Bioterrorism Defense and Improved Healthcare Through Coherent Informatics

The following essential services can now be delivered economically at the same time, while also facilitating a nationwide, mission-critical communication infrastructure:

- Bioterrorism Defense
- Identification and Management of Medical Crises
- Patient Record Management
- Integration of Clinical Laboratory Systems
- Patient Care Quality Assurance
- Continuing Medical Education
- Remote Medical Consultation
- Inter/Intra-group Medical Research
- Health Service Administration

The above services are currently managed as independent processes. Through a technology called Coherent Informatics (CI) they can be managed in a unified and cost effective fashion using the public Internet. The CI based solution presented herein is designed to support every healthcare provider, first responder, public health official and all local, state and federal agencies at the same time. It can facilitate communication and information management that is real-time, secure and available nationally, particularly during a crisis. It is also scalable, reliable, easy to use, easily maintained, extensible and deliverable at a fixed cost. A unified medical community that possesses true situational awareness will measurably improve healthcare and provide defense against an increasing array of insidious health threats.

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1. Introduction. The use of a shared cost communication and information management infrastructure by every healthcare provider is a viable way to universally lower healthcare costs. It is also a viable way to measurably increase the quality, efficiency and productivity of healthcare delivery. Considering recent world events this capability is clearly required now. Only by facilitating real-time reliable nationwide communications and automating how information is managed and distributed will it be possible to contain a rapidly spreading nuclear, biological or chemical threat.

It is essential to make the knowledge of the entire medical community more accessible to those areas with a shortage of key medical expertise. Our rural communities need reliable, permanent and equal access to all of the nation's public health and medical resources. It is also essential to provide all public health officials and medical researchers with a common means of gathering and analyzing the right information in a timely fashion. The critical information and observations generated on a daily basis by millions of healthcare providers is not automatically captured and distributed for analysis. Therefore, the health of all citizens cannot be locally, regionally or nationally monitored by the respective agencies. This leaves the entire nation blind to the existence of numerous threats until after there is grievous injury or loss of life. As presented herein, through the integration of numerous open standards based technologies, it is now economically feasible to immediately deliver a solution.

The nature of nuclear, biological and chemical threats dictate that every healthcare provider, first responder, public health official as well as all local, state and federal agencies be on a single nationwide communication network. It is not economically feasible to build and maintain a private dedicated network for the millions of simultaneous users this represents. This leaves two alternatives, the Public Switched Telephone Network (PSTN) or the public Internet.

All have access to the PSTN. Unfortunately, the PSTN fails if only a small percentage of its subscribers use it at the same time. Subsequently, the PSTN does not operate during a crisis and current dependency on it continues to make our nation vulnerable. A terrorist need simply cause panic in the general public and the nation's primary means of communication is shut down as effectively as if our key telephone assets were destroyed with explosives. The PSTN is engineered for voice only and cannot support high-speed data transmissions. It cannot facilitate the real-time distribution of video, high-resolution medical imagery and numerous other medical diagnostic data formats required by healthcare providers. This leaves the public Internet as the only remaining candidate to facilitate a nationwide communication infrastructure.

The public Internet possesses the right foundation. The common components of the Internet (switches, routers, servers, and computers) comprise what is called a Packet Switched Network (PSN). In a PSN, all information of any format (documents, images, audio, video, etc.) is divided into sub-units called "packets", which are suitable for electronic transmission. A properly implemented and managed PSN can guarantee the delivery of packets across the network. This gives the Internet the inherent ability to support real-time secure reliable communication. Additionally, in anticipation of explosive growth of the Internet all major communication providers have placed tens of thousands of miles of fiber optic cable in the ground. Sitting idle today are trillions upon trillions of bits per second of nationwide communication capacity.

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Unfortunately, there are critical oversubscription, performance and security issues with the Internet's current implementation. Of particular note is the use of dialup modems on telephone lines to connect computers to the Internet. Because this utilizes the PSTN, access to the Internet in this fashion is not possible during a crisis. Considering the wealth of more reliable ways to connect to the Internet this problem can be economically and rapidly solved. The biggest issue is how to transform the Internet from an unpredictable, "best effort" and oversubscribed network that lacks security into a mission-critical real-time secure communication infrastructure.

Through decades of research on communication and information theory an elegantly simple solution has presented itself. By enforcing a simple set of rules implemented entirely in software, running on the appropriate computers and servers, it is possible to radically improve the predictability, performance and security of any PSN including the Internet. This means that the Internet can be immediately repurposed for bioterrorism defense and improving healthcare delivery. The complete protocol (set of rules) is called Coherent Informatics (CI). This document presents the CI protocols and their implementation using open standards based elements.

In the late 1970s the Secretary of Defense signed into effect the Internet Protocol (IP). This relatively simple open standard defined a format for packets to be used by all defense contractors. This single act facilitated the ultimate creation of the public Internet. Just like the width of railroad tracks, the format of electrical outlets and the configuration for traffic lights are standards in this nation, CI proposes a standard for how to guarantee the delivery of packets over the Internet. CI also proposes a standard for how to manage and collaborate with information from any source over the same Internet. In combination this represents the foundation on which to deliver bioterrorism defense and improved healthcare.

The remaining issue is one of national security. If this capability is so easy to implement, why is it not already implemented? The primary reason is that there is no economic incentive for communication providers to deliver a mission-critical infrastructure. The PSTN could be delivered in a fashion that works during a crisis, but who will pay for the multi-billion dollar upgrade? The current PSTN architecture was designed to be profitable, not to provide homeland defense. The Internet can easily displace the PSTN and already supports lower cost delivery of voice calls. However, PSTN providers aggressively defend their primary revenue source and expect a multi-decade return on their capital investments. The political power of the phone companies is formidable. Internet component providers are organized around financial quarter after quarter growth. Complexity and planned obsolescence represents billions of dollars a year in service and sales revenue for this industry. There is a clear conflict of interest between national security and the financial needs of the respective industries. The answer lies in how our nation treats its communication assets. They should be treated just like the interstate highway system. Viable nationwide communication is the foundation of national security. All forms of communication need to be held to a much higher standard of performance, security and compatibility than they currently are. A possible course of action is to accelerate the adoption of the Global Information Grid (GIG) requirements established by the Department of Defense. The CI protocols and implementation are designed to exceed current GIG requirements. At minimum the government must enforce Internet connectivity service level guarantees that ensure our first responders can reliably communicate during a crises. The CI approach of using software to solve the performance, reliability and security problems makes the solution economically feasible.

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2. Status of the Public Internet. The current public Internet is a "best effort message delivery" network. "Best effort" means that there is absolutely no guarantee of any kind that any packets sent will arrive at their destination. "Message delivery" describes the original design intent of the Internet, which was to send text messages between researchers. Delivering web pages is just a form of messaging. A text message consisting of web page drawing instructions is sent by a web server to a web browser for interpretation. A user's web browser mouse clicks and keystrokes are packaged as messages, which contain instructions for a web server to interpret. Internet users do not see the packet collisions, the network congestion and the number of times various message packets are retransmitted. Web browser users often see the results of a web server that receives too many messages at the same time. An over utilized web server rapidly grinds to a halt and ceases to function. The current Internet is exactly like an extremely busy intersection with multiple lanes in all directions with the packets moving through the Internet being the cars and trucks. However, there is no posted speed limit, no traffic lights and no police. The lack of a set of rules (protocols) for managing the Internet's performance makes it an unpredictable and unreliable resource.

The ability to send messages to anyone is obviously of significant value. For example, email and file transfers have rapidly become the most indispensable form of Internet messaging and are universally utilized by every organization. However, homeland defense, bioterrorism defense, medical crisis management and healthcare delivery require a higher level of predictability and reliability. The ability to send "messages" during a crisis in real-time must be guaranteed. Additionally, the more critical need to communicate and collaborate in real-time using live audio, video and data of any format must be supported. The good news is that the common components that comprise the Internet have the capacity to deliver the desired guarantees.

The first part of the solution is to define protocols that would make the behavior of the Internet more predictable, manageable and secure. For example, if a web server's capacity was at a high utilization level, either redirect a new request for service to an under utilized server or notify the requestor that the request will be delayed, retried later or denied. Additionally, if a protocol required requestors to have priority levels, a medical first responder during a crisis could displace a lower priority request for service. The current approach of lowering the performance of every user's access to a network service to the point of failure is unacceptable.

The second part of the solution is to implement these protocols in a way that is economically viable. This implies that the protocols must be based on open standards. There are numerous internationally recognized standards bodies influencing everything from the format of high-resolution images to data encryption. The global community clearly sees the value of being able to economically and efficiently share information and conduct commerce. The Internet Protocol (IP) is a primary example of the impact of a truly open standard.

Coherent Informatics (CI) defines a precise set of protocols designed to shape the public Internet to support the critical communication and collaboration needs of homeland defense, bioterrorism defense, medical crisis management and healthcare delivery. It also includes a measurably viable approach to implementing these protocols using current open standards based technology components.

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3. Open Standards Based Components of Coherent Informatics (CI). A large number of new open standards based technologies have matured sufficiently through commercialization to make CI immediately feasible. Much of this progress has been driven by intense competition in the communication and computing industries. Numerous published books, clearly documented Application Programmer's Interfaces (APIs), readily available source code samples, test benches, test laboratories and access to experienced skilled laborers make implementing these open standards economical. The following is a partial summary of a large number of open standards based components that are currently being used to facilitate CI:

3.1. ISO/ANSI C++ Programming Language. The International Organization for Standards (ISO) and the American National Standards Institute (ANSI) jointly standardized the C++ programming language in 1998. This relatively silent event has a profound impact on solving the information flow problems for healthcare providers. Extremely mature C++ compilers and integrated development environments are now available from multiple sources. Sophisticated and complex principles like inheritance, polymorphism, runtime type identification (RTTI), exception mechanisms and function overloading are now readily exploitable and no longer the major focus of a typical software development effort. These capabilities are essential to delivering highly reusable software objects. Of even greater importance is the efficiency and performance of the generated executable code. C++ compilers now typically generate code so optimized that in many cases it matches the performance of what normally required hand optimization by senior master programmers. To deliver real-time full-duplex communications in software over common packet switched networks dictates the performance C++ now offers. A key component of the CI implementation is to provide open source C++ based building blocks that allow any vendor to rapidly produce device controls and data analysis tools that seamlessly integrate into the overall CI architecture. It is essential to base these building blocks on a reliable, international and portable (cross platform) open standard. The international pervasiveness of C++ also ensures that a sufficient body of affordable skilled labor is available. This approach eliminates risks inherent in choosing a lower performance language like Java, which is owned by a single vendor. Any language owned by a single vendor is vulnerable to anti-competitive practices. For example, Microsoft dropped Java support in its Windows XP operating system, which would have essentially terminated or limited distribution of any major Java based medical application development initiative.

3.2. Session Initiation Protocol (SIP). The Internet Engineering Task Force (IEFT) recently ratified SIP. SIP is a signaling protocol for conferencing, telephony, presence, event notification and instant messaging. SIP lets you know what people and what services are on line and their availability for communication or access respectively. Called "presence", this capability is a significant productivity multiplier over the current inefficiency of calling people on a telephone when you have no idea if they are available or not. There is no restriction to media, data format or number of users when establishing a conference. Additionally, SIP allows communication policies and priorities to be established over a network. For example, the entire medical community can have a graduate alert status - emergency medical personnel could be given the ability to interrupt an active communication session in order to communicate in an emergency. SIP can also discover the availability of services. In the case of an act of terrorism, war or major natural disaster that may physically destroy a significant percentage of a network, SIP can work in conjunction with other communication protocols to effectively heal and route around damaged portions of a network thus maximizing survivability.

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SIP also supports the delivery of billing services, consultation services, usage analysis, productivity analysis and security monitoring. SIP can provide network administrators with all of the necessary details to assist them in maintaining a secure, reliable, real-time communications infrastructure. It can also assist the entire medical community in automating the billing of online consultations and treatments.

3.3. Advanced Encryption Standard (AES). The National Institute of Standards and Technology (NIST) has recently announced the approval of the Federal Information Processing Standard (FIPS) for the Advanced Encryption Standard (FIPS-197). This standard specifies Rijndael as a FIPS-approved symmetric encryption algorithm that may be used by U.S. Government organizations (and others) to protect sensitive information. There is a 128 bit, 192 bit and a 256 bit version of AES. Assuming that one could build a machine that could recover 255 keys in a second, then it would take that machine approximately 149 thousand-billion (149 trillion) years to crack a 128-bit AES key.

3.4. Transport Layer Security (TLS). The Internet Engineering Task Force (IEFT) has recently ratified TLS. The TLS protocol was developed to provide communications privacy over the Internet. It allows client and server applications to communicate in a way that prevents eavesdropping, tampering, or message forgery. TLS works with AES, Kerberos and other open standards based security protocols that are considered essential prerequisites for use by numerous federal agencies. An advantage of TLS is that higher-level communication protocols can layer on top of it transparently. This means it can be combined with SIP to implement usage and prioritization policies in a secure fashion. This makes TLS an important element in economically achieving compliance with the Health Insurance Portability and Accountability Act of 1996 (HIPAA) for all healthcare providers nationwide. When combined with other security measures discussed in this document, TLS will also make it possible to eliminate problems like the denial of service attacks that occasionally collapse the current Internet.

3.5. Open Graphics Language (OpenGL). OpenGL is a cross-platform standard for 3D rendering and 3D hardware acceleration. The OpenGL software runtime library ships with all Windows, Macintosh, Linux and Unix operating systems. OpenGL delivers fast and complete 3D hardware acceleration, makes real-time 3D effects possible, is designed to support future innovations in software and hardware and is very stable. This standard graphics language will play a key role in the real-time visualization of information in the medical community.

3.6. QuickTime. QuickTime is a package of system-level code with C++ programming interfaces that higher-level software can use to control time-based data like video. In QuickTime, a structure of time-based data is called a movie. Applications can use it to create, display, edit, copy, and compress movies and movie data in the same ways that they currently manipulate text and still-image graphics. It can also organize still images, animated images, vector graphics, multiple sound channels, MIDI music, OpenGL objects and even text. It is the ideal cross platform format to record the output from any medical device that generates video or other time-based biosignal. Outside of the Microsoft Windows operating system, QuickTime is on more computers than any other software on the planet making it sufficiently pervasive for this application. The International Organization for Standards (ISO) has defined QuickTime as the data structure for MPEG-4, the newest international standard for low bandwidth interactive video streaming and conferencing.

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3.7. eXstensible Markup Language (XML). A significant barrier to the flow of information in the medical community is the number of proprietary document formats. As the applications evolve and change, older documents become difficult to manage and access. Proprietary documents are also difficult to distribute because the recipient(s) may not have the application necessary to view or use the document. It is also impossible or difficult to cross-reference and to organize the sub-elements of these documents for further research. Developed by the World Wide Web Consortium (W3C), XML is an open standard markup language for documents containing structured information. It allows documents of any conceivable complexity to be created. It can reference elements of any desired data format to include audio, video and high-resolution medical imagery. Using XML for all documents and the patient record provides longevity, extensibility and persistence to the data, information and knowledge generated by the entire medical community. XML is already a key element of the HIPAA, Health Level 7 (HL7), Digital Imaging and Communications in Medicine (DICOM) and Integrating the Healthcare Enterprise (IHE) standards. It is important to note that the biggest barrier to facilitating bioterrorism defense is the inability to distribute the critical information and observations generated on a daily basis by millions of healthcare providers. CI takes full advantage of XML's ability to facilitate data and information reuse, distribution, collaboration and even an entirely new form of comprehensive security detailed later in this document. Combined, these characteristics allow CI to deliver true situational awareness, the foundation of homeland defense, bioterrorism defense and medical crisis management.

4. Coherent Informatics (CI). The physics of delivering packets over a PSN is extraordinarily complicated. However, immense benefit can be derived from the fact that each packet contains the address of its destination. Unlike the PSTN, which uses a fixed number of pre-established physical connections (circuit switching), a PSN uses a more flexible logical approach. A packet entering a port on a packet switch can be transmitted out any desired port(s) at the speed of the network connection (non-blocking wire speed switch). The addressing information inside the packet drives the switching process. This allows a PSN to dynamically determine the best route a packet should take on a packet-by-packet basis. A properly designed PSN can be "self configuring" and "self healing" enabling it to solve communication and information flow problems of unimaginable complexity. Unfortunately, the Internet has been crippled by the economics of oversubscription. Accounts have been sold to more users than the infrastructure can sustain at the same time. Additionally, there are no protocols implemented that manage the consumption of network capacity. Any device connected to the Internet can transmit any number of packets of varying packet sizes at any time. This makes the performance of the Internet as predictable as the weather. The goal of CI is to create order out of chaos.

Like the laws of thermodynamics, there are a number of immutable principals that cannot be ignored when attempting to reliably deliver packets. The following summarizes just a few of the simplest principals:

- A computer can only send one packet at a time and receive one packet at a time (per network interface).

- The data contained in a packet cannot be used until the entire packet is received and its validity is checked.

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• Propagation delay along a network path (the number of bytes in a packet divided by the number of bytes that can be moved per second along its network path) is determined by the lowest speed segment in the traveled network path.

• There is approximately 8 milliseconds of delay for every 1,000 miles of fiber optic cable a packet must transit.

These and many other principles directly influence the CI protocols and their implementation. They also clearly define the scope of the problem. Using an analytical approach to managing packet delivery allows numerous questions to be answered like how many simultaneous users can be supported, what types of communication and information management services are possible and how reliably can these services be delivered.

4.1. CI Protocols. The following represents a partial summary of the set of rules that the CI architecture uses to guide the open standards based implementation process. The detailed justification for each of these rules is beyond the scope of this document. However, one must ask the following questions: What is the value to the nation of reliably knowing all of the time the status and location of every doctor, nurse, paramedic, policeman, fireman, ambulance, fire truck, hospital bed, container of new gas mask filters, etc.? What is the value of being able to precisely manage what and who goes where and what occurs all of the time during any crisis? What is the value of knowing instantly that a terrorist has attacked the communication infrastructure, where the attack(s) occurred and being able to dynamically heal the damage and continue to maintain true situational awareness? What is the value of being able to securely retrieve a complete medical record of any patient from any location in seconds?

4.1.1. Unique Addressing. Every device on the network shall have a unique and permanent address.

4.1.2. Positioning. The location of every device on the network shall be known at all times accurate to less than 1 meter.

4.1.3. Service Request. A device must request and receive permission before it can utilize any service that consumes any network resources.

4.1.4. Authentication. The user of a device and the device must be authenticated prior to the utilization of any service that consumes any network resources.

4.1.5. Policy. The network shall facilitate the ability to prioritize by user or device the use of any service that consumes any network resources.

4.1.6. Persistence. All documents stored to any storage medium for any purpose by any application or other executable code running on any device connected to the network shall utilize XML.

4.1.7. Journaling. A history of the network service usage of all users shall be maintained at all times.

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4.1.8. Bandwidth Control. A device shall be able to precisely control the number of bytes per second it transmits over the network.

4.1.9. LAN/WAN Bandwidth. The total symmetrical bandwidth available in a Local Area Network (LAN) and in the connection to the Wide Area Network (WAN) shall not be less than a guaranteed minimum full-duplex bandwidth for each device multiplied by the total number of connected devices within the LAN.

4.2. CI Workspace. Open standards and protocols define the specific format of data and instructions and the order in which events occur. However, it is up to a team of programmers to actually implement them. It has taken over a decade and hundreds of man-years of research and development to produce a software architecture that seamlessly and efficiently integrates all of the components necessary to facilitate reliable real-time voice, video and data based communication, collaboration and information management over the Internet. Of note is a critical observation, for the CI approach itself to become a standard its implementation must include tools that allow others to build complete solutions. This is reflected in the CI Workspace implementation.

The CI Workspace is a software application that runs on computers, servers, Personal Digital Assistants (PDAs) and other network devices. It is designed to run on all popular operating system and computing platform combinations. It is 100% ISO/ANSI C++ based and represents the state-of-the-art in ultra-high-performance object-oriented programming. From a user perspective it may appear to be similar to a web browser. However, instead of delivering just web pages it gives the user access to an extremely wide array of real-time two-way communication, collaboration and information management services -services designed from inception to work efficiently over a PSN like the Internet. Unlike the vast majority of applications in use today, the ability to send, receive and share data over a network is an optimized and integrated capability of the CI Workspace. For example, why must you use other applications to share or distribute a Microsoft Word, Excel or PowerPoint document over the Internet? It is because these applications were designed to run in a standalone fashion on a single computer. The operation of these legacy applications over a network is an afterthought, not an inherent capability. Imagine the ability to be editing a document and to have two, a dozen or even a few thousand people view it at the same time in real-time whenever desired. Imagine the ability to instantly receive feedback from subject matter experts anywhere on the planet on what changes and improvements should be made to the document. The impact of integrating distribution and collaboration seamlessly within a traditional production process has staggering implications on global productivity. This capability is profoundly essential for delivering bioterrorism defense and represents the essential increase in response time required to save lives.

It is important to realize that this single piece of software does for communication and information management over a PSN what a computer operating system does for a stand-alone computer or server. It provides the common shared services required to facilitate an extraordinarily wide range of capabilities. The CI Workspace has numerous unique characteristics that make this possible and they are summarized below.

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4.2.1. Advanced Plug-In Architecture. The CI Workspace is designed to host application modules called CI Tools. These "tools" can provide any conceivable capability from video conferencing to database access. The CI Workspace provides a state-of-the-art object-oriented "plug-in" architecture. Unlike current web browsers that have critical performance limitations that prevent them from hosting two-way real-time communication and information management services, this plug-in approach facilitates unlimited extensibility. CI Tools face no memory or performance limitations and can expand to utilize the full performance capabilities of the computing device on which they run. The CI plug-in approach also allows the CI Workspace to deliver a significant array of shared resources for all CI Tools.

4.2.2. Shared Resources. A typical software development effort is an extraordinarily complicated process. Even with the most modern development tools currently available, a team of programmers must implement sophisticated capabilities that allow applications on different computers to manage processes over a network. Implementing a capability like "copy, drag and drop" represents an enormous programming effort, particularly if this action must be reliably coordinated over a network of multiple computers. The shared library of code that comprises the CI Workspace fully automates a wide range of processes of this type. This means that any CI Tool gains these complex capabilities without any of its programmers having to gain the necessary decade of experience required to understand the physics of reliable packet based communication. Particularly in the medical community, CI Tools that are completely and reliably "network aware" can be written in a fraction of the time in comparison to any other known approach. For example, if a tool is written that automates the analysis of a tissue sample, the pathologist does not need to know anything about the following network enabled tasks:

- Copy and Paste
- Undo and Redo
- Drag and Drop
- User Interface Component Design
- User Interface Interactivity
- Persistence
- Journaling
- Validity Checking
- Authentication
- Encryption and Decryption
- Compression and Decompression
- Data Packetization and Reassembly
- Event Serialization
- Signaling
- Addressing

These are all individual tasks that by themselves would consume numerous man-years of labor to reliably produce. The pathologist need only implement an algorithm that delivers the desired analysis. The CI Workspace Application Programmer's Interface (API) will be available in the public domain and will include numerous CI Tool source code examples allowing any conceivable network service or network aware productivity tool to be built.

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An extraordinary breakthrough has been observed from this approach - what may appear to a user to be a large and sophisticated application is in actuality an ultra-small source code file or even a text file with XML formatted instructions. A CI Tool of enormous complexity and capability will typically be well less than 1/10th size of the currently distributed monolithic applications. This facilitates a significant advantage - if you are communicating with a number of individuals and you need them to have a capability that does not exist on their computer it will be possible to distribute and run a CI Tool dynamically. This means that any individual can repurpose any network device for any use at any time. In an environment where terrorists are trying to destroy or deny access to resources, allowing a doctor to borrow a police officer's network device to do an emergency consult represents an extreme tactical advantage.

4.2.3. Persistence. The eXtensible Markup Language (XML) has rapidly become the global standard for storing complex documents on a storage medium (persistence). The advantage of XML is that each item of information, from a persons name to the location of a video clip, includes a tag (description of what the item of information is). This means that months or even decades later any application that understands XML can parse through a document and discern what each item of information is. It also means that different XML aware applications can parse through any document and collect and analyze critical items of information. The impact XML will have on medical research, bioterrorism defense and healthcare in general (medical records) is nothing less than profound. Compare the advantages of XML to the rapidly changing proprietary Microsoft Word document format that forces users to purchase new copies of the Word application every few years.

The CI Workspace implementation possesses one of the most comprehensive uses of XML in the industry. All of the data structures that comprise it or that it manages can express themselves in XML. All software objects send and receive messages in an XML format. A Journal (history of all user actions) is recorded in XML to facilitate unlimited undo and redo locally or during a live network session. All of the data a user enters into any CI Tool is written to the desired storage medium anywhere on the network in XML as the data is entered. This means no more forgetting to save a document. Its ultra-high performance XML parsing capability allows the CI Workspace to rapidly open and render the XML documents it saves. The user interface of the CI Workspace and every CI Tool is defined entirely in XML - they simply read in a small XML formatted text file and render a complete interactive user interface of any desired complexity.

Even more powerful is the use of XML to increase the reliability of all software. As a CI Tool is written it is initially released in a "debug mode". As large numbers of users interact with the tool it conducts a real-time validity check between the user data stored in memory and the XML formatted data written to the storage medium. If the CI Workspace identifies a difference between the two it sends specific state information about the respective CI Tool over the Internet to a debug database. The XML formatted debug information is so thorough that any problem can be rapidly reproduced and solved. Since the improvements are made to a master shared library each new generation of the CI Workspace, and subsequently all CI Tools that it hosts, get geometrically more robust. Since each network device can get a CI Workspace update in an automated fashion the entire population of users immediately experiences increased reliability. All of this means that absolutely every aspect of the entire architecture is fully extensible. Merging the "inheritance" capability of ISO/ANSI C++ and the extensibility of XML forever changes the current understanding of software development costs, time and reliability.

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4.2.4. Journaling. As a user interacts with the CI Workspace or any CI Tool, every action is recorded in an XML format to the desired storage medium. This is called journaling. This was originally implemented to facilitate real-time unlimited undo and redo of absolutely any user action. However, its purpose has been extended to solve one of the most complicated and sensitive problems - security. According to numerous published reports the majority of all security breaches are the acts of trusted individuals. This means that firewalls, encryption, authentication, physical security, biometrics and literally billions of dollars worth of other security measures cannot stop the largest problem this nation faces to its national security. By simply transmitting a network device's journal to multiple physically distributed and securely stored servers, a complete history of the actions taken on that device is recorded. It is possible to analyze this XML data and surface any conceivable security breach. This easily represents the most economical and reliable way to deliver compliance with the Health Insurance Portability and Accountability Act of 1996 (HIPAA).

In addition to security, several other advantages of journaling have surfaced. It represents a means to automate the productivity and efficiency analysis of any network task. It allows multiple blind evaluations to be conducted on the efficiency of a user interface design facilitating rapid improvements. It allows educators to see the true level of participation of students in a self-paced learning environment. It allows for the first time a reliable way to track the use of and to protect copyrighted materials. Finally, it facilitates true commercialization of any network service - any provider gets a granular billing capability virtually for free.

4.2.5. Unconstrained Data Structure. There are a significant number of companies that sell and maintain relational database software and most use standards like the Standard Query Language (SQL) to provide access to their databases. What they all have in common is that the format of each field in a record is defined in advance. This means that if you need to model a process or automate a specific information flow problem a significant amount of planning and analysis must take place before the record structure is implemented. However, life is vastly more dynamic and unpredictable than can be implemented in such a "constrained architecture" - it is not possible to automate problems of extreme complexity if you have to anticipate all of the types and formats of information in advance. With this constraint in mind, the CI Workspace utilizes a completely unconstrained data structure approach. The shared library that comprises the CI Workspace has a highly optimized set of tools that allow the implementation and management of parent child hierarchies of any complexity. Every feature from user interfaces to the XML document generation takes advantage of this capability. Every CI Tool has access to this capability through the CI Workspace APIs. This capability in combination with the other highly integrated functionality will have a profound impact on delivering solutions like a national electronic medical record system that can be shared by both healthcare providers and medical researchers at the same time, a reliable command and control capability, a real-time threat monitoring capability and the automation of numerous other extraordinarily complex information flow problems. Without the right technology foundation none of these advanced capabilities can be delivered in a viable fashion.

4.2.6. Coherent Collaboration. All of the functionality of the CI Workspace combined delivers a productivity breakthrough called "Coherent Collaboration". Imagine 10 individuals in 10 different cities sitting at their respective computers and they all receive a CI Workspace "call" to join a session. A document is presented in a window on their screen. Note

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that an XML document can be of any complexity representing anything from a data entry form to a building design. The point is that an XML document represents "something" this group is working on together at the same time. Unlike any other technology available today, all 10 individuals can make changes to the document at the same time and all 10 can see all changes at the same time. For some things this level of parallelism might not make sense. For example, only one person should be allowed at a time to make changes to data in a single data entry field. However, for other processes this capability is a matter of life or death. Imagine extremely large numbers of network aware radiation sensors streaming data to a central team of public health officials. In this case you need to know that multiple events have occurred simultaneously and where they occurred. Bioterrorism defense requires this unique capability.

4.3. CI Tool Suite. The CI development team is producing a large number of CI Tools. This assists in rapidly maturing the CI Workspace, it measurably verifies the advantages of the CI architecture and provides the medical community with an invaluable suite of productivity tools. It also creates a solid foundation of sample code for the broadest possible range of software developers. The source code to these CI Tools is being made available to a large number of scientists within the more than 100 academic health sciences centers in the U.S. It is this community that produces our doctors, nurses, public health officials and other key medical first responders. Usage in this community immediately translates in facilitating bioterrorism defense. The following briefly summarizes some of the currently developed and proposed tools:

4.3.1. CI Contacts. This initiative is all about people communicating with people in a more efficient fashion. Through the CI Contacts Tool, the CI architecture provides "continuous presence" so that all users know all of the time who and what resources are available via the network. The CI Contacts tool also allows a user to organize into groups the individuals they need to communicate with on a regular basis. From CI Contacts a user can initiate any CI based service by first selecting the desired individual(s) then the desired service, without the need to know phone numbers, IP addresses or the location of the individuals.

4.3.2. CI Audio. The CI Audio tool delivers ultra-high quality low latency group audio conferencing on demand. One goal of the CI architecture is to assist in maturing the right wireless LAN technology through which packet-based audio can be delivered to any number of paramedics, firemen and policemen at the same time in real-time in any scenario, including disasters in skyscrapers.

4.3.3. CI Video. The CI Video tool delivers ultra-high quality low latency group video conferencing on demand. In fact, the CI development team delivered the first live real-time two-way 30 frames-per-second video conferencing technology that has been proven to work reliably over the global public Internet.

4.3.4. CI Share. The CI Share tool allows large groups to collaborate in real-time at the same using anything from high-resolution medical imagery to digital video clips. One may think of CI Share as a real-time group XML rendering engine. It also allows a user to deliver complex media rich presentations to even large groups in a precisely synchronized fashion. The ability to reliably synchronize what a group sees, particularly while CI Audio and CI Video are running at the same time has already proven to be immensely valuable for remote medical consultation.

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4.3.5. CI Message. The CI Message tool integrates secure email, chat and instant messaging into a single package. Due to the high performance data management capabilities of the CI Workspace, combined with the flexibility of XML, this tool will add a new dimension of productivity and capability to a very popular suite of traditional technologies.

4.3.6. CI Admin. The CI Admin tool allows network administrators to add and manage all user accounts and to establish network usage policies.

4.3.7. CI Schedule. The CI Schedule tool does vastly more than manage resources like rooms and an individual's time. It allows numerous network services to be established at desired times. Everything from managing the delivery of schedule reminders to transferring lab pathology results to designated computers for a pre-established consult time is possible.

4.3.8. CI Assess. The nation desperately needs a common, cost effective and reliable means of training healthcare providers how to deal with a wide array of nuclear, biological and chemical threats. One of the missing elements of current distance and self-paced learning systems is the ability to randomly assess a "student's" understanding of the respective subject matter. CI Assess allows any user to assess any size group at the same time at any time in real-time. A user can rapidly create, organize, deliver, grade and analyze the results of yes/no, true/false, short answer and multiple-choice questions. Additionally, any media format can be incorporated into each question. This facilitates the automation of feedback processes like quizzes, exams, surveys, polling and voting.

4.3.9. CI Phone. The CI Phone tool allows a user to enter or select a telephone number and to establish an audio session between their network device and any telephone or cell phone. It also supports inbound phone calls.

4.3.10. CI Form. Good logistics is the foundation of bioterrorism defense. All emergency personnel should be able to answer the following questions: "Where are the gas masks?", "How many gas masks are there?", "How many gas mask filters are available for each type of chemical or biological threat?" and "What is the shelf life of each type of filter?", etc. Being able to answer questions like this demonstrates the value of an integrated, secure, real-time information management system. The CI Form tool allows a user to access CI "database" services. In concert with the CI Assets tool, defined later, everything from order entry to inventory control can be implemented. This tool also includes a form generator that allows rapid development and customization.

4.3.11. CI Reports. The CI Reports tool allows a user to create reports from the XML data managed by the CI Assets tool.

4.3.12. CI Browser. Using open standards based web browser technology, the CI Browser tool allows a user to open a web page as a live collaborative session and ensure that every participant sees the same web page content at the same time.

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4.4. CI Server Suite. In order to support scalable service delivery the following CI Tools that comprise the CI Server Suite are typically placed on more powerful computers with significant data storage capacity. For clarity, the CI architecture views this type of network device as a server. The CI architecture has been engineered to be fully "symmetrical" meaning that any network device can run the CI Workspace and subsequently any CI Tool. Symmetry is a critical characteristic for bioterrorism defense and medical crisis management. Any device should be able to dynamically host any of the CI Server Suite based CI Tools at any time. This is the only way to ensure that a group of individuals can continue to communicate when key server resources are destroyed or made inaccessible. The only exception to the symmetrical approach is that some devices have insufficient memory or processing power for a particular service. The following summarizes the CI Server Suite:

4.4.1. CI Locator. The CI architecture uses Session Initiation Protocol (SIP) addressing. SIP addressing provides unlimited scalability for providing the unique identification of any resource. The CI Locator manages the mapping of a SIP address to a physical layer address regardless of the standard. For example, this allows Internet Protocol version 4 (IPv4) addresses, Internet Protocol version 4 (IPv6) addresses, ATM addresses, telephone numbers and other addressing formats required by the respective technology to be mapped to a SIP address. It also allows a file, a document or a sub-element of a document to be uniquely addressed for reliable retrieval from anywhere on the network. The CI architecture does not and should not know the difference between an item of data, a file, an XML document, a device or a person. This allows a small, highly optimized and extremely reliable software module to manage the location, identification, prioritization, availability and security of anything from individuals and devices to very specific items of information. The efficiency, performance, extensibility and code reuse this approach represents is extraordinary.

4.4.2. CI Reflector. The CI Reflector tool facilitates real-time large group and coherent collaboration. It implements the important event serialization process that ensures synchronization. This is a symmetrical process that is universally available to all CI Tools. The CI Reflector does not know or care which CI Tool is using it or for what purpose. For example, any CI Tool that possesses a user interface can be placed into a "training mode". In this mode any action taken by any user in the user interface of their CI Tool is reflected in the user interface of all other CI Tools participating in the session. This powerful capability is possible through the combination of the CI Reflector and the XML and C++ based object-oriented capabilities of the CI Workspace. All CI Tool developers literally get this capability for free.

4.4.3. CI Policy. The CI Policy tool enforces network based service priorities. Through the CI Admin tool, users, devices and services are given priority levels. If a network resource, like the bandwidth between two points, is not available when a service request is made lower priority users can be dropped or other active session characteristics can be degraded. It is preferable to eliminate oversubscription of resources on a network, but where there is insufficient funding this approach can ensure key healthcare providers and first responders can accomplish their jobs during a crisis.

4.4.4. CI Assets. The CI Assets tool lets other CI Tools like the CI Form tool check in and check out XML documents. Once a document is checked in, using the powerful unconstrained data architecture of the CI Workspace, the XML elements of every document are

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indexed and cross-referenced for granular retrieval and analysis. CI Tools like CI Report utilize this capability. CI Assets makes the process so transparent that it can handle anything from patient records to inventory control.

In the CI architecture a document is defined as a text file in the XML format. A file is defined as a "blob" of binary data like a video clip stored as a QuickTime movie, an audio clip stored in the MP3 format or a high-resolution medical image stored in a JPEG 2 000 format. A document can contain XML elements that are Universal Resource Identifiers (URIs), which can point to any file. In this fashion it is possible to build complex media rich relationships. This means CI Assets can organize and facilitate the analysis of any information of any format with relationships of any complexity. Again the symmetry, efficiency, extensibility and code reuse of the CI architecture becomes evident.

4.4.5. CI Journal. CI Journal is just a version of CI Assets that is managed more securely to support the journaling capability. For the highest level of security, the servers on which this tool runs should be treated as a controlled item with limited access.

4.4.6. CI SQL Gateway. There is a significant amount of information stored globally on legacy SQL accessible databases. This tool maps SQL to and from XML. This facilitates a common national medical record system while the medical facilities continue to use their current information systems. Because of the sensitive nature of medical information, hospital administrators are averse to adopting new technology standards. The CI SQL Gateway allows the nation to facilitate bioterrorism defense while also allowing medical facilities to control the timing of their information system changes.

4.4.7. CI XML Gateway. The medical community has not adopted a standard set of "tags" or data values for its XML implementation. For example, there are different tags for "blood type" and different text values for the actual blood type declaration. This is an easy problem to solve in the CI architecture - simply pick the most common standard for the CI XML format and transparently map the other formats to and from it. Legacy XML implementations do not have to change and a common national medical record system can be maintained. The CI XML Gateway does a simple look-up-and-replace and passes on the new values.

4.4.8. CI PSTN Gateway. The CI PSTN Gateway tool provides the link between IP packet-based audio and the standard telephone network. The CI PSTN Gateway tool translates the packet based audio stream to the format required by the PSTN. This is a symmetrical process. The implication of this ability is that long distance phone charges can be completely eliminated. If you put the PSTN servers in the right locations every call looks like a local call. To facilitate the use of the CI Phone tool, the servers that host the CI PSTN Gateway tool must be equipped with PRI speed ISDN line network interface cards.

4.5. CI Library Suite. The CI Workspace and CI Tools make use of special purpose libraries of executable code. For example, the CI Workspace uses the CI Comm Library for all packet management. The following summarizes a few of the CI Libraries:

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4.5.1. CI Com. This CI Library contains all of the communication and signaling protocol stacks. This includes the Session Initiation Protocol (SIP), Real-time Transport Protocol (RTP), Transport Layer Security (TLS), Transmission Control Protocol (TCP), User Datagram Protocol (UDP), etc. Of note is the simple relationship between the CI Workspace and CI Com Library. It consists of only a few calls to include "Publish", "Join", "Send", "Receive" and "End". The complexities, specifications, protocols, packet header formats, packet address formats and configurations of the current network infrastructure are completely hidden from CI Workspace. In fact, when a CI Workspace code object sends a message to other code objects, it is not aware that it may be communicating with thousands of other code objects on an equal number of computers anywhere on the network. This has enormous implications. CI Tools can facilitate services regardless of what changes are made at some future date to the underlying network infrastructure or to the network devices on which they run. This ensures a long-term return on investment in any network infrastructure upgrades and the training that goes into all users.

4.5.2. CI Media. This CI Library contains a suite of highly optimized audio, video, high-resolution imagery and generic binary data compression and decompression algorithms. This includes the ability to deliver both lossless and lossy compression and decompression of the broadest possible range of media rich data formats and data streams. High compression ratios translate directly into lower network bandwidth consumption, lower propagation latencies or a greater number of simultaneous users of a shared network resource. These algorithms have been highly optimized to reduce network transmission latency, device memory access bandwidth, device memory requirements and device storage medium requirements.

4.5.3. CI Security. This CI Library contains the various data encryption and decryption algorithms.

4.6. CI Certification. The CI development team is designing a certification system that includes software tools that measure the performance, security, latency, oversubscription and other network characteristics. A formal specification for achieving various CI certification levels will be published. A CI enabled network by definition will become vastly more stable and reliable. However, a heavily oversubscribed network with numerous low-bandwidth data paths has very pronounced performance limitations. In the case of sending real-time two-way video, it only takes a small number of simultaneous sessions to consume all available capacity over a poorly implemented network. Additionally, if only a small number of devices utilize the CI software, the network is still largely unreliable and unpredictable. The ultimate goal of the CI certification process is to facilitate bioterrorism defense and improved healthcare delivery by educating communities on how to cost effectively improve their current networks.

5. Conclusion. The medical community's need for a common reliable communication infrastructure is extremely obvious. Unfortunately, the barriers of cost and complexity have been too high, until now. By taking immediate advantage of numerous rapidly maturing open standards it is possible to affordably deliver a comprehensive and highly extensible solution at a fixed cost. It is difficult for people to comprehend how rapidly threats like a highly contagious disease can spread, particularly if it is spread intentionally. This engineering effort will deliver a solution that allows the medical community to provide a defense against such insidious threats. It will also empower our healthcare providers with the tools necessary to ultimately improve the quality of life for all citizens.

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