Smart Health: A Flexible, Open Path to Community Health Interoperability

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Abstract

This paper explores the application of e-commerce technologies to healthcare and concludes that there is indeed a substantial opportunity to leverage both experience and technology from industry. We begin by discussing the major integration challenges encountered in e-business, and how they are being addressed through e-marketplaces and business service networks (BSNs). We then outline the design for a healthcare BSN for the Silicon Valley, and discuss implementation and adoption issues. We conclude by speculating about the implications of this approach for other Regional Health Information Organizations (RHIOs), the National Health Information Infrastructure (NHII), and the future of healthcare.

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1. Introduction

> American medical technology may be the envy of the world, but the US health care industry is downright backward with it comes to running its own business. While banks, airlines and other service businesses long ago embraced automation to perform routine tasks, technology has been slow to take hold in health care. The US medical system of mostly independent doctors is highly fragmented. Administrative and clinical procedures are rarely standardized. And insurers have different rules for everything … but thanks to the Internet, technology is slowly starting to simplify the business of health.
>
> — *The Wall Street Journal*, October 23, 2000

US healthcare is a highly fragmented enterprise, with complex paper-based processes that are inefficient, error prone, and often redundant. There are few standards for either the processes themselves or the data they generate. At best, these shortcomings create annoyance and waste; at worst, they pose a threat to the health of patients. These same shortcomings create formidable barriers to collaborative medical research and the rapid dissemination of research results into clinical practice.

Fortunately, Internet-based integration frameworks have helped solve similar problems in other industries, and there is good reason to believe that they will be equally effective in healthcare. Our optimism stems from a belief that healthcare faces integration challenges similar to those in other domains:

- Sharing data and information among heterogeneous systems that were never designed to interoperate;
- Automating and integrating ad hoc paper-based processes within and across organizations;
- Managing identities and authorizations across trust boundaries; and
- Minimizing the need for custom systems integration, so that small organizations can afford to participate.

2. The Evolution Of Business Services Networks

The fundamental challenge of e-commerce is enabling companies to do business with one another across a network, despite different business processes and computer systems. Traditionally, these problems were overcome through custom point-to-point (N2) interfaces or Electronic Data Interchange (EDI) networks. These expensive, time-consuming approaches make economic sense only when companies do a lot of business together. The promise of the Internet, by contrast, is an open e-business platform where companies can do business spontaneously with anyone, anywhere, anytime. Fulfilling this promise requires a radically new integration paradigm.

How can one connect business systems from multiple vendors that were never designed to interact? In the absence of universally accepted e-commerce standards, a two-step solution emerged. First, create many specialized Internet markets and trading communities, each focused on a narrow vertical or horizontal business sector (e.g., tires, logistics). By standardizing business processes and data formats for a sector, companies could connect once to the marketplace and do business with anyone in their industry. Second, integrate these vertical net markets through industry exchanges or regional hubs, transforming the net into a true global marketplace. Nearly four thousand vertical marketplaces have been created, along with about 75 industry and regional exchanges, such as Covisint for the auto industry, Asia2B for the greater China market, and claims clearing houses like WebMD in the healthcare industry.

E-marketplaces and clearinghouses suffer from several problems, though. Interfacing to them is difficult, which locks in users; using them is expensive because of per-transaction fees; and service offerings are limited because they are closed store-and-forward platforms. Claims clearinghouses, for example, do not offer real-time eligibility and claims tracking. Increasingly, companies are opting to connect directly with trading partners via the Internet.

Connecting directly is conceptually straightforward. In principle, every company can simply make available through its website the information that it wishes to share with trading partners – for example, the data included in the continuity-of-care record (CCR). The information is formatted using XML tags so that it can be understood by computers as well as viewed manually using a browser. In practice, however, key issues must be resolved, including whether and how tag names are standardized, how security (e.g., identity, authentication, authorization, integrity, attribution, and audit services) is managed, and how quality of service is assured.

Business Services Networks (BSNs) help address these issues, bringing the Internet closer to a truly open business integration platform. BSNs are Internet business communities where companies collaborate through loosely coupled business services. Participants register business services (e.g., schedule an appointment, make a payment) that others can discover and incorporate into their own business processes with a few clicks of a mouse. Companies can build on each other's services, creating new services and linking them into industry-transforming, network-centric business models.

BSNs can be public or private. They can be Internet-wide or focused on a particular vertical industry (e.g., retail, healthcare), horizontal sector (e.g., payment, logistics), or geographic region (e.g., Silicon Valley, the San Joaquin Valley). A retailer, for example, can build an online store in an afternoon by outsourcing fulfillment to Ingram, shipping to Fed Ex, and payment processing to Citibank. High-tech manufacturers can eliminate billions of dollars in returns and write-downs by polling the real-time "inventory services" of thousands of distributors and resellers. Although capable of spanning global industries, BSNs can grow organically, beginning with one company publishing a single service that another company subscribes to.

BSNs represent the latest stage in the evolution of Internet commerce: from "swivel-chair" integration to hard-coded interfaces to lightweight web service application programming interfaces (APIs). BSNs extend web services for inter-company use, first by using business services and documents to integrate business processes rather than applications or systems that were never designed to be integrated, and second by using shared utility services to harden the security and manageability of web services. The potent combination of loose coupling through registries and documents, shared utilities, and organic growth reduces the cost, complexity and risk of large-scale enterprise integration projects.

3. Smart Health

> "Silicon Valley led the way in inventing information technologies. Now, we need to lead the way in employing them intelligently for broad social purposes."
>
> — Eric Benhamou, Smart Valley Chair; Chairman, 3Com Corporation and palmOne, Inc.

Smart Health is an open Internet-based healthcare BSN being developed in Silicon Valley. We have partnered with Smart Valley, a community action program whose goals are improving quality of life for Valley residents while creating economic opportunities for local companies.

Like other community health initiatives, Smart Health will provide a simple and secure way to electronically share patient data across organizations. However, unlike previous initiatives, Smart Health will be built on an open BSN platform, whose service-oriented architecture imparts important benefits, including:

- Reduces the time and cost of deployment, and enables the network to grow organically, without a central bureaucracy or a central patient registry.
- Encourages widespread participation from diverse participants including providers, payers, patients, pharmacies, labs, government agencies, and consumers, as well as third party software and service providers (e.g., clearinghouses, billing services, contract research organizations, data mining)
- Enables experimentation with different technical approaches (e.g., security, data models, (de)centralization), which is important given the lack of consensus about the "right" architecture for local health networks
- Supports the exchange of both administrative and clinical data (and ultimately, research and public health data, too)
- Creates a test bed for innovative health processes and services, ultimately extending from "bench to bed." For example, payers can offer services that enable providers to check a patient's eligibility and submit and track claims in real time, and providers can publish services for scheduling appointments, and use services to order labs and e-prescribe.

Smart Health will link the region's clinics; community, county and tertiary-care hospitals; and small and large physician practices through real-time electronic medical records and claims processing. We will start with a few institutions that share a specific business problem and will encourage new organizations to join the network organically as their business needs support it. Legacy services, including EDI-based claims networks, clearinghouses and third-party billing services will be wrapped as business services to rapidly expand the functionality and reach of the network. A web portal will enable consumers to view their health data along with the status of insurance claims. A similar web portal will provide a hosted electronic medical record (EMR) service for small providers who lack systems of their own. Pharmacies and labs will be recruited early to add valuable data (prescriptions filled, lab results) to the network.

4. Our Architectural Approach

Smart Health will be a distributed peer-to-peer web services network based on the eCo reference architecture. This reference architecture describes how business services, documents and grid (utility) services work together to create enterprise-grade security, interoperability and manageability, beyond that provided by basic web-services standards (e.g., SOAP, WSDL, UDDI).

Business Services are transaction processors with publicly-defined Document interfaces: they are invoked dynamically by documents (e.g., sending them a purchase order, an invoice); and they respond in kind (e.g., by returning an acknowledgement, a receipt). Behind the scenes, business services in the Smart Health architecture will rely on distributed, web service utilities called Grid Services to route documents securely and reliably.

4.1 Business Services

Business services have long been used in distributed computing frameworks to provide simple ways of accessing a company's core processes. A manufacturing company, for example, could offer services that enable customers to "search a catalog," "request a bid" or "place an order." A physician's office will use Smart Health services to "request a medical record," "submit a prescription," or "check eligibility."

In distributed computing, services are accessed through proprietary application programming interfaces (APIs). Unfortunately, APIs are complex and proprietary, designed to interface idiosyncratic computer systems rather than generic business processes. That's part of why traditional systems integration is so costly and time-consuming.

4.2 Documents

Documents are ideal interfaces to services; they are how healthcare organizations communicate today, routinely exchanging documents via mail, EDI, and fax. Because of this ubiquity, many common healthcare documents (e.g., medical records, referral letters, immunization records, claims-related explanations of benefit) will become de facto standards. Unlike traditional, tightly-coupled software APIs, with their multi-step calls and unstructured argument lists, the information in documents is easy for people to understand, and it's often structured so that machines can easily 'understand' it, too.

Integrating services loosely through the exchange of documents is fundamentally simpler than coupling them tightly through APIs. Organizations need only agree on the type of information in a document (e.g., patient DOB) and the format of the information (e.g., MM/DD/YYYY), not how that information is processed. Each organization can then utilize the information freely in its own processes and systems. When a service receives a document, rules can route it to an application or another service for automated processing, or to a person for manual processing. Documents thus provide an intuitive way of integrating people and services over a network.

4.3 Grid Services

In the Smart Health architecture, web services called Grid Services provide utility functions that facilitate cross-organizational processes. Because these services are shared, utility-level functionality doesn't need to be replicated in every application.

Registries tell organizations how to do business with each other. Each organization can publish a listing of its available online services, which documents to use in interacting with those services, and in what order the services should be utilized.

Security includes identity, authentication, authorization, integrity, attribution, and audit services. Identification services enable a system to 'recognize' a user, generally through unique, machine-readable names. Authentication services ensure that an entity is who that entity purports to be. Authorization services ensure that people and computer systems can use only those resources that they are authorized to access and for only the purposes for which they are authorized. Integrity services verify that the data is intact and has not been modified by unauthorized resources (human or automated). Attribution services confirm that actions performed on a system are attributable to the persons that performed them and that actions cannot be repudiated. Audit services provide a record of all attempts to access or modify data, and include both logging and retrieval services.

Provisioning is how subscribers sign up to use a service and customize it to work with their systems and processes. Each subscriber can specify preferences such as how they want to receive new information (e.g., fax, email, alert in EMR); security (passwords, Kerberos tickets, private-key signature challenges), or which decision support protocols they want to use (e.g., American College of Physicians, their own custom protocols).

Interoperability Services provide on-demand data mapping and protocol transformation. The architecture is standards-agnostic, supporting standards when they exist and relying on provisioning or negotiation ("tell me what standard to use") and translators when there are none, or when organizations can't agree on which one(s) to use. This pragmatic approach, which we call aggressive interoperation, is a key differentiator because it allows everyone to use whatever standard they want, and to map dynamically when necessary. That said, we will require that all participants map once to a common Smart Health standard, which is significantly more efficient than point-to-point N2 mappings.

Grid services are the essence of the eCo architecture because they enable companies to do business without significant integration or prior agreement on standards. Companies can consult the registry to learn various ways of communicating with a particular trading partner, and then select their preferred option during provisioning. For example, a large supplier could register with an OEM customer to receive purchase orders in SAP format in real time via FTP, whereas a smaller supplier might opt to receive its purchase orders in Excel format, batched and emailed once a day at 4 p.m.

Grid services also encourage the development of light-weight business services that derive most of their functionality from other services. Utilities like registry lookups, provisioning, process management and other support functions can be obtained through global subscription, rather than building them into each service. A basic Smart Health service, such as a claims processing service, might just route an incoming claims attachment to the right person, application or business service in the receiving organization.

5. Instantiating the Architecture for Smart Health

There's no, one 'right' solution to the knottier problems of integrating medical information systems. Invariably, there are many choices to be made along the continuum of system design, e.g., from centralizing everything about a patient, to centralizing nothing. Smart Health defines a minimal set of architectural 'fixed points' that allow the architecture to accomplish the stated goals while preserving the flexibility to experiment with alternative implementations and accommodate new services. We used basic models of healthcare data and workflow to define these fixed points:

- What federated transactions and data does Smart Health support?
- Who are the principals – both organizations and individuals – that can access and control these data and transactions? How are they identified?
- How is the system secured?
- How is the system extended to new participants and to new services?
- How is data viewed and tracked?

5.1 Transactions & Data

The most basic goal of the system is to facilitate the exchange of patient data between healthcare stakeholders for care delivery. The data will also be used for services such as registration, documentation, decision support, and billing. Examples of transactions that the system will support include:

- Request medical information
- Submit orders / prescriptions
- Request results
- Request consult / send referral
- Check or confirm eligibility / reimbursement rate (patient, drug, provider)
- Submit and process claims

Of course, all transactions will be HIPAA-compliant. In addition, Smart Health will utilize the following standards:

- HL-7
- Clinical terminology, such as SNOMED, LOINC, ICD-9, CPT-4, NDC
- CCR

5.2 Identification of Principals

Physicians: HIPAA requires a unique identifier for all physicians in the US. This unique national provider identifier (NPI) will be used to index a provider registry. Since most institution's legacy systems either won't support NPI, or will only support it for their own physicians, Smart Health may host this registry for all participants. In its early form, the registry will require only provider name and identifier; later versions may include additional physician directory information (location, hours, languages, degrees, certifications, etc.).

Patients: Healthcare organizations typically have at least one, and, in the case of hospitals, multiple, patient registries. Much as some community data exchanges and large institutions like Kaiser have developed a master patient index (MPI), we will create one or more patient registries containing a record of where the patient has been seen and for what condition(s). These will be federated, so that a search of one relays the query to all of the other registries in that federation. Essentially, the federated system will answer the query 'who has records on John Smith?'

Initially, we will rely on one-time patient questionnaires and centralized, shared de-duping services to populate these registries. Because de-duping is both relatively expensive in terms of the time it takes and a potentially error-prone process, the system will support caching both for reliability and speed. This cache will be indexed by a concatenated form of the patient's unique identifier at each participant facility (e.g., SiliconValleyHospitalX:123567). The Smart Health community will agree on the basic requirements to establish a firm 'match.' Only firm matches will be cached. Each individual facility can optionally establish less restrictive match criteria. Any such optional-matches can be forwarded to the facility for independent review. This may occur in a number of ways, including something as simple as forwarding an email to the system administrator at the receiving system, identifying a less-intense patient match.

5.3 Roles and Security

Securing federated systems is notoriously difficult, because we are expanding the system 'perimeter' by combining multiple systems. One participant's undocumented assumptions, which they relied upon during design, can easily violate or be violated by other participant's systems, which don't share the same assumptions. All participants will trust all other participants to 'tell the truth.' However, if Hospital-B has looser security standards than Hospital A, Hospital B's trust in its own security process is not sufficient for Hospital A to feel confident that security has been maintained.

Further, we must avoid the trap of designing to a compelling (but false) threat model. Non-technologists often assume that end-point applications are secure, and that risk exists primarily within the Internet, which they consider insecure and easy to 'wire-tap.' In reality, the situation is the reverse. Because of the way packets are routed on the Internet, it is extraordinarily difficult to 'steal' data en-route, or to meaningfully interpret it even if it is accessed. With simple data encryption, the Internet is, for all practical purposes, a secure network. In contrast, people routinely share passwords or use insecure passwords (e.g., their child's name) to access legacy applications. This makes it extremely difficult to reliably tell who did what on the system.

Consistent with this more realistic threat model, Smart Health will rely on a small (albeit distributed) trusted computing base that robustly supports principal identification and activity logging. Although the system will make reasonable efforts to ensure all actions are legitimate and appropriate, as in the real world, a participant's final recourse will be detection and prosecution of error and malfeasance. Thus, although the system will use digital signatures and encryption, and will enforce authorization models, Smart Health will *emphasize* audit functions. Through these, we will know with high assurance the identity of everyone who uses the (federated) system, we will log every step these users take, and we will log every action the system makes on their behalf.

Each organization will continue to have its own unique policy for *identification*. For patients, this will probably include a simple password or challenge / response login. However, since trust is not transitive and a wrongly identified user can have system-wide implications at the organizational level, Smart Health will establish minimum requirements for verifying the identity of institutional users. Specifically, we will require that a token (e.g., USB dongles, smart cards) or physical feature (e.g., fingerprints) be used for identification.

Institutions will be *authenticated* by Smart Health, which will maintain a trust root (hosted or outsourced) for the system. Institutions, in turn, will be responsible for authenticating their users. County or state medical societies and professional organizations will credential users who are not attached to an institution (e.g., the CMA can authenticate sole-practitioner physician).

Each organization will also set its own policies on the level of *authorization* necessary to gain access to information. This includes establishing role-based policy around what each player can do, including whether agency is supported. For instance, one institution might establish a policy that only physicians can retrieve cross-enterprise information, while a small physician practice might establish an agency relationship between the physician and any RNs working in the practice.

Audit services provide a record of all attempts to access or modify data, including time / date stamps and identifying information about the user, the services invoked, and any actions taken. HIPAA-compliance is really the minimum standard that has to be met; the potentially more challenging set of requirements may come from the users themselves. When medical information begins to be shared, experience at the Santa Barbara Care Data Exchange indicates that patients will want to know who's been accessing their medical information, and why. Thus, Smart Health will capture and maintain robust logging data, which organizations will be permitted to query. The most common types of queries will be supported real-time, but all data exchanged will be retrievable in an intact form. Finally, in addition to detailed logging and query capabilities, Smart Health will develop a series of velocity checks to identify any unusual user behaviors. This is analogous to an ATM network's daily limits on cash withdrawals, or Visa's scrutiny of the geographic locations of same-day transactions.

5.4 Extensibility

New Participants: Participants will interface backend legacy systems with the Smart Health platform by using a Smart Health adapter. This adapter, implemented on trusted hardware, will route documents to the appropriate person, application or service, and will store data that legacy systems don't account. The adapter will use grid services to do registry lookups, schema-based data mapping, and logging, audit, and identity mapping.

Registry lookups, logging, audit and identity mapping have been described in detail already. For data mapping, Smart Health supports a 'connect-once' model. While each institution and vendor will be free to use whatever data schema and standards they desire, we will require each institution or vendor participant to map their data – once – to the Smart Health master schema, which will utilize the standards listed above. When organizations or vendors have employed standards-based data models, this mapping should take little effort, typically only a few hours to a few days.

Smart Health will provide open source adapter templates and code, so that healthcare organizations with sophisticated IT resources and application vendors can develop their own. Smaller users will rely on their vendors, consultants and outsourcers, or may access the system through a hosted portal, described in §5.

New Services: A fundamental tenet of BSNs is that they will promote the creation of innovative new services. These services will be identified in a UDDI services registry, which describes what they do, their document interface specifications, and governance policies. Vendors and participants will be able to publish their services in the registry. Any participant looking for a service would use this registry to find the available suppliers and to understand the terms of use.

5.5 Data Display & Provenance

With a virtual EMR, information comes from both within and outside of an organization's system. Thus, there is a pressing need to be able to understand not only content (e.g., the patient's allergies), but also the origin of the information (e.g., the patient's primary care provider), as well as the timing and source of modifications made to it (e.g., the hospital the patient was discharged from yesterday).

If the institution's legacy system doesn't have the ability to read integrated data (i.e., data from multiple sources), Smart Health will provide a universal viewer that can display both legacy and retrieved data. Once the data has been translated via the adapter (which is required for any data display), this becomes a relatively mechanical process. The Smart Health architecture recognizes that healthcare data has different degrees of 'changeability.' Index data is relatively static, and thus is cached for performance reasons. Health and access data, on the other hand, is relatively dynamic and thus is not cached, both to minimize security concerns and to ensure that the data is up-to-date.

Integrated data display raises a fundamental issue: can the receiving institution import new data into their legacy system? Such data-merge functionality potentially opens a Pandora's Box of data provenance (lineage) and interpretation questions. If the user receives conflicting information, how do they know which information takes precedence (unless they understand the data sources)? Additionally, if there is room for discretion on how to interpret the data, how can the records be merged? For example, if a patient's temperature is reported in Celsius on one system, or the patient is simply reported as having a 'fever,' then there is significant room for interpretation if the other system reports temperature in Fahrenheit.

Today, provenance is not handled by most EMR applications, which were designed as enterprise applications. Similarly, while most EMR applications allow for significant customization, to the point where providers can document in their own 'vocabulary,' these same systems typically don't offer sophisticated semantic or ontological services, making it difficult to establish equivalencies.

In the first release, any retrieved data will be wrapped with metadata so that the data can be understood in context. It will be up to the receiving institution to decide what to do with the data (e.g., to import it into the record electronically, to review and dump it, to print it and file it, etc.). In subsequent releases, we expect the Smart Health system to allow the legacy systems to merge CCR-formatted records, since they have a standard construction. HL-7 describes draft standards to address this issue in a recent whitepaper,1 which will ultimately drive the required additional functionality into EMR applications. In later phases, attribution will more likely be handled as a shared service provided by the platform.

5.6 Summary

In the Smart Health instantiation, we have established certain base principles for participating organizations and patients.

Organizations: Each participating institution must agree to install a trusted computing base and support Smart Health policies, which include:

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[1] HL-7 EHR-SIG, *Electronic Health Record System Functional Model and Standard, Draft Standard for Trial Use (EHR-S, DTSU).* http://www.hl7.org/ehr/downloads/index.asp

- Specifying the identity of authorized users in a secure server (e.g., LDAP)
- Supporting certain minimum security and identity standards (e.g., the level of credentialing before you put someone into this directory)
- Supporting a basic transaction set (e.g., data display)
- Committing to use token-based (e.g., dongles, smart cards, etc.) or physical-feature authentication for anyone who can 'command' the system
- Mapping their data to a standard schema (which is probably HL-7 / CCR)

Patients: The requirements for patients sound relatively straight-forward, but require significant cultural shifts on several levels. They include:

- Assuming responsibility for the quality and distribution of their healthcare information, or delegating this responsibility to someone else (e.g., their spouse, their physician)
- Protecting their data by using secure passwords, and changing them with relative frequency.

6. Jumpstarting Smart Health

Wanting to jumpstart Smart Health, we used our experience with the early Internet boom and with B2B ecosystems as sources of inspiration. The Internet is perhaps the best example of the viral and organic growth of an idea; as quickly as barriers to adoption were identified, new technology was developed to surmount them. As the pool of users grew, human ingenuity created a vibrant 'stew of ideas,' from which new uses were launched exponentially. Most of the "jumpstart" ideas are focused on driving access, adoption, and expanding use by tackling the most significant barriers to health information exchange: the entropy of current processes, the mammoth task of populating clinical data, the lack of accessible 'viewer' capabilities, and the perceived complexity of the technology's security, utility, and management. These include:

- HIPAA-Compliant "Hotmail"
- HIPAA-Compliant "eFax"
- Personal Portals
- Web Service Wrappers
- Agents and Screen Scrapers
- Internet "Terminal" Appliance
- Open Source Service Repository
- Seed Application Services

6.1 HIPAA-Compliant "Hotmail"

Just as web-based email services like Microsoft's Hotmail and Yahoo jump-started email for the masses, Smart Health "Hotmail" will be a way that healthcare stakeholders can immediately – reliably, securely – communicate electronically. Smart Health will offer a secure, web-based email service for patients, payers and providers to request and exchange electronic documents (e.g., claims, medical records, etc.). This service will be accessible through both browsers and web service interfaces, which will allow recipients to either view the document 'as-is', or to download it into a web-services compliant application.

6.2 HIPAA-Compliant "e-Fax"

An e-fax service will integrate paper documents into the "Hotmail" world. This service will allow paper documents to move into the electronic world through a fax or scanner. Small amounts of metadata will be attached to the e-fax file to facilitate filing and retrieval, thus allowing users to manage all the information electronically, and paper users to maintain their paper and, at the same time, manage their extended workflow electronically. Electronic documents create the opportunity for asynchronous and spontaneous workflows, because staff can send, receive, track, and audit documents without ever leaving their chair. Never again will they have to remain on eternal hold to see if a document had been received.

The importance of aligning with existing processes was painfully demonstrated when General Motors launched an e-procurement service. Only a tiny fraction of the possible benefit from their $85 billion annual spend was realized, because the e-procurement service failed to capture existing deal flow that was being managed with faxes and EDI.

The combination of these two services will allow Smart Health users to capture immediate, tangible benefit. Additionally, documents that are authenticated through electronic signatures are both more secure and more private. New web-based forms that automate existing reporting (e.g., Worker's Compensation first report of injury) can be designed, and then extended to provide new functionality like easy patient permissioning for more granular data sharing (e.g., time or condition-limited information sharing).

6.3 Personal Portals

Yahoo, and later MyYahoo, became the default home page for millions of Internet users by aggregating content in a way that made the web useful. This approach was critical to the early growth of the Internet, and portals will offer patients and providers similar, web-based access to their medical records. Portals can compete by offering value-added services, such as access to relevant medical information (e.g., disease-specific educational material); local storage of frequently retrieved documents; or even a simple, hosted EMR application for the thousands of physicians and millions of patients who don't currently have access to an EMR. Moreover, the collective impact of many users and many records can stimulate the creation of new content- and process-rich services, for example, individualized medical searches in response to a newly-diagnosed condition, or formatting a child's immunization record for their school or camp registration. In this way, web-based portals have the potential to profoundly transform the way EMRs – and the health data they contain – are structured and used.

6.4 Web Service Wrappers

Web service wrappers are lightweight connectors that allow organizations that already provide browser-based applications and data access (e.g., checking claim status, reviewing an EMR) to quickly provide direct machine-to-machine access. Web service wrappers represent a simple entry strategy for new network participants, and are more efficient than screen scraping, a technique that allows a user to 'copy' data from someone else's web-site.

Web service wrappers offer another significant business advantage to organizations that adopt them: they allow network participants to deeply imbed themselves into the extended processes of partner organizations. Destination sites like Amazon, Google and eBay have provided web services interfaces to partners, making themselves both "sticky" for the customer and effectively indispensable as channels for their partners. Their partners also benefit by becoming more agile; because they don't have to build a better distribution channel, a better search engine, or a better online auction, smaller partners can participate, further enriching the marketplace.

6.5 Agents and Screen Scrapers

Screen scraping allows users or applications to collect data from another system's display, which was not meant for data transport. By collecting this data from multiple sources, users can create whole new services that utilize someone else's data. Services in consumer banking, for instance, used screen scraping to give consumers the ability to aggregate their bill paying and banking activities by capturing detailed information from consumer-specified 'detail' sites (e.g., a bank or one of the consumer's creditors) in a single, central location (e.g., their bank or ISP's portal). When web-service interfaces do not exist, we believe that consumers will similarly use Agents and Screen Scrapers to populate their personal web-based EMRs from Internet-accessible legacy medical records systems. Once significant data has been populated in the portal, it becomes a powerful place for providers and patients to sit down and review, discuss, and edit the information.

6.6 "Terminal" Internet Appliance

Just as 'green screen' emulation opened up legacy mainframe systems to client-server applications, Terminal Internet Appliances will enable legacy front- and back-office provider applications to participate in Smart Health. The appliance will be trusted hardware that uses terminal emulation to connect legacy applications (e.g., PMS, EMRs) to the Smart Health network through the Internet. Our proximity to the technology wizards of Silicon Valley allows Smart Health to benefit from disparate experimentation around the role of hardware in data exchange networks. These same appliances can then be used to integrate multiple, legacy systems within an organization that are currently hampered by its legacy systems. We have already seen creative use of such new hardware in a global network built by British American Tobacco, which used hardware to integrate data between their corporate offices in London, and their businesses in third world countries in Africa and Asia.

6.7 Open-Source Repository

Market fragmentation has created multiple, proprietary platforms, and thus a fundamental barrier to interoperability across organizations. The argument for open source is simple: the fastest path to interoperability is when everyone uses the same code to communicate. BSNs will be fueled by open source standards and code in much the same way the Internet was. An open source repository of Smart Health-compliant Internet grid and application services, along with toolkits and document templates, provides a way for technologists to incorporate the code into proprietary platforms and for healthcare organizations to publish and subscribe to new services through the repository. This repository is analogous to SourceForge, the largest open source software development web site, which provides a centralized place for almost a million open source developers to control and manage open source software development.

6.8 Seed Application Services

Smart Health will find, recruit and, if necessary, host initial application services to attract participants to the network and prime the innovation pump. Experience in B2B procurement has shown that a critical mass of functionality is essential for widespread adoption. These services may be provisioned from other regions, donated by local vendors, or launched specifically for Smart Health. In determining which services to offer, we considered the needs of the various stakeholder groups:

- Large-scale healthcare providers already have major back-end systems with their own comprehensive records, and their own way of doing things. Such users will likely provide (build, commission, operate) both their own application services and their own connectors to interface their backend with the Smart Health platform.
- Medium or specialized healthcare providers, such as clinics have their own systems, and thus also need connectors. However, it is more likely that consultants or application vendors will provide this service.
- Small healthcare providers are most likely to have informal, often manual, systems. For them, we need to support a hosted model, which will be fully integrated with the Smart Health platform.

In order to drive adoption, Smart Health will also provide hosted EMRs and portals as default applications on a short term basis. Once they are commercially available in the market, these services will be transferred to commercial vendors. In addition, Smart Health will provide a patient de-duping application (service) and provider, patient and service registries – again, short-term – to support the grid functions.

7. Conclusions

Smart Health leverages state-of-the-art e-commerce components – specifically web services, the Internet, and BSNs – to significantly reduce the risk of deploying health information networks. Hosted solutions and self-provisioning minimize the need for systems integrators, allowing small and medium players to participate, thus driving wide-spread adoption. These same e-commerce components enable us to provision services from other regions (so we don't have to reinvent something being done well), and to provide services to other regions (so they don't have to reinvent something we're doing well). We see this mutual, regional provisioning as a model for how the NHII will evolve and scale over time.

The Smart Health architecture will be robust enough to meet the stringent demands of clinical and administrative processes, yet flexible enough to support both the experimentation that attends emerging standards and regional differences, and the explosive innovation of new products and services that historically accompanies technology-driven transformation. In this way, Smart Health benefits particularly from its proximity to Silicon Valley. Our extraordinary access to both high-tech and bio-tech creates pressure to apply technology for the betterment of our community, and allows us to be a living laboratory for the new products and services developed here. An important part of our mission is fostering a new, more entrepreneurial model in healthcare, by creating partnerships between vendors and local providers that promote translational medicine.

Much as the web changed business, it will change healthcare. Imagine an oncologist having real-time access to chemical assays on a patient's tumor specimens to design a custom chemotherapy cocktail for that patient, or researchers using nearly real-time, blinded data from day-to-day clinical encounters to create virtual, stage-IV clinical trials that uncover interesting off-label applications for drugs. New services like these will transform the way that medicine is practiced, reducing the time for research to move from bench to bedside and personalizing medicine in ways we've barely imagined. Networks like Smart Health are one of the first steps in this transformation.