus
- Microsoft
- Novell
Industry analysts predict that the implementation of EIPs would occur within 95% of all corporations by 2008—up from 60% in 2003. This rapid growth suggests a huge opportunity for design, development, hosting, and on-going support—even if the adoption predictions are a bit exaggerated. Subsumed in the EIP trend is applications integration tools and technology.

Architectures: Embedded Applications and Peer-to-Peer Computing

Programmable digital signal processors (DSPs) and microcontrollers have made all sorts of embedded application development possible for decades. If we assume that pervasive computing is continuous computing, that commerce will become increasingly automated and that applications will have to adapt to dynamic transaction processing, then the market for embedded applications should grow considerably. Real-time scheduling, interfacing, and hardware-software optimization are but a few of the applications that can enhance performance.

Peer-to-peer architectures are also taking hold. While everyone’s familiar with Napster-like applications, there are already a handful of start-ups exploiting the capabilities of peer-to-peer (such as Microsoft’s Groove Networks). Pure peer-to-peer—where peers have equal capabilities—and hybrid peer-to-peer models, where servers participate in the task allocation and sharing process, represent terrific potential especially when targeted at specific horizontal tasks (like virus protection and encryption) and vertical tasks (like financial transactions). Peer-to-peer architectures will enable all sorts of pervasive computing applications.

Voice Recognition/Natural Interfaces

It is been almost three decades since the first promises about voice recognition were made by researchers at the Defense Advanced Research Projects Agency (DARPA, the same Defense Department agency that created the underlying technology for the Internet). The idea was simple enough: develop hardware and software that could understand what people said—as well as what they meant by the words they used—and then, through “natural language understanding” respond coherently in the same, or even another, language, as appropriate. Full voice input and output was, and remains, the goal, which includes “semantic understanding,” or the ability to understand the meaning and context of language, not just the structure of
sentences (“syntactic understanding”). Impressive progress was made early on but real-time knowledge-based language understanding has proved difficult—so hard, in fact, that the most impressive progress was made on syntactic side (with limited vocabularies with less-than-perfect speech input recognition devices).

So where are we now, and why should we care? Pervasive computing will require lots of “natural” interaction. Just assume for a moment that it is possible to converse in continuous sentences with machine that understands exactly what you say and what you mean—regardless of the language you are using. In order for this to work several things have to be true. First, for privacy and personalization purposes, the system must distinguish among speakers. Next, it must understand the discrete commands they give as well as the continuous sentences they speak. Numerous knowledge bases help the system understand structure, inferences, and purpose.

Let us look at the pieces of this capability and where we are today and the applications that might benefit the most from improving voice and speech recognition technology.

Discrete speech input applications—those that recognize specific commands (like “Open Powerpoint”)—are improving. Some have vocabularies for thousands of words, and some permit users to customize vocabularies to meet the requirements of specific vertical industries. Discrete speech recognition applications work well in specific contexts especially when lots of people will be using the commands in so-called “speaker independent” applications. (Other “continuous speech” applications work best when they are well-trained by their users, which occurs when users speak extensively to the application so the application can “learn” the sounds the user is likely to make when specific words are spoken.)

Efficient continuous speech recognition is harder to achieve. While the goal is to support the kinds of communication that people naturally experience, sometimes the delay between spoken words and their appearance on the screen (or the delay between a spoken word and some reaction) becomes annoying, primarily because delays are unnatural. Research suggests that the most productive users of continuous speech recognition applications are professionals who are also experienced with the use of dictation systems, where pauses, punctuation, and other language structures are part of the process.

We are still some years away from true natural language understanding where software “reasons” what the speaker means when a request like: “show all of the flights from New York to Miami that leave at midnight and cost less than $500” is made. While there is specificity in the query, the speaker is actually interested in getting to Miami relatively cheaply late at night, and would be delighted to receive a response from a natural language understanding system like: “there are no flights from New York to Miami at midnight that cost less than $500, but there are five flights that leave between 11PM and 1AM that cost in the range of $400 - $600
… would you like to see them?” In order to provide this kind of response the application needs to understand what the speaker really wants and in order to do that it must understand travel, priorities and goals. Imagine how sophisticated natural language understanding applications would have to be to understand all possible queries in every conceivable context. Or put another way, while humans take for granted our ability to understand queries like: “how many aces were served,” and the requisite (tennis, not poker) contextual interpretation of the query, deep natural language understanding systems will have to understand thousands of inter-related contexts before they can interpret and infer meaning and purpose. Today we have several applications that can convert sounds into parts of speech that can be recognized, displayed and stored—and trigger some predetermined action. While these applications are far from intelligent they are extremely powerful and for selected tasks very productive.

How can this technology be exploited? There are any number of uses that might benefit business including:

- Data base, e-mail, knowledge access
- Call center customer service
- Account balance checking
- Order processing
- Manufacturing production control
- Personal tasking
- Speech-to-text/text-to-speech

Access to information or transactions can be through devices mounted in desktop and laptop computers, hands-free embedded devices (such as in automobiles), personal digital assistants (especially the voice/phone-enabled ones), assembly line devices, and even voice portals to enterprise resource planning (ERP) applications.

Part of the adoption challenge lies in the integration of voice into existing access and communications capabilities. As always, integration and interoperability become important opportunities and constraints in the deployment and support of speech recognition applications. Sophisticated users of information technology appreciate that enabling technologies like speech recognition are best exploited as extensions of existing business processes already supported by technology. Voice-enabled customer service, for example, represents a great way to extend a company’s care and handling of its employees, customers, and suppliers so long as it works well with the other care and handling tools in use at the company.

Who are the players here? The major speech recognition vendors include IBM and Philips. These vendors have been in the market for a long time. A number of additional vendors have come and gone focusing on speech-enabling the Web.
They include: BeVocal, Foodline.com, General Magic, Onebox.com, SpeechWorks, Tellme and Vocal Point, among others.

Track these companies and their products. All of the progress in CRM, customization, personalization, and automation will require sophisticated natural interfaces. Voice is the most natural interface, so track the technologies that enable natural communications among data, applications, and infrastructures.

Web Services and Service-Oriented Architectures

In spite of the word “services,” Web services represents quintessential integration. In a nutshell, Web services refers to a suite of standards-based tools and techniques that permit continuous e-business. In a sense, the current trend in Web services is toward a relatively imprecise coupling of applications and functionality through some flexible technologies, like XML. In some respects, it is the ultimate IAI methodology, though in some others it is an evolutionary response to the relatively clumsy integration efforts that occurred in the late 1990s. Web services also represents an attempt to integrate disparate platforms and architectures with the 21st century’s version of wrapper technology, XML.

As suggested above in the context of integration and interoperability, Web services exhibits all of the characteristics of a trend that has long-term legs. The idea is simple: get the industry to adopt a set of common technology standards to make applications (and data) integrate and interoperate. Wouldn’t that be nice? There are at least three XML-based standards that define Web services: Simple object access protocol (SOAP), Web services description language (WSDL), and universal description, discovery, and integration (UDDI). SOAP permits applications to talk to each other; WSDL is a kind of self-description of a process that allows other applications to use it; and UDDI is like the Yellow Pages where services can be listed. The simplest understanding of Web services is a collection of capabilities that allow primarily newer applications to work with each other over the Internet. Because of the relative agreement about the standards that define Web services there is potential efficiency in their adoption. Conventional glue, for example, may consist of middleware, EAI technology and portals, where Web services—because it is standards-based—can reduce the number of data and transaction hops by reducing the number of necessary protocols and interfaces. Eventually, the plan is to extend Web services to our entire collaborative world, suppliers, partners, customers, and employees. Web services reduces the need for conventional integration technology.

Track what the big vendors are doing in the space. Already IBM, Oracle, Microsoft, and other vendors have announced their commitment to Web services standards, though their actual commitments remain to be precisely defined.
Web services is a fascinating technology development with enormous potential. But the reason why you need to track progress here so closely is because of the relationship between Web services—standards-based integration—and collaborative business models. Web services has real cornerstone potential. It is likely to become a major enabling technology.

Service-oriented architectures (SOAs) represent the next step toward integration and interoperability. Building on Web services standards, SOAs make it possible for software components to be shared and assembled on the Web to solve specific transaction processing problems. In its their ambitious form, SOAs will permit the virtual and temporary assembly of software components necessary to achieve some specific functionality—like checking remote inventory—and then immediately disassemble themselves, after they have determined how much the fee should be for the execution of the transaction. Libraries of components will live on the Web and be available for work at a moment's notice.

There are all sorts of opportunities in the SOA world for CIOs, vendors, and VCs. This is open territory for users, creators, and investors.

**Services Trends**

The services trends consistent with the theme of pervasive computing fall into the following broad categories:

- Outsourced service providers
- Application integration service providers
- Rich content management service providers
- Development services
- Infrastructure engineering services → solutions

**Outsourced Service Providers**

Pervasive computing will require service expertise that may extend well beyond the capabilities of many companies. Outsourcing in one form or another will continue to increase. The big story here continues to be applications services and hosting. Just about every vendor is moving into this space. The packaged software vendors, the telecommunications vendors, and the systems integrators are all offering applications-for-rent. Pressures on traditional software licensing models is growing and the nature of the offerings themselves is changing dramatically.

As small and medium-sized businesses accept the application service provider (ASP) model, which they will, more services will be required as these companies outsource more and more of their technology. While the large enterprises will lag in
their adoption of this model—for a variety of capital and cultural reasons—they will eventually succumb to the logic of renting vs. buying, building, or maintaining.

Commoditization remains a real threat to the profitability of the current ASP model. Without higher margin services, the “basic” ASP model—like the basic cable TV service—is relatively unprofitable. So the ASP services model will expand to include a variety of capabilities that range from applications support to security (just like cable companies try to sell their existing customers more and more high margin services, like video-on-demand, and premium channels).

The most obvious software support trend continues to be this move toward ASP—and commoditization. AppCity, Inc., announced “no-charge” apps and expects to launch proprietary applications (in business, information, lifestyle, and shopping) that will be free to users (who will suffer through banner ads—the principal way AppCity expects to generate revenue). While there will be “free” competition, especially on the B2C side, the trends indicate that this model will be short-lived on the B2B side though price compression will continue and many these companies will probably go under.

Another trend is the segmentation of the ASP market which includes single-app ASPs, choose-your-own app ASPs, flexible pricing-based ASPs, and vertical ASPs, among other variations on the ASP theme. Surebridge, for example, offered customers the option of renting-to-own apps licenses or a strict rental model. Single application ASPs, which are often proprietary, offer customers bare-bones support and can offer them inexpensively because the apps were architected for the Web from the outset and therefore cheaper to build, modify, and support.

Many of the ASP models, as well as the purer hosting models will merge into full service total solutions providers (TSPs) that will initially emerge as horizontal TSPs and then morph into divisions that will be vertically targeted. Successful vertical TSPs will—if they can achieve critical mass—be acquired by the leading TSPs. Competition here is likely to be fierce, because the largest technology service providers, through partnerships with leading independent software vendors (ISVs), are able to move into the space relatively easily. Their movement into the space will, however, occur in exactly the opposite way the current ASPs/TSPs are trying to penetrate the market, that is, first into the small and medium-sized businesses and then into the large enterprises. The larger technology providers are today primarily in the large enterprises. Within 3 years, however, we can expect all resistance to fall. The race is now on to see which TSPs win and how the markets will segment. Companies that cannot morph fast enough (like Exodus Communications, a leading pioneering ASP, failed in the late 1990s) will become M&A targets. Watch also for the storage area network companies to first become “independent” ASPs and then become part of a larger TSP offering.
Full service TSPs will see their margins grow over time, though there will clearly be “division envy” within these organizations, with some divisions commanding high margins and others relatively small ones. The lower margin TSP services will become loss leaders for many TSPs, while the higher margin services will pay all of the bills—and then some. There is no great danger of overall revenue/profit compression in the space: the introduction of new technologies and services will keep the margins healthy for some years to come, although there may be an overall reduction in profitability—and even regulatory pressure on the industry—as we move toward a pure technology “utility.”

This concept of “utility” is important for pervasive computing. As commerce becomes continuous, we are all going to need reliable, scalable, secure operational support—which itself will be defined broadly to include the introduction of new applications. Stated somewhat differently, pervasive computing will require “utilities.” The total solutions providers (TSPs) will evolve into these utilities.

The Web professional services companies (also known as interactive agencies) will also have to continue morph toward additional services. The first additional service to be added will be strategic services, where Web consultancies will offer full-strategic business consulting services, encroaching on what companies like Accenture, PWC, and IBM Global Services now do. This is a natural initial service addition for the e-business and Web professional services companies. After that, they will either develop full implementation and support service offerings or partner to achieve an end-to-end capability.

Another major trend: once ASPs achieve a critical mass of capabilities why would they not expand into related service areas, like e-call centers? Trends analysis suggest that the morphing will not stop among ASPs, hosters, and services companies—all of which are primarily horizontal—but will morph into “vorizontal” areas like call centers, customer relationship management (CRM), sales force automation (SFA), and the like.

While there are lots of Web applications performance metrics point products, there is a need for a metrics framework that would track internal and external performance metrics, such as how well a Web site’s applications are performing as well as how much business they are generating. The necessary technology to provide this service is general “sniffer” technology as well as data warehousing and mining technology, or so-called “web-intelligence” technology. In short, while Media Metrix does a great job, there is a ton of additional analysis that will be necessary to keep sites up and productive, especially as transactions become automated.

The outsourced service provider market is clearly changing. The models have evolved so far that companies, like Jamcracker and Agiliti, actually integrate the disparate services of multiple vendors and multiple service providers. This kind of services integration, by the way, is completely consistent with pervasive computing.
requirements: this discussion is about the economics of making it all work. The facts are simple: as more and more services are outsourced, more and more companies will require integrated, managed solutions.

Traction is easier to achieve in vertical markets, where applications and computing and communications infrastructures are distinct. The earliest shakeout in the ASP market took place among the pure plays, the horizontal ASPs. The more vertically inclined ASPs have fared relatively better.

Vertical xSPs (VSPs) can focus on specific sectors more easily than pure plays, since small vertical players will often evolve into larger ones (on the same scalable infrastructure). VSPs like Casecentral (legal), DocumentForum (legal), EchoPass (high-tech), HotSamba (manufacturing), InfoCure (health care), Trizetto (health care), TalkingNets (telecommunications), Virtual Financial Services (financial services), and General Growth Properties (retail) focus on the unique (though large market) requirements of specific vertical industries. It is also important to note that focusing on small and medium-sized business will by definition require a more complete solution than focusing on large enterprises, which already have substantial infrastructures they usually need to amortize.

The recommendation here is to track companies that:

- Focus on specific vertical industries
- Offer integrated solutions
- Have extensive partnerships with software and telecommunications vendors and so forth

Application Integration Service Providers

The enterprise application integration (EAI) and Internet application integration (IAI) service market continues to grow. It is likely to do so for several years to come - especially as early Internet applications achieve “legacy” status—and especially as enterprise information portals (EIPs) continue to grow in popularity.

The EAI/IAI services market will expand to include the enterprise resource planning and extended resource planning (ERP/XRP) markets, the front/virtual office market, the supply chain market, and the horizontal middleware market. Specializing in one or all of these markets without a corresponding focus on applications and related solutions services will, however, increase pressure on the pure EAI/IAI services vendors. The question for leading EAI/middleware vendors—like BEA Systems—is whether to dominate the software market, the software + services market or the solutions market.

Advances in Web services will level much of the EAI/IAI playing field. As more and more software vendors build Web services compatibility into their offerings,
the proprietary EAI/IAI tools will lose much of their appeal—another reason to track developments in Web services and service-oriented architectures closely.

Development Services

The development market is changing quickly. As suggested above, the e-business professional services market has included implementation + strategy and in so doing is promising enterprise and Internet applications development as part of the package.

Development platforms and architectures are also evolving. Web services will emerge as the killer integration standard. It is just too powerful to ignore and even the proprietary incarnations of the technology—like Microsoft’s .Net and Sun Microsystems J2EE—are more “standard” than not.

The big news is the penetration of Linux in selected markets. The adoption curve for Linux is very similar to the early adoption curve for Windows: it is adopted first as a file and print server and then as an applications server. Windows (and of course UNIX) are way ahead in the apps server market; but Linux is earning its stripes in lots of companies. Part of entry into the club is cost-effectiveness: UNIX has for years been seen as “expensive,” while Windows relatively “inexpensive.” Support costs for Linux are impressively low.

The Linux service market is also expanding. As its penetration continues, demand for services around the OS are also increasing. Large technology service providers, like IBM, CSC, and Perot, are in relatively strong positions to offer Linux support easier than smaller ones focused more on e-business services or Linux-only service vendors like RedHat (which will have to include support for heterogeneous environments to survive).

Linux is playing a role in the pervasive computing era. It has adaptive capabilities, is relatively inexpensive to install and maintain, and as an open architecture provides integration with other open applications and even some proprietary ones.

A key trend is the development of Linux applications and the development and deployment of integrated development environments (IDEs) to accelerate development of Linux applications. Inprise supports Linux apps in its Java IDE—an important step in the legitimization of Linux and in the development of open applications—that will accelerate pervasive computing progress.

Another important trend is the arrival of systems management tools and services that support Linux. Computer Associates has evolved its Unicenter TNG framework to support Linux. Veritas and Mission Critical Linux are developing systems management tools for Linux as well. Similarly, another key to Linux adoption, clustering, is beginning to appear through offerings from companies like TurboLinux, SGI, and Veritas. As Linux knocks down the development/ROI metrics, systems management
and clustering barriers to adoption, its penetration will continue to rise so long as other events, like UNIX and Windows effectiveness, evolve as expected. There is still a raging debate about the long term viability of open vs. proprietary software and the proprietary vendors are systematically opening their architectures to respond to the Linux and other open systems threats to their markets. Likely long-term outlook: a combined open/proprietary standard will emerge that will render the debate less important than it is today. The trends toward TSP utilities and Web services will also make many of these architecture religious wars irrelevant.

Infrastructure Engineering Services → Solutions

One of the areas that is receiving a great deal of attention is Internet infrastructure engineering services, especially all of the services that revolve around the Internet protocol (IP). A typical IP-centric service portfolio would include applications services, networking services, and integrated access services.

As more and more business models become increasingly distributed and IP-based, we can expect this class of service provider to prosper. In terms of the above discussion of ASPs/TSPs and the hot horizontal areas, infrastructure architects would fall in the communications/connectivity solutions space with capabilities everyone will need.

Communications Trends

Pervasive computing communications trends include:

- Wireless applications
- Network security solutions
- Bandwidth management and optimization
- Telecom
- Broadband
- Network applications and services
- Optical networking
- Touch technologies

Wireless Applications

Wireless technology and applications continue to explode. The wireless applications space is also still poised to grow dramatically. Applications that integrate with the existing large market share of tethered applications, that extend these applications, and that represent whole new wireless Internet-based functionality will enable
large segments of pervasive computing. If we assume the continued development of 2-way packet data networks, wireless local area networks, and 2-way paging networks, smart phones, wireless modems, and PDAs, we can expect opportunities for second generation and 2.5 generation wireless applications—from Web clippers and microbrowsers to intelligent agent-based applications that execute serious B2B and B2C transactions. (Investments in 3G or third generation networks with enormous wireless bandwidth will only slightly lag 2.5 generation investments, which may be adequate for serious pervasive computing—or at least the initial phases of the revolution—but 3G → 4G applications will continue to evolve and eventually dominate network architectures.)

Next generation networks will redefine next generation applications. The interrelationships among latency, security, and bandwidth changes the nature of voice, e-mail, video conferencing, large file transfer, and Intranet applications. The previous discussion about voice input and output assumes robust IP-networks to support wireless voice interaction.

Other applications include mobile inventory management applications, product location applications, service management applications, mobile auction and reverse auction applications, mobile entertainment applications, m-distance education applications and, of course, m-music applications.

As always, there are significant integration and interoperability opportunities, especially as they involve connections among mobile devices, communications towers, mobile switching centers, wireless protocol-to-IP gateways, Web servers, the Internet itself, application/middleware servers, single sign-on servers, and all of the front and back office applications and data stores inside small, medium, and large businesses (including ERP apps, CRM apps, e-mail/messaging/groupware applications, data base applications, and the like). Applications that glue all of these parts together wrapped in reliable, scalable functionality represent real opportunities in the pervasive computing era. In other words, wireless middleware and wireless middleware-based applications will play huge roles enabling pervasive computing. Web services standards will help here.

There are also wireless integration requirements that must be satisfied. As the pure play e-business professional services companies move into the space, so too are the device manufacturers and carriers targeting opportunities in what is certainly more than an incremental opportunity. Those that make ubiquitous devices have a vested interest in the quality, security, and reach of IP-networks—just as pervasive computing requirements evolve.

Wireless technology and applications are exploding. This is, arguably, the hottest sector of the new economy and Internet infrastructure (still followed closely by optical networking).
The wireless applications space is poised to grow dramatically—and in some counter-intuitive ways. For example, wireless voice portals that exploit speech recognition and text-to-speech (TTS) technology that will support B2B and B2C commerce, have begun to penetrate the market.

Today the wireless network space is the largest growth space, while the applications space is the smallest, but by 2008 – 2010 the ratio will reverse, with applications dominating the space.

Capabilities will soon exist to develop applications that integrate with the existing large market share tethered applications, that extend these applications, and that represent whole new wireless Internet-based functionality.

The Internet content adaptation protocol (ICAP) will make content viewable from cell phones, pagers, PDAs, and other mobile devices. Other standards—like the wireless application protocol (WAP), Bluetooth, global systems for mobile communication (GSM), 802.X (WiFi), and WiMax—are all defining the direction of wireless communications, content management and display, and support.

Mobile e-commerce (or so-called “m-commerce” banking, payment, shopping, entertainment, and so forth) will drive wireless applications and services; virtual carriers will emerge, carriers who will outsource the wireless pipe operation to commodity carriers and focus instead on owning and servicing a large customer base and the multiple revenue streams it will generate.

Network Security Solutions

The security area continues to search for an integrated solution that addresses authentication, authorization, administration, and recovery for applications inside and outside of the firewall. Security is its own outcome but increasingly privacy is becoming a major driver of security applications and services. We are also seeing the arrival of “pure play” security solutions companies. The tragic events of September 11, 2001, have raised the digital security stakes considerably.

Biometric authentication will finally come into its own. As advances in public key infrastructure (PKI) and digital certificate technology continue, the need for a biometric overlay appears to be growing as a hybrid or partial solution to a variety of security problems. While it is true that biometric authentication offers the only reliable authentication technology, it is also true that the appeal of biometric authentication has historically been associated not with routine access but special purpose, highly sensitive access. The events of September 11, 2001, will increase the appeal of biometric and other authentication technologies that up to this point have enjoyed limited application.

The real payoff lies in integrated security solutions. This is still a relatively uncrowded market, though companies like Verisign are rapidly redefining themselves as comprehensive security solutions companies.
Bandwidth Management and Optimization

This area segments into several areas we all need to track:

- Broadband provisioning software
- Quality of service (QoS)
- IP (Vertical) virtual private networks (VPNs)
- TSB/BLECs/BPL

The provisioning software market is growing. Regardless of the connection technology or the bandwidth provided, there is a need for broadband provisioning software. Continuous commerce will demand it.

Solid provisioning software solutions would provision all flavors of broadband (optical, cable, etc.) on all forms of backbone network protocols (frame relay, IP, ATM, and so forth). While the need is great, the space is relatively uncrowded, though Cisco has claimed the space (along with a few other vendors).

QoS opportunities are still impressive, though some analysts are beginning to distinguish between QoS and QoE (quality of experience), the latter characterized by an external view of network and communications performance. Other analysts see QoS evolving to QoE. The ideal applications here are intrusive and non-intrusive, real-time, introspective and predictive. They also integrate among carrier operation support services (OSSs) through selected middleware applications.

IP VPNs (virtual private networks) continue to be high on the list of fast, cheap remotely accessible voice/data WANs (wide area networks). There are opportunities to verticalize VPNs (building on the horizontal VPN technology products and services now on the market. The combination of managed vertical VPNs, remote access, and dedicated Internet connectivity in a single service represents an integrated solution. Opportunities also exist to create services around vertical VPNs that provide private data and voice traffic. There is also a natural marriage among QoS/QoE, security solutions and the deployment of vertical VPNs.

The TSP/BLEC (tall, shiny buildings/building local exchange carrier) market offers opportunities to provide in-building managed IP services. The DSL (digital subscriber line) and other broadband carriers and service providers are into the space (sometimes pulling fiber or coaxial media directly into buildings). But there are “pure plays” in the space as well. These service providers are somewhat unique in their partnerships with real estate investment trusts, building owners, property managers and major players in the industrial real estate market. The unique (real estate-based) point of entry into the business represents a legitimate barrier to entry to the traditional carriers and communications service providers. It is likely that hybrids will emerge with BLEC partners providing access to value-added services.
The trend is interesting because it represents an alternative path to customers. Broadband over power lines (BPL) is yet another broadband delivery technology that bears watching. Recent government regulatory decisions have made BPL delivery systems viable.

**Telecom**

Traditional telecoms continue to migrate their PSTN platforms to next generation network architectures based on IP. The primary lag effect? The huge costs sunk in fiber cable, SONET, SDH transmission equipment, undersea investments, and analog copper loops, among other indirect sunk costs. There is also the belief, that trends analysis suggest is misdirected, that the demand for higher priced broadband services will lag for a significant percentage of the population. Is this a conspiracy to amortize these investments? Unlikely. If there is money to be made in next generation telecommunications, especially broadband, those telecommunications solutions will emerge.

As data traffic rises, the need to revamp existing infrastructures and architectures will also rise; telecoms are trying to have it both ways: they want to optimize their existing infrastructures while migrating to the next generation (which is happening faster outside the local loops than inside). They all know they need to migrate to a consolidated packet backbone infrastructure. Many companies are already well into the long march, a march whose outcome is absolutely essential to pervasive computing.

**Broadband**

Digital subscriber line (DSL) technology still looks strong—especially given the infrastructure realities described above. Given that there is nearly 200 million installed telephone copper wire lines in the U.S., and that DSL rides on existing copper, there is every reason to believe that Internet access will be largely accomplished through DSL.

The need for broadband will also be driven by the demand for new classes of applications, such as video teleconferencing, telemedicine, interactive TV (broadcast quality video), 3D, and virtual reality-based applications. These applications cross the B2C and B2B markets where entertainment will meet learning and synchronous and asynchronous communications.

DSL will compete with cable modems and wireless access to the Internet. Wireless looks strong—stronger than cable modem-based access to the Internet—but is lagging in deployment because of its newness and because of persistent line-of-sight requirements. Nevertheless, as wireless technologies mature, we can expect it to
take its place alongside DSL and cable within 2 to 3 years. If there is one industry that the cable industry fears it is the satellite access/content industry.

The demand for DSL services will grow as DSL is deployed, but the services will extend well beyond the core capabilities of DSL to include applications monitoring, hosting and even customization. In effect, just as ASPs are morphing into "solutions providers" (that must offer always-on, reliable connectivity) so too will smart DSL providers morph into a full service providers. Cable companies will move into the communications space through voice-over-IP offerings.

There is no question that telecommunications and broadband capabilities will drive significant aspects of pervasive computing. Cost-effective broadband connectivity will power the digital economy.

**Network Applications and Services**

By 2008–2010, we will see the full integration of voice and data with IP as the adhesive. Voice will be carried in every which way, and voice-over-IP will emerge as a mass market alternative to the PSTN over the same timeframe.

Unified messaging (UM; integrated phone, fax, pager, e-mail) is still a killer communications application. All next generation networks will provide UM. Convergence is already driving this (as evidenced) most clearly in the newest phones/Web access/pager/PDA devices. Stand-alone—or integrated—opportunities here should be monitored.

Optical networking (see below) will continue to gain steam. Once gear is deployed that can send signals over long distances without regeneration, and once the fiber-optic backbone is fully deployed, then applications and services opportunities will explode.

Network operating systems (NOSs) and network operating centers (NOCs) are changing dramatically, and quickly. As the Internet becomes the new public data network, the demand for services supporting this network is rising faster than the industry can define or provide them. Our trends analyses suggest that intranets will converge with extranets to create “virtual enterprise networks”—which will require complex support services. A key capability will be heterogeneous platform integration and support services.

Network and systems management is receiving more and more attention as more and more applications are integrated and extended outside of corporate firewalls. Performance tools that monitor and manage networks are numerous. In fact, there are over 50 network and systems management point solutions and over 10 “frameworks” that offer integrated network and systems management capabilities. Vertical frameworks will also emerge as network and systems management solutions.
Service providers in this space will have to offer multiple mobile and wireless network service capabilities, including wireless LANs, wireless loops, celluer/PCS, mobile IP, wireless ATM, and satellite access and support. Coverage issues, bandwidth, integrated applications, among other criteria, will determine which of these network topologies actually “wins.” Networks will be heterogeneous and service providers will have to integrate and guarantee the quality of multiple network combinations.

The wireless service industry is attracting lots of attention as wireless penetrates the market. Some of these companies are applications companies, while others are more wireless network service providers.

**Optical Networking**

Every indication is that the optical networking space will remain hot. Like the wireless space, the optical network space—and all of the derivative spaces (like photonics)—is developing capabilities in equipment, technology, and services.

There are a number of specific capabilities in the space. They are rank-ordered below.

- Optical service provisioning
- Passive optical network services
- Gigabit Ethernet over fiber switches
- Optical switches and transmission equipment
- Optical switching components
- Optical integrated circuits

In addition, the deployment of optical technology should be endowed with intelligence. Sycamore’s tagline—“intelligent optical networks”—makes good technology and business sense, and provides a key pervasive computing enabling technology.

The end game is an optical mesh network with an IP overlay that supports intelligent optical transport, flexible (multi-gigabit) service delivery, wavelength traffic engineering, optimization and management, end-to-end provisioning, and restoration—all of which is essential to the communications infrastructure necessary to support pervasive computing and continuous commerce.

**Touch Technologies**

Technologies that touch employees, customers, suppliers, and partners are exploding through applications that support new call center models, new customer rela-
tionship management processes, and new transaction processing capabilities. The proliferation of Internet access, broadband, and wireless access devices is fueling the requirement for enabling touch technologies.

On the list are voice over IP (and DSL), speech recognition, and client-side intelligent agents (discussed above). These technologies can power a variety of applications that dovetail with access and transaction processing trends. These applications support:

• Integrated messaging and chat (through instant messaging and related technologies)
• “Assisted browsing”
• “Web callback”
• Integrated eCRM voice/video/data
• Voice-enabled search
• Interactive training

These kinds of applications are enabled by touch technologies we should track.

Touch technologies close the loop between quality of service (QoS) applications and quality of experience (QoE) applications, or quality behind and in front of the firewall.

A PERVASIVE COMPUTING ACTION PLAN

The trends analyses we have conducted indicate some profound changes in the structure of the technology industry, changes that will have major effects on the way we do business. Taken together, they define a whole new suite of capabilities, capabilities that will define what computing Era 4—pervasive computing—will actually look like.

There is a shift occurring in the nature of the technology “platforms” being provided to small, medium-sized, and large customers. In the software area, we are seeing a proliferation of “me-too” packages: in fact, it appears as though the software industry is evolving faster than anyone predicted to packaged applications as the preferred software deployment strategy for all-sized organizations. This means that the software industry will be run by “professional” software developers and deployers (ASPs/TSPs), not by systems integrators (who will, nevertheless, still have plenty to do). The shift is from ownership of source code to the deployment and support of the code. ASPs/TSPs—which includes just about every service provider out there—will become the primary software delivery mechanism for the
industry. They will not develop primary software but will implement the software from other vendors, at least initially. Some ASPs/TSPs will implement their own software (such as Oracle, Siebel and SAP) competing, for a time, with the multiple channels that they have encouraged.

In effect, software will become “servitized”: buyers will not buy software, software implementation, or software support services from multiple vendors. Nor will they build complex applications in-house. If this trend—supported by adoption rates and surveys—continues, then the future will belong to those who combine software (plus all varieties of clients), support, integration and interoperability services. Enterprise applications integration will occur within these mega software service organizations (who will become expert at the use of EAI and IAI tools, Web services, service-oriented architectures, and all related middleware).

In addition to software-related services, we can expect the same buyers to force the integration of telecommunications (integrated voice, video and data) hardware, software, and services. Since much of today’s business is e-business, and since so much of e-business will be supported by TSPs, connectivity is inseparable from the development, delivery, and support of business models. This means that first generation ASPs will have to continue to include communications support to their customers and second generation ASPS (TSPs) will unquestionably provide “tethered” and “un-tethered” connectivity to their clients’ employees, customers, and suppliers.

We are also seeing the rejuvenation of so-called “old economy” companies who are rethinking their use of technology. Just as “neutral” B2B exchanges appeared at an incredible rate, just as quickly selected vertical industries pre-empted the neutral penetration of their supply chains by establishing their own exchanges. In a sense this represents the revenge of the verticals—who are using off-the-shelf software packages to implement their own controlled exchanges.

Finally, we are seeing a growing role for business and e-business strategists. But here too the prediction is that disembodied services—regardless of where they are along the margin continuum—will always lose to integrated services and, ultimately, integration solutions. Creative insight into supply chains and the creation of new business processes will drive the application of new technologies, but, again, it is the integrated services and solutions that will be the most appealing.

When taken together all of this spells pervasive computing. Without question the Internet protocol (IP) has revolutionized the way we store, process and communicate data, information, content, and knowledge.

The movement toward pervasive computing is well afoot: access devices will increasingly not be traditional laptops or desktops. PDAs and converged communications devices will dominate e-business and mobile commerce within 2 to 3 years. Software is changing and architectures are becoming more and more distributed:
just 10 years ago (when first generation client/server architectures were deployed) applications were still centralized, if not actually, then certainly conceptually. First generation client/server applications were viewed as extensions of mainframe-based applications, not as revolutionary architectures destined to replace their data center-based parents. Today new applications are conceived as distributed, deployed as distributed, and supported in the same way, often by a third party geographically distributed from the companies that built or bought them. The real impact is just this, a predisposition toward distributed transaction processing—and pervasive computing provides the enabling infrastructure to make the whole centralized/distributed architecture moot. But much more importantly, personal and professional transaction processing requirements can only be fulfilled by ubiquitous connectivity, always-on connectivity, and automated applications, among other capabilities.