Abstract—From rural United States to the battlefield and beyond, connecting patients with their formal and informal caregivers, along with emergency response workers—as well as providing each party with essential information that improves outcomes—are daunting challenges. There is currently great concern in the healthcare industry over health information technology (HIT), including high cost, security and privacy problems, health information exchange (HIE)\(^1\) failures, and weak decision support. In addition, universal connectivity is hampered by last mile connectivity\(^2\) and bandwidth constraints, poor interoperability, disaster vulnerability and other communication problems.

Managing these challenges and concerns requires convenient, economical, secure, durable, flexible and easy-to-use, patient-centric HIT systems. These systems must deploy truly useful software applications and network architectures that help improve healthcare quality, safety and efficiency by enabling/promoting:

- Fluid exchange, transformation and personalized presentation of relevant cross-disciplinary health information
- Rapid dissemination of evolving evidence-based decision support to clinicians and patients
- Seamless communications between disparate data silos and with people in remote locations
- Survivable and sustainable connectivity even in disaster situations
- Timely delivery of de-identified patient data to researchers.

That means twenty-first century HIT systems must operate quickly and stably in a wide variety of situations and settings, including locations where Internet access is intermittent or sluggish. This means the US needs to embrace next-generation HIT if it is going to contain healthcare costs, radically improve care and lead the world into the twenty-first century.

\(^1\) A HIE is a service that enables the electronic exchange of healthcare information across organizations within a region, community or hospital system.
\(^2\) Last Mile Connectivity refers to the "last mile" or "last kilometer" is the final leg of delivering connectivity from a communications provider to a customer.
solution, the U.S. lags as much as a dozen years behind other industrialized countries in the adoption of HIT [1], [2], [3].

In addition, fragmentation, poor collaboration, resistance to change and doubts that adequate transformation is possible are some of the issues that complicate a resolution of the crises.

A. Fragmented Model Creates Disconcerting Alphabet Soup the Diminishes Understanding

Recent attempts to find a solution to the healthcare crisis—along with two decades of failed federal healthcare reform interventions—has given rise to a dizzying array of terms, such as: Health Information Exchange (HIE), Meaningful Use (MU), Disease Management (DM), the Patient Centered Medical Home (PCMH), Computer Physician Order Entry (CPOE) and Electronic Health Record (EHR) systems, Project Direct, Community-based Care Transitions Program (CCTP), Community Based organizations (CBO), Continuous Quality Improvement (CQI), Accountable Care Organization (ACO), Vertically Integrated Provider (VIP), Value-Based Purchasing (VBP), and. This complexity makes the situation difficult to understanding, which leads to fear, uncertainty and doubt.

B. Independence versus Collaboration

There has long been a rift in American healthcare regarding the independence of individual clinicians/practitioners and attempts to strengthen collaboration among these and other providers in order to improve care coordination and outcomes. Unlike integrated care organizations, such as ACOs and integrated healthcare delivery system (e.g., Kaiser Permanente), these providers do not come from a culture where focusing on close collaboration and teamwork replaces the desire for independence. The challenge is to find ways for independent practitioners to collaborate in a way that improves care effectively and efficiency, without losing their sense of independence.

C. Many Providers Continue to Resist Meaningful Change

Many providers resist meaningful change for financial, organizational and personal reasons [4]. Regarding HIT, their resistance comes from the cost of software, hardware training, unintended consequences, and lost productivity due to time required for data input. These costs can far exceed any monetary incentives and result in diminished income, revenue and profit [5].

D. Adequate Positive Transformation of the Healthcare System is in Doubt

The Health Reform Law [6] is under attack and there are many concerns about its ability to transform our fragmented and poorly functioning healthcare system into one that can control cost and improve quality. Troubling issues include the incredible complexity of the problem, vested interests who want to maintain the status quo, economic models that reward waste and inefficiency, resistance to change, issues of autonomy and control, inadequate HIT architectures and applications, and a serious knowledge gap. The situation is even worse than most have assumed as evidence by recent research showing that adverse events in hospitals appear to be ten times greater than previously measured [7].

Despite these daunting challenges, however, the crisis in healthcare can be resolved.

III. STRATEGIES FOR RESOLVING THE HEALTHCARE CRISIS

Many individuals and organizations, including states and the Federal government, are currently evaluating and experimenting with strategies for resolving the healthcare crisis through systemic transformation. In Pennsylvania, for example, one of the authors (Monasteri) has been engaged in local and statewide efforts to define the problems and potential solutions.

A. Efforts in Pennsylvania

The following describe the efforts of two Pennsylvania organizations to transform healthcare in their state.

1) PAeHI Leading the Transformation in PA: PAeHI is leading the drive to establish widespread adoption of HIT in Pennsylvania [8] and recognizes the need to build a sustainable model for health information exchange in the State [9]. This organization has, therefore, initiated a go forward strategy exploring areas of need within Pennsylvania, including problems with health-related: 1) education, 2) efficacy, 3) meaningful use, 4) medically managed wellness, 5) network and application technology, 6) patient advocacy, 7) quality management, 8) revenue-cost and profit transparency, 9) small business survival and 10) the unintended consequences of health information exchange.

2) NEPA HRTF—Stakeholders Outline Their Concerns: The NEPA HRTF identified possible ways able to provide quality, accessible and affordable healthcare for all Americans [10]. They concluded that the critical areas of technology to be leveraged include: 1) RAS, 2) privacy and security, 3) collaboration and coordination of care, 4) effective use of patient information for research into best practices, 5) emergency care, 6) E-prescribing and information exchange, 7) interoperability, and 8) cost/profit control.

The NEPA HRTF developed, and is continuing to investigate, an HIE sustainability market research model [11]. This model identifies the following key requirements for sustaining HIEs across the country:

- A healthcare delivery culture, cost structures and its value chain that reflect a value based

An adverse event is any unfavorable and unintended negative consequence of care.
revenue stream exhibiting decent return on investment (ROI) and price transparency

- An integrated supply chain in which players prove that they are providing high quality products and service that:
  - Provide a single workflow, linking together pharmaceutical and insurance companies, medical equipment manufacturers, doctors and patients
  - Focus on implementing six sigma methods and lean healthcare delivery approaches
- A committed and trained work force dedicated to continuous quality improvement, education and the integration of “sick-care” and “well-care” that:
  - Require the use of instruments like the ISO 9000 certification of hospitals and medical practices and specialty providers such as MRI, radiology and other lab facilities
  - Provide a means for health facility quality reporting.
- A commitment to support innovation that provides ample security and privacy controls, including encryption and trusted partner agreements
- Guaranteeing economic survivability of small businesses, while incorporating community based compassionate care through medical managed wellness.

In addition to such state efforts, the Federal government has launched its own initiatives.

B. Federal Government Initiatives

The cornerstone of the Federal government’s initiative is the Patient Protection and Affordable Care Act [12] whose strategy contains numerous reforms to healthcare delivery and payment. These reforms include provisions for: 1) increasing access to information on the quality of care; 2) addressing the imbalance between primary and specialty care by increasing primary care Medicare and Medicaid payment rates; 3) establishing new healthcare organizations that are accountable for both patient outcomes and the resources devoted to care; 4) ensuring uninsured people with pre-existing medical conditions find coverage options; 5) reducing health disparities in low income, minority and other populations; and 6) supplying better information, tools, and technical assistance to ensure essential services are provided efficiently and effectively.

C. A Strategy for Dealing with all this Complexity

Due to the complexity of the problem, America must implement a multifaceted strategy to resolve the healthcare crisis through significant systemic transformation. The remainder of this paper focuses on the role of HIT in transforming the healthcare system.

IV. STRATEGIC HEALTHCARE REFORM AND HIT

To have a viable and sustainable American healthcare system, we must implement a strategy that, at the very least, improves healthcare quality and lowers costs. This strategy, therefore, must focus on increasing the effectiveness, efficiency and safety of products and services focused on “well-care” (prevention of illness and self-management of chronic conditions), “sick-care” (treatment of illness and dysfunction), and emergency-care for individuals and populations [13]. We have identified seven primary objectives for this strategy, in which HIT plays a crucial role.

A. The Seven Strategic Objectives

The strategy’s primary objectives are to foster realization of the following seven objectives:

1) Coordination of care: Coordinating care aims to reduce the likelihood of treatment errors, as well as duplication of tests and procedures, through secure and timely exchange of patient and treatment information

2) Collaboration among providers: When providers treating the same patient form tightly organized, continuously communicating teams, care improves because: 1) each person has specific tasks and roles, similar to a car-racing pit crew [14] and 2) the transition of care from one provider to another is done smoothly and effectively; this may include community-based organizations that provide care transition services from inpatient to outpatient [15]

3) Growth and dissemination of ever-evolving evidence-based knowledge: This knowledge is presented as useful preferred practice guidelines that support diagnostic, treatment and preventive care decisions

4) Shared decision-making that engages patients: When patients and their providers engage in shared decision-making, outcomes improve because their providers: 1) educate them about care options in understandable language and 2) take into account patients’ individualized needs, circumstances and preferences [16].

5) Easy and secure patient access to their own health information and its presentation in a way that enables them to manage their health effectively: Outcomes improve when patients easily access secure health information that enhances their level of awareness and understanding

6) Better community health: Improvement in the health of communities can be achieved: 1) through ongoing biosurveillance and post-market drug & medical device surveillance that rapidly notifies all relevant parties when there is a threat to public health from biologic terrorism, epidemics, dangerous and ineffective medications and equipment, and other such health-related crises [17] and 2) by assuring patients’ immunizations are up-to-date.
B. HIT’s Potential, Results and Gaps

HIT plays a crucial role in achieving each of these seven objectives. A review of recent studies showed mixed—though overall positive—effects of HIT on key aspects of healthcare quality and efficiency [19]. While this is promising, conventional HIT has serious functional gaps that cause today’s software architectures and applications to fall short of what is ultimately needed. The reason is that, for the most part, conventional HIT does not do enough to:

1. Enable easy, low cost, durable connectivity/communications among all stakeholders in all situations and environments.
2. Enable global interoperability.6
3. Help coordinate care across the entire healthcare continuum, including all types of providers, pharmaceutical companies, durable medical equipment (DME) vendors, insurers/third party payers, first responders and governmental health agencies.
4. Manage the enormous diversity of healthcare data sets required to accommodate the needs of all parties—and to cover all forms of sick-care, well-care, and emergency care. Needed is a complex mix of physiological (medical and non-medical) and psychosocial (mental, emotional, behavioral and interpersonal) data, across patients’ entire lifetimes. These data include: 1) patients’ diseases, dysfunctions, strengths, weaknesses and risks; 2) health products and services prescribed and used; 3) clinical outcomes resulting from the care delivered; 4) genetic and environmental data; and 5) expense/financial and utilization (e.g., length of stay) data [20].
5. Bridge the knowledge gap by using comprehensive details of each person’s health status, risks and treatments—along with quality reporting and outcomes research—to: 1) make the best possible treatment decisions within a personalized care framework, 2) deliver that care efficiently and effectively, and 3) enable all patients to be informed participants in the healthcare decision process and in promoting their own health.
6. Increase workflow efficiencies and introduce continuous quality improvement methods to ensure high-value (cost-effective) healthcare delivery.
7. Reduce variability in care quality and access to promote better health across all communities.
8. Advance the role and self-management abilities of the patient to foster healthier ways of living, control of chronic conditions, and greater compliance/adherence to plans of care.
9. Strengthen privacy and data protection to give patients’ greater peace of mind and to reduce provider culpability.
10. Protect public health and preparedness by implementing processes for ongoing biosurveillance, post-market surveillance, first-responder assistance in case of emergencies, and immunization management at the local level.
11. Help improve medical education by ensuring the introduction of best practices.

The remainder of this paper focuses on discussing resilient and pragmatic ways to realize HIT’s vast potential by bridging these eleven gaps with a novel technology.

V. BRIDGING HIT’S GAPS AND REALIZING ITS POTENTIAL LEVERAGING NOVEL TECHNOLOGY

The ReAsure HealthNode system (RAHN) consists of a next-generation HIT architecture and software applications that bridge current HIT gaps. RAHN operates with other HIT tools to help increase care quality, improve care safety and control care costs, as well as implement “meaningful use” rules [21]. It bridges these gaps by through RAS capability that leverages the asynchronous “store-and-forward” capability of novel node-to-node technology [22].

Following is a brief description of RAHN’s novel architecture and applications.

A. Simple, Efficient, Low Cost Architecture

RAHN employs a low cost, low-bandwidth, asynchronous, publish/subscribe (pub/sub), store-and-forward, mesh node network architecture that exchanges vast amounts of patient data conveniently from desktop-to-desktop. Using automated spreadsheet templates and e-mail in new ways, it offers authorized individuals a quick, easy, secure and inexpensive method for sharing, analyzing and viewing patient information originating in disparate sources and communication environments. It accommodates the needs of all users, from people with continuous broadband to occasionally connected

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6 Interoperability refers to the ability to exchange and use information across large heterogeneous networks and applications.

7 Asynchronous store and forward capability means that: 1) files can be sent from one computer to another without requiring that they both be online at the same time and 2) once received, the files are stored in the recipient’s computer before any portions of that file are sent to other computers.
individuals using low speed dial-up, or even radio, service.

To use RAHN, end-users download and install a small software program in their computerized device, which provides the basic pub/sub node capabilities. These node programs have both publisher and subscriber functionality. A node uses its publisher functionality to send information to its subscribing nodes; a node uses its subscriber functionality to retrieve information it receives from publishing nodes. A publishing node can send data files to any number of subscribers, and a subscribing node can receive data files from any number of publishing nodes. This decentralized node-to-node (“point-to-point”) network architecture resembles the telephone system in which two people can converse with each other, or in which many people communicate back and forth as in a conference call. The difference is that, instead of real-time speech, the nodes asynchronously send and receive specially configure RAHN data files.

RAHN data files can contain any type of content, including detailed health information accumulated over a person’s entire lifetime. The content can be obtained from any data stores (e.g., databases and electronic documents), streamed from any devices, and be manually input. It is then stored securely in the data files. Transmitting the data files from publishing to subscribing nodes requires only brief, occasional Internet connectivity and minimal bandwidth (e.g., dial-up). For example, a publishing node can automatically send files as small, encrypted e-mail attachments to its subscribing nodes. Once received, a subscribing node automatically retrieves the data file, stores it locally, and enables the user to launch a RAHN application (discussed below). The application, in turn, may render and present any of the data file’s contents. It can also export any portions of a data file to a database and send them to other nodes via it publishing functions. In addition, a subscribing node that receives related data files from multiple publishing nodes can combine them all into a “composite” data file that is locally stored, rendered or transmitted to other nodes.

B. High-Impact, Low Cost, Easy-to-Use Applications

While the RAHN pub/sub node transmits and retrieves specially crafted data files (as described above), the RAHN applications use automated (macro-driven) spreadsheet templates to produce, consume and render those data files in customized dynamic (interactive) reports via a patented method [23]. To do this, the templates use computer algorithms (subroutines) in reusable code modules, along with formulas and functions in spreadsheet cells. These modules and cells enable the application’s publishing templates and node program to:

1. Obtain huge amounts of (disparate) health data from anywhere
2. Alter, aggregate and analyze the data as needed
3. Assemble the data sensibly and efficiently in preplanned structures organized in a meaningful/logical way within the template’s spreadsheet cell “containers,” similar to arranging a child’s building blocks according to some thoughtful plan (see Fig. 1 below)
4. Share any of the data by automatically copying them from the template’s cells—without the overhead of metadata and formatting instructions—and storing the data in a small (“lightweight”) encrypted data file, which it attaches to an e-mail and sends to one or more authorized recipients (as per Fig. 2).

When the e-mail arrives, the application’s subscribing templates and node program then:

1. Extract the file attachments and store it in a folder—encrypts the data file, extracts its contents, and copies those data to the corresponding rendering template of recipient’s application, which is organized according to the same preplanned structure (as per Fig. 3)
2. Rapidly present those data in dynamic (interactive) reports by formatting the data in the rendering template—based on their cell locations—in a way that assures the resulting information is readily understandable and useful to the recipient (as per Fig. 4)
3. Easily update the data as needed through manual input and database queries, as well as re-organize and reformat any portions of the data in any manner required so it can be exchanged with other software systems, databases and RAHN applications.

This unique process provides a high level of information availability and responsiveness because the data files 1) are stored locally in “report ready formats” and 2) local computerized resources are used to format and present the data files’ contents in response to user instructions. This means there is never any latency, network bottlenecks, single point of failure, continuous connectivity requirements or bandwidth limitations. Furthermore, these reports can easily accommodate any

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8 The content in a data file can include data (e.g., individual numeric values, alphanumeric arrays, data labels, sentences and paragraphs (“blobs”), delimited strings, hyperlinks to local and remote sites/files, and graphic images.

9 Local storage means saving the data file to a folder in the hard drive of the standalone computer or in the server of a networked client computer.

10 “Report ready formats” refers to notion that the data stored in a RAHN data file are ready for immediate presentation (i.e., they are report ready) because data queries and transformations are not required. Instead, a RAHN application presents a report by copying the data from a data file into the cells of its rendering template and then apply formatting instructions based on the cell locations of those data in the rendering template.
evolving information models through use of flexible modeling templates. Thus, this process minimizes complexity and cost, while maximizing convenience, security, usability and interoperability.

C. Cuts across Vertical Markets

RAHN is not limited to healthcare; it can cut across many vertical markets with its pub/sub architecture and the capacity to deliver an unlimited variety novel applications. The grid presented in Fig 5 lists several of the RAHN healthcare applications, along with its architecture and various software components shared by the applications. Any existing or new applications for any market can use the RAHN architecture and horizontal components.

To exemplify how the RAHN process works from the perspective of an end-users and system’s engineer, a referral healthcare manager application will now be described.

D. How It Works: A User Perspective

The RAHN Referral Manager helps manage referrals and coordinate care in collaborative networks of providers. It works with or without electronic health records (EHR/EMRs) and requires only Microsoft Office and an e-mail account. Installation involves downloading and launching an automated setup file, which installs all the necessary files (i.e., the node program and application).

Described in Fig. 6 is its ten-step operational process from a user’s perspective.
With a few mouse clicks, a primary care physician (PCP) sends referral forms—tailored to each patient’s condition—to selected specialists and receives their replies via HIPAA-compliant, encrypted, RAHN data file e-mail attachments. In the same way, the PCP then sends a continuity of care document (CCD) data file to the specialists and receives their feedback. All the data files sent and received, as well as any new and modified data they contain, are tracked by the software and easily retrievable.

The following unique set of functions and feature makes using the Referral Manager application easy to use, convenient, secure and inexpensive.

1) **User interface—Simplifying complexity:** The user-interface consists of:
   - User-forms containing command buttons, checkboxes, option buttons and linked-lists
   - Dynamic spreadsheets templates formatted to look like referral forms and CCDs.

   a) **User-forms and linked-lists:** The user-forms are for inputting provider data (e.g., specialists’ contact information and areas of specialty) and initial patient data (name, address, date of birth, etc.). If there is an EHR from which to import that data, then those data can be queried from the EHR database instead of from the user-forms. The user forms also contain lists for selecting patients and their primary conditions (health problems).

   To populate a referral form, the PCP selects a patient from one list; the conditions list automatically appears. After selecting the patient's condition, the software automatically creates and displays filtered lists containing the 1) specialists whose areas of specialization have been
associated with the selected condition and 2) associated reasons for referral. Filtering the lists based on the patient’s condition simplifies the data selection process by removing irrelevant items from the lists.

After selecting the desired items from those lists, the software automatically transfers the data to the spreadsheet-based referral form and displays it. If additional data are added to the referral form, other user-forms appear as described below.

Furthermore, whenever the software notices that required data are missing (e.g., there have been no specialists associated with the selected condition), it alerts the PCP and uses wizards to guide him/her to input the missing data on the fly, as needed. These wizards enable the PCP to build and modify the linked-lists with ease, which would otherwise be a very complex task. Referral form and CCD as dynamic spreadsheets templates: RAHN referral forms and CCDs are spreadsheet-based “rendering templates.” The software may prepopulate the template with data that are: 1) copied from the patient’s local RAHN data file, 2) parsed from an XML document or other electronic file, and/or 3) queried from a database. If the PCP wants to add, delete or modify any data in the rendering template, s/he simply mouse-clicks the cell within which the data element is stored (or clicks a button to add a new row or column of data). Another user-form then automatically appears into which the PCP enters the desired data. If the PCP chooses to add a medication, lab test or diagnostic code, a modifiable list of relevant items appears and, as the PCP types in the first few letters, the software filters the lists to display only appropriate items. Once the data are input, the software writes them to the appropriate cells in the rendering template. A similar process enables the PCP to delete patient data. Furthermore, whenever a PCP make changes to a CCD, the software creates an audit trail that enables the PCP to view the history of changes at any time with a button click.
2) Data file storage and retrieval: Whenever a PCP adds a patient, the RAHN application creates a data file, encrypts it, and stores it in a folder in the PCP’s computer; this is called the “main” data file. Whenever the PCP sends a referral form, the data it contains is stored in one section of the data file; and whenever s/he sends a CCD, its data are stored in another section of the file. Furthermore, whenever the PCP modifies a referral form or CCD, the changed data are stored in a third section.

In addition, a data file containing a copy of the sent referral form or CCD is stored in other folders for both the PCP and specialist receiving it. The user can retrieve and view these copies at any time, as well as retrieve, view and update the referral form or CCD stored in the “main” data file.

3) Authentication, authorization and encryption: Since the RAHN Referral Manager uses encrypted e-mail, authentication and authorization are simple processes. To authenticate that a received data file came from an authorized publisher, the application compares the e-mail address of the publishing node against an approved list of e-mail addresses. If there is a match, the application accepts the data file; otherwise, it notifies the user and destroys the e-mail and file. Another means of authentication is the use of corresponding encryption and decryption keys by the publishing and subscribing nodes; if they do not match, the subscriber’s application cannot decrypt the data file, so it destroys it. Authorization occurs when the PCP distributes the RAHN software to the specialists and adds the specialists’ information (which includes areas of specialization and e-mail addresses) into a user-form that stores it in an encrypted list. The software will only allow the publisher to send data files to the authorized subscribers in the list.

4) RAHN Integration: New RAHN applications can re-use code modules existing in other RAHN applications to give the new application certain key including the node’s pub/sub node functionality. This makes all the applications interoperable and speeds their development.

The primary difference between RAHN applications is the particular data and presentation models used by their templates. In fact, if multiple applications have similar data models, but different presentation models, they can simply exchange and consume the same (or similar) data files, then render them using different formatting templates.

E. How It Works: A System Engineer’s Perspective

The RAHN system aligns with the Open System Interconnect (OSI) model by leveraging Microsoft Office and Windows desktop technology. An explanation of how it operates from a system engineer’s perspective follows.

1) Spreadsheet templates, e-mail client and .Net program: RAHN’s primary functions take advantage of MS Office’s spreadsheet (Excel) and e-mail client (Outlook) capabilities. Note that any spreadsheet program with macro capabilities, and any e-mail client allowing third-party desktop application control, could be used instead of Office.

One of the application publisher functions uses the spreadsheet technology to create the RAHN data files. A data file contains a patient’s health record, which may be a comprehensive lifetime medical record or any subset of data. A macro-driven spreadsheet workbook template creates the data through use of code modules and cell functions that instruct it to do the following:

1. Obtain patient data wherever they may reside, including querying database, parsing XML files, streaming in data, consuming an existing data file, and obtaining data through manual input.
2. Manipulate those data by, for example, performing statistical computations, parsing and concatenating strings, exporting data to third-party applications for analysis and importing the results, etc.
3. Organizing the data into predefined data structures by writing each data element into a particular cell location that uniquely indexes the data element to that spreadsheet cell.
4. Copying those data to a RAHN data file and saving it.

Another of the application’s publisher functions involves transmitting the data file as an e-mail attachment. This is done by compressing (zipping) the data file, encrypting it, creating an e-mail addressed to a particular recipient (subscriber), attaching it to an e-mail, and sending it to the e-mail (MS Outlook) outbox for delivery.

A .Net program, called the RAHN Outlook Inbox Scanner, continually scans the subscriber’s inbox looking for an e-mail message with a particular subject line and type of attachment. When found, it automatically extracts the attachments, puts them in a predefined folder, deletes the e-mail, and notifies the user via a spinning icon that data files are ready for processing.

When the subscriber clicks on the spinning icon, the Outlook Inbox Scanner launches his/her spreadsheet application. The application then retrieves the data file from the folder, decrypts it, and copies the contents of the data file to the spreadsheet’s rendering template, formats it and then presents it via a user-interactive report. Other functionality within the rendering template can do the following:

- Enables the user to manually modify the data in the report and add new data

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13 Data models refer to the particular type of data elements used by an application, as well as rules for processing (e.g., analyzing and organizing) the data. Presentation models, on the other hand, contain the rules for formatting and presenting those data in dynamic reports.
- Changes the way the data are displayed through built-in or ad hoc views
- Performs real-time analytics and displays the results, such as alerts and warnings of possible drug-drug interactions and overdue inoculations, abnormal lab test results, and troubling vital sign and lab test trends indicative of health risks
- Presents diagnostic suggestions and recommendations
- Presents evidence-based treatment guidelines
- Analyzes and presents outcomes data measuring care quality
- Exports any portions of the data.

Note that when the application performs any of these functions, it may access other types of data files that contain information about the providers, patient conditions, medications, lab tests, etc. There can also be data files from which the application retrieves evidence-based guidelines, clinical notes, and any other information that adds richness to the presented information. Still other data files provide authorization and authentication checks.

2) How RAHN differs from RDMS—visual vs. columnar: The RAHN system differs in significant ways from a relational database management system (RDMS). In a RDMS, the data elements are organized into tables and linked tables are referenced by a schema that conveys the meanings (semantics) of the data. Furthermore, each table contains a group of related attributes, or columns, that exhibit specific nuances of the object being described. In the database construct, individual data elements reside in rows (“records”) and are related through a construct known as a tuple; patient name, address, and telephone number is an example of related data in a tuple. Each tuple traverses multiple columns (“fields”). The rows of a table store instances of an entity, i.e., each row is a customer and all customers are in one table. To link each of the entities to other attributes requires the use of a primary key that, for example, links a patient to all possible conditions.

RAHN, in contrast, visualizes the object in its spreadsheet space through which publishing templates arrange/organize the data elements into report ready configurations (patterns) within its cells and then stores the data and their cell locations in a data file. Subscribing templates, in turn, simply put the data file’s contents into corresponding cell within its own spreadsheet templates. Each cell in a template “knows” the attributes of the data it sends and receives by storing the data element-to-attribute associations within the templates. Various methods manage these associations, including: 1) having data labels in cells adjacent to the data cells, 2) writing comments about the associations within the cells, 3) linking cell to other cells with which they are associated, and 4) using code variables that define data attributes of the cells. Being report ready, the rendering template quickly formats and presents the data in dynamic reports by applying formatting instructions to the data based only on their cell locations. By carrying the cell locations of the corresponding templates along with the data elements, the data files convey the data semantics without needing tables, tuples and primary keys. RAHN, therefore, has replaced the complexity of the database with a simple spreadsheet structure that quickly crosses the semantic gap existing between the computerized model and real world the model reflects.

By storing all of the data, for an individual patient in a single data file, RAHN creates a virtual facsimile of the clinician filing cabinet in which a patient’s medical chart resides in a manila folder.

3) Inheritance and the CCD: Inheritance in this context refers a “child” object taking on the characteristics of its “parent” object. An “object” is a software entity containing programming code (instructions), which may be merged with the data the code manipulates. In spreadsheets, such as MS Excel, the code modules have hundreds of objects available to it (such as workbook, worksheets and cell ranges). Thus, one spreadsheet template (the child) can inherit the data elements and formatting instructions (attributes and methods) associated with a range (group) of cells in another spreadsheet template (the parent).

Inheritance in healthcare could be a CCD template object (the child) inheriting the attributes and methods of another CCD template object (the parent). What is inherited could be a patient’s conditions, medications, treatment procedures and outcomes, as well as the data models, analytics, longitudinal time frames, formatting instructions, and anything else related to the parent object. In RAHN, such inheritance occurs automatically because it connects all descriptive elements and sub-elements directly to all of their attributes, and the data file conveys these connections from one template object to another. For example, an application containing a CCD template (the parent) can send to another CCD template (the child) a data file containing all the information the recipient’s application needs to render a report on a diabetic patient’s condition; neither database queries nor additional data processing is needed to present the report.

4) Networking with RAHN: Using RAHN in a network environment is easy. Pairs of users agree to connect with each other. They then install and configure their pub/sub nodes and application; they are now connected. This process quickly overcomes the disparity, fragmentation and complexity that would otherwise make it difficult for dissimilar HIT (claim processing system, EHR, CPOE and case management, etc.) systems to interoperate. Furthermore, RAHN’s universal translator function can transform and translate disparate data as they pass from one HIT system to another, which would resolve database field name incompatibilities and constraints. All providers in a community of referral (a geography where clinician refer patients to one another)
using RAHN behind their firewalls would then have a secure link to each other’s HIT systems anywhere in the world. Furthermore, this would make it very easy to de-identify patient data and send them to centralized databases for use by researchers. This approach would significantly reduce the cost and complexity of data exchange.

5) OSI rendition: The Open System Interconnection model is a standard prospered by the International Standards Organization (ISO). ISO and the International Consultative Committee on Telephony and Telegraphy (CCITT), along with the American National Standards Institute (ANSI), have close links with ISO. They develop and publish the ISO standard and support its application to layered technologies. Each of the layers performs a well-defined function. RAHN merges its functionality with a Microsoft Windows OS to take maximum advantage of this layered approach, thus enabling end-to-end, node-to-node communications. RAHN’s architecture and applications presented in Fig. 5 (above)—most of which are constructed in an Excel spreadsheet environment that includes Visual Basic for Applications (VBA)—provides its functionality.

Fig. 7 presents a map of RAHN functionality to the ISO standard. In the healthcare vertical market, the applications create longitudinal patient records and provide decision support based on that patient information; this is done through a human-machine interface resident at the application layer. The patient identifier, which can be a biometric index or unique medical identification number, is maintained by the software and transmitted with the patient information. As additions or deletions are made to the longitudinal record by any other provider, the software at this layer automatically ensures that all authorized parties are notified of the changes and can allow the application to modify the patient’s data files. Once information is captured at this layer, either through keystroke entry or by electronic means, it can be easily manipulated, transformed and operated on by Excel’s extended function set.

To ensure interoperability, RAHN promotes a mapping of EHR data elements by constructing a translation table and leveraging the presentation layer functionality to deliver the data in a readily modifiable form. For example, the RAHN interface can string together the data elements from EHRs as comma-delimited strings and parse them as necessary to create, consume, format and present its data files. Disparity of entity names between and among different EHR databases would be resolved at this layer. RAHN would deploy a universal dictionary to foster this translation. Further, end-to-end encryption/decryption (in transit and at rest) are used along with data compression and decompression to help assure the security and privacy of patient data, and to
minimize bandwidth requirements. The middleware used to enable this functionality is pub/sub spreadsheet templates.

RAHN uses Microsoft Windows OS, file management and Outlook e-mail capability, at the session layer, to provide secure authentication and authorization, along with asynchronous communications between and among all trusted partners. The Outlook Inbox Scanner program automates the collection, detection, notification and capture of RAHN-specific e-mail. Thus, the RAHN software working at the session layer makes the communication operation a “hands free” service at the desktop.

The remaining three layers are conventional and use the integration of computing and telephony effectively to complete the end-to-end, node-to-node connection. The router, modem and physical layer all have universal use in modern social networks. The unique character of RAHN inherited through the layered approach and manifested in the Outlook Inbox Scanner is that e-mail could be routed through any medium that supports automatic failover. If a RAHN node is connected to the Internet through a radio transceiver, as noted in Fig. 8, and it fails, it could easily be routed to the Internet via a coax cable device, a twisted pair as in DSL, or through dialup via a Plain Old Telephone Service (POTS) connection. This unique store-and-forward approach ensures that there is minimal interruption to clinician workflow.

- Being non-disruptive to existing IT systems and networks
- Reducing complexity and problems by requiring no VPN configuration, avoiding firewall issues, and needing little, if any, ongoing IT support
- Reducing demands for central servers and conserves precious resources
- Eliminating the “last mile” connectivity problem and bandwidth constraints often existing in rural communities
- Remaining operational even when most networks and communication links fail
- Avoiding slowdowns caused by network traffic, bottlenecks and latency
- Being able to interoperate with any databases and consume any file formats
- Providing powerful security and privacy methods.

Other benefits are manifest by fostering learning, knowledge-building, and collaborative decision-making. RAHN accomplishes this by:

- Rapidly disseminating evolving evidence based guidelines that support decisions of clinicians and patients
- Enabling networks of individuals—across organizational, professional and physical boundaries—to share diverse experiences, data sources, knowledge, ideas and insights to increase innovation and more effective decision-making in virtual community environments
- Delivering de-identified patient data to researchers effortlessly
- Supporting and integrating HIEs easily and at low cost
- Tailoring reports and just-in-time instructional materials to end-users’ particular roles, responsibilities and needs
- Assuring information is useful through adoption of meaningful use requirements.

Delivering this unique set of benefits requires bridging the gaps in today HIT systems, which will now be discussed.

VI. BENEFITS OF RAHN’S NOVEL ARCHITECTURE AND APPLICATIONS

The unique value proposition of the RAHN system includes benefits related to saving time, money, resources and hassle by:

- Enabling easy, low cost, durable connectivity/communications with global interoperability

RAHN provides an easy and low cost way for all stakeholders to have durable connectivity/communications in all situations and environments right from their desktops. It accomplishes this by using communication mechanisms that are as inexpensive as dial-up, simple as e-mail and convenient as Microsoft Windows and Office. In addition, RAHN’s asynchronous, pub/sub, store-and-forward, mesh node network model of integration promotes interoperability and ensures survivability (i.e., connectivity any time or place even with network disruptions), while at the same time providing low cost file transfers that solve the last mile
problem by leveraging TCP-IP via radio, landlines, satellites and automatic failover.

In case of catastrophic events that disrupt the Internet, RAHN can be integrated with radio technology, such as Winlink 2000 (WL2K), to enable patient information exchange and provider communications using radio waves [24]. WL2K is a worldwide system of volunteer resources supporting email by radio with non-commercial links to the Internet. The system provides valuable service to emergency communicators and to licensed radio operators without access to the Internet using modern computer and networking technology. It is an extremely effective method for delivering email service to an agency that has suffered a disruption in Internet access due to a prolonged power outage or telecommunications infrastructure failure. If an agency has a critical need to send important email traffic, an ARES-RACES field digital communication station can be deployed. Emails can be sent from a laptop computer interfaced with a two-meter transceiver and TNC and transmitted on 144.910 MHz to the W3AEC-10 (example repeater/transceiver node) at an Emergency Operations Center. The emails received at the W3AEC-10 RMS node are forwarded to the Internet and delivered in a normal manner to the addressee. And in situations where the distance from an affected agency to the nearest RMS packet node is too great for a VHF link to be effective, HF frequencies can be used at a lower baud rate with reduced throughput. Fig. 8 depicts the W3AEC-10RMS implementation.

B. Helps Coordinate Care by Promoting Collaboration

RAHN™'s architecture and tools enable providers to transition from the isolated, episodic activities of independent clinicians to network of collaborating providers. The providers in these networks maintain their ability to work independently—i.e., by working in their own solo or group practices, rather than working as a paid employee at an integrated care organization—while teaming with other independents. This collaboration promotes coordinated care across the entire healthcare continuum, in virtual space, using a longitudinal patient record. Sharing information within a community of referral, and even across oceans, is as simple as using a FAX machine, but with the added advantage of RAHN’s end-to-end encryption, which eliminates the HIPAA security concern of not identifying who receives the patient information on the remote end.

C. Manage the Enormous Diversity of Healthcare Data

RAHN manages the enormous diversity of healthcare data sets required to accommodate the needs of all parties. It does this: 1) by building secure data files for each patient containing longitudinal health records tailored to the needs of PCPs, specialists and patients, and 2) by storing the data files in virtual “filing cabinets” (i.e., hard drive folders) that belong to those parties. These health records, which may be presented in many different ways (e.g., as a CCD), can contain a wide range of physiological (medical and non-medical) and psychosocial data across patients’ entire lifetimes. The data may include: 1) patients’ current and past diseases and dysfunctions, signs (such as lab test results and imaging studies) and subjective symptoms; 2) health risks and trends; 3) current and past treatments and outcomes; 4) inoculation schedules; 5) genetic data; 6) demographic data and family history; and 7) expense/financial/utilization data [18].

When large graphic images are included in a data set, leveraging the Internet 2 high bandwidth network would provide dynamic bandwidth allocation to ensure ease of transport for the files at reduced cost since the user pays for bandwidth only when needed. This accounting mechanism ensures that very large files such as CAT and MRI are delivered safely and quickly with a guarantee that information integrity is maintained. With this in place, the RAHN system can transmit these graphics as email attachments, display them upon receipt, and even store them locally for subsequent retrieval, if desired.

D. Bridges the Knowledge Gap

RAHN helps bridge the knowledge gap by: 1) compiling, analyzing and intelligently presenting comprehensive, detailed information about each person and his/her care; 2) enabling quality reporting through sharing of outcomes data with researchers; and 3) integrating evidence-based guidelines into an application’s presentation space. This helps providers make good treatment decisions within a personalized care framework and deliver that care efficiently and effectively. It also enables patients to be informed participants in the healthcare decision process and to manage their own health more effectively.

E. Reduces Variability in Care Quality and Access

RAHN can help reduce variability in care quality and access by enabling increased workflow efficiencies by supporting three proven strategies: 1) real-time presentation of preferred practice guidelines, 2) relevant patient data at the clinical encounter, and 3) promoting healthcare cost reduction and healthcare delivery quality improvement through continuous coordination of care information [25].

Integrating telemedicine into the mesh node network further reduced such variability by promoting patient compliance, fostering greater care coordination, and helping ensure the provision of care in rural areas and at a disaster sites by enabling (virtual) patient contact and provider support from a remote location using telecommunications technology.

14 Telemedicine (also referred to as "telehealth" or "e-health") allows providers to evaluate, diagnose and treat patients in remote locations using telecommunications technology. It offers more efficient use of limited expert resources because providers can "see" patients in multiple locations without leaving their facility.
F. Advances the Patient’s Role and Self-Management Abilities

RAHN can advance the role and self-management abilities of the patient by delivering compliance-promoting applications to the patient or guardian. This capability would enable the patient or guardian to track medication use, identify lifestyle problems, and access key health information when needed and instructional materials that help foster positive attitudinal and behavioral change.

G. Strengthens Privacy and Data Security

RAHN strengthens patient privacy protection and data security with authentication, authorization and end-to-end encryption described earlier. It also employs a “Trusted Partner Agreement” (TPA) by which authorized parties establish the ground rules for sharing patient information. The TPA specifies the specific information each party can receive and the conditions under which the information is to be sent. The software’s automated audit trail guarantees that forensics can be initiated at any time during the care delivery process. When information is destined for a party for which the TPA does not apply (such as government or research institutions), then the software automatically de-identifies the patient's data before transmitting it.

H. Protects Public Health and Emergency Preparedness & Response

By providing a convenient and low cost means for supporting ongoing biosurveillance, post-market surveillance, first-responder assistance and immunization management, RAHN can play an important role in promoting public health, as well as emergency preparedness and response. This holds true even in the battlefield as evidenced in the “unexpected survivor” phenomena in which a survivor is found when none are expected to have survived [26]. The RAHN architecture is the best way to get information to the right people in an emergency where the victims’ health records are stored in distant locations.

I. Improves Medical Education

Offering HIT courses at medical schools would enable future medical students to understand the complexity and capacity of HIT, and to enable them to take advantage of the benefits HIT can provide. Teaching institutions are beginning to recognize that HIT is essential in growing and using healthcare knowledge.

The Commonwealth Medical College (TCMC) is one such organization. It is moving into the future by fostering medical students’ awareness and knowledge of HIT. TCMC—a new and innovative community-based medical school—is committed to integrating HIT education throughout its curriculum. Today, the value of technological innovation is not typically taught to medical students nor delivered as part of medical education’s outreach to practicing physicians. Presently, there are no standardized ways for medical schools to deliver this education to students and the community. In fact, such inconsistencies seem to reflect divisiveness among educators and may be due to a number of factors, such as lack of faculty experience and comfort with the technology, lack of guidance regarding the role of technology in medical student education and finally, lack of data on how to best integrate the experience into medical education [27]. TCMC plans to incorporate a longitudinal integrated clerkship model into its curriculum. The model for TCMC curriculum development [28] is presented in Fig 9.
VII. CONCLUSION

During the health reform debate, health policy experts subtly target physicians as the cause of many of our healthcare system’s woes [29]. The reality, however, is much more complex and fraught with daunting challenges. The actual reasons for the American healthcare crisis is that our country has created a fragmented system in which inefficiency is rewarded, ineffectiveness is acceptable, ignorance abounds, collaboration and care coordination are weak, disparity of access is commonplace, costs are very high and profound change is avoided.

Overcoming these barriers to resolve the healthcare crises requires changes in the legacy systems, social policies and professional cultures existing today. We have to change the way business is done, but that can take a long time and necessitates significant emotional and monetary investment. Dealing with many of these human barriers requires overcoming resistance to change and a fostering a paradigm shift in a magnitude similar to when people first adapted to using light bulbs, telephones and automobiles, and began making them an integral part of the social fabric.

Resolving the healthcare crisis also require a new generation of HIT that is cost effective, easy to use, adapts easily into current workflow and overcomes many of the barriers introduced in this paper. RAHN provides such HIT with its novel architecture and applications that can: 1) exchange comprehensive, cross-disciplinary patient information quickly, securely and privately; 2) foster collaboration and care continuity in a way that connects independent providers; 3) build, evolve and disseminate solid knowledge; 4) help guide diagnostic and treatment decisions; 5) recommend the better treatment alternatives and assist in its delivery; 6) provide warnings and alerts to help avoid and manage problems; 7) measure outcomes and deliver the data to researchers; 8) support public health and emergency response; and 9) enable effective self-care and management of chronic conditions.

References


