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Rapid Delivery e-Health Service (RDeHS) Platform

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Abstract—As the e-Health world is geared up for a more efficient rollout of fast healthcare resources, we designed our new Rapid Delivery e-Health Service (RDeHS) platform, which not only streamlines standard conformance through emerging technologies in e-Health resources. This paper reports the evolution in our new architectural approach for the purpose of rapid development and deployment of e-Health services to reduce healthcare costs and enhance quality of care.

Keywords— *e-Health Emerging Technology; Rapid e-Health Service Delivery; e-Health Fast Resources; Healthcare Flow Orchestration; Quality of Service Control*

I. INTRODUCTION

While e-Health standards have become a complex barrier to implement interoperable solutions [1], new technologies emerge in rapid e-Health resources in order to streamline the realization of performance driven precision medicine. Instead of chasing the exponential growth of healthcare standards, a -different concentration in the most common use cases may become the norm of the e-Health industry trend. These rapid resources have become key success factors in transformation into affordable and interoperable care e-Health services, which follow a new e-Health engineering paradigm [2,3,4].

With new engineering research on e-Health it is our goal to enable interoperable and scalable infrastructures, applications, and services for a continuously learning system solution for current and future e-Health where data originate from diverse sources in multiple formats, touch multiple fast care resources, pass through numerous care flows, meet security and privacy regulations, and provide performance accountability for e-Health quality of service control.

This paper reports the evolution in our new architectural approach for the purposes of rapid applications of e-Health services to reduce healthcare costs and enhance quality of care. The paper is organized as follows. In section II, we provide overviews of our original big data e-Health services design and the past connected and smart e-Health solution. Next the essential functions are identified to meet the roles of better delivery of rapid e-Health resources in section IV. We further extend the Rapid Delivery e-Health Service approach in

regulatory compliance and deviation detection of e-Health meaningful usages. The final section concludes with a summary of our contributions.

II. EVOLUTION OF OUR E-HEALTH ARCHITECTURE

A. Original Big Data e-Health Service Architecture

We started out with a big data approach [5,6] to include advanced processing methods for controlling and maintaining data integrity, provenance, security, privacy, and reliability of original as well as aggregated data. The original BDeHS big data e-Health model provided trustworthy patient identification and authentication and access control protocols, maintaining the sensitivity to the legal, cultural and ethical issues associated with universally accessible e-Health data.

In our original approach [5], a variety of data types (structured, semi-structured and unstructured) were identified from variable data sources, including

- HL 7 (Health Level 7) well-structured messaging [7]
- NCPDP (National Council for Prescription Drug Program) prescription insurance claims and NCPDP SCRIPT for electronic prescription messaging [8]
- DICOM (Digital Imaging and Communications in Medicine) semi-structured data for radiology image exchanges over IP networks [9].
- HIPAA transactions for insurance claims and other processes are based on American Standard Institute accredited committees X12 messaging standards [10].
- ISO/IEEE suite of protocols and messaging standards for digital health monitoring and diagnostics devices [11]
- Internal e-Health system logging and security audit records with semi-structured data as far as end-to-end system flows are concerned
- Patient-support system GUI data of medical history, allergies, vaccinations, appointments, and invoices as well as inquiry supports

- Internal clinical-support system medical information for internal use by physicians and healthcare workers delivering services at the point of care
- Research-portal system data used by researchers and for government Centers for Disease Control reporting
- National health information network generated communicational data from NHIN and data flows
- Operational data including security events and usage accounting/charging functions

As far as the stream processing flows in [5], the detail processing stages including data fork points, stream joints, as well as event and message logging. All of which are specified in a policy format that controls the in-flight processing of data. An entry gateway adapted the feeding data formats into a common format as required by the e-Health metadata model, while security policies are tagged along with the flows.

Data Federation is extended into the processing nodes with e-Health data processing logics (filtering, logging, aggregation, exploratory and iterative analysis, regulatory checkpoints, and so on). Data sinking gateways provide the exit points of the e-Health data flows when anomalies (e.g., adverse treatment or drug effects) are detected on flight or when e-Health data security events have to be reported.

In between the data entries and exits, a number of middle storage and processing stages supply data replications and parallel processing logics for additional data segmentation, summarization, (security and health regulation) policy enforcement, filtering, data transformation, header and trailer expansion, message split or union, state synchronization, and coordination with other distributed processing nodes.

Due to the difficulty in implementation of big data e-Health, we felt quickly that we need a better process reengineering to the level of e-Health components connected via data virtualization and exchange protocols, to support the creation of application flows and e-Health service development and deployment. The enhancement led to the architecture design of the Smart and Connected e-Health Architecture.

B. Smart and Connected e-Health Platform Architecture

The next evolution phase became the result of the Smart and Connected e-Health Service (SCeHS) program [2,12] to develop next generation healthcare I.T. solutions. The smart and connected platform consists of the infrastructure layer, a tool set platform, a functional layer and the e-Health resource layer.

In our SCeHS approach[2], the basic resource layer modeled the external data sources into elements, where each element will represent a complex HIS/CIS/RIS/e-Subscribe with external connectivity as well as perfected archives of EMR, LOCIC, PACS, DICOM, NCPDP and insurance records. Due to divergent sources and varying format structures, data maps and processing tools were studied and researched.

Another key solution of the smart and connected architecture solution was in the formulation of e-Health APIs for planning evidence-based programs, for predicting disease onset to intervene earlier, for delivering the right case services to support the individual with the exact treatment, to improve quality and for optimizing e-Health care resources, and so on. The APIS and other tool sets of data mapping and flow configuration formed an overall tool set layer in this architecture evolution.

Although we minimize the physical connectivity with external health IT systems in this lab environment, the networking service layer still plays a key role in the development of new services of this platform since various network deployment scenarios have to be considered when the applications and services are to be deployed into a production HIT environment. In [2] network layer was the key concern of the infrastructure layer design. Due to limitation and lack of access to HIT environments, a virtualized network controlled data network capability was proposed to minimize the physical connectivity. The gateway models in [5] enabled the lab design to accommodate the different service context management for various providers (the so called covered entities and their associates) and patients. These e-Health service contexts were called domains in the SCeHS architecture across multiple industries (that go beyond the core healthcare providers and patients).

Key domains include Electronic Health Records including data interoperability, security and privacy. Another domain is big data medicine where personal genetic markers in DNA assist in disease prevention, diagnosis, and treatment decisions, has continued to progress. The third domain includes remote clinical care, diagnostics, and electronic patient monitoring driven by the pervasiveness devices and wireless capabilities, by the relative affordability of devices, and by new remote clinical care technologies that enable doctors to provide medical assessments and treatments from a remote location away from the patients without onsite specialist medical doctors.

Additional application domains include personalized medicine, which is combined with e-Health computing and genomic technologies to utilize information about a person's genes, proteins, and environment to prevent, diagnose, and to treat diseases. Clinical decision supports, operational quality monitoring, insurance and billings are all interesting components of our application domains. All became an integral part of the SCeHS architecture paradigm.

C. Rapid Delivery e-Health Service Platform Architecture

Experiences in field practices (courtesy of co-author Professor Zhu's research team internal results) suggested that a strict adherence to the same medication process is practically impossible to enforce as empirical experiences may result variation of medication and care delivery. Our evolution of the smart and connected design is further enhanced into a next generation Rapid Delivery e-Health Service (RDeHS) architecture.

Another main reason of a new practical RDeHS is motivated by the new trend [1] of rapid e-Health resources

where 80% of standard use cases shall be in fast resources, which allows us to streamline the previously complex architecture functions. As such, the new and rapid delivery e-Health service approach shall succeed the SCeHS [2] design approach.

III. E-HEALTH SOLUTION PLATFORM ARCHITECTURE

First we describe the essential functional sets. Then we present the architecture analysis with detail platform design and evaluation. For acceptance, the user realms and certification process need further consideration. Security flows and enforcement can be dealt with in operational architectural process. And conformance toolsets will also be addressed with the coverage sets.

A. Essential e-Health Functional Sets

Following the new HL7 standards [12], a number of resources become the core e-Health functional sets. They include the general functions, diagnosis, immunization, care provision and medications.

General functions further include the following resources:

- Allergy Intolerance
- Patient Condition (Problem)
- Procedure
- Clinical Impression
- Family Member History
- Risk Assessment
- Detected Issue

Diagnostics:

- Observation
- Diagnostic Report
- Diagnostic Order
- Specimen
- Body Site
- Imaging Study
- Imaging Selection

Immunization:

- Immunization History
- Immunization Recommendation

Care Provision:

- Care Plan

- Goal
- Referral Request
- Procedure Request
- Nutrition Order
- Vision Prescription

Medication:

- Medication
- Medication Order
- Medication Administration
- Medication Dispense
- Medication Statement.

B. New Generation of RDeHS Architecture

Once the essential e-Health functional sets (i.e., the fast resources) are available, our new generation of BDeHS architecture kicks in to support the orchestration layer in coordination of end-to-end services with quality of service control. The following figure shows the major architecture compartments for the new rapid delivery e-Health service model.

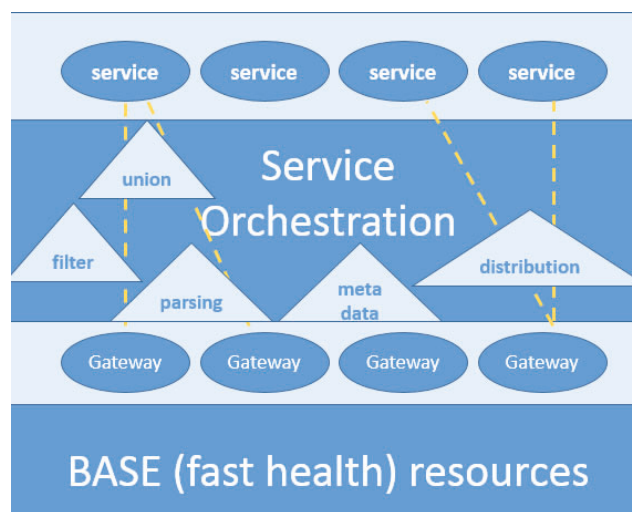


Figure 1. Gateways and orchestration to enable new services

Previously in [5] our gateways were mainly adaptations of data sources, in this new architecture “gateways” become the entry/exit points of the orchestration layer to unify the follows from (and to) individuals (patients and practitioners), groups (healthcare service and organizations) and entities (locations and devices). The service orchestration layer is to present healthcare industry standardized service interfaces towards to all parties served by our infrastructure. Additional service profiles may create, deploy, and maintain policies controlling QoS (Quality of Service) parameters.

Most importantly, as new inputs resources become available from BSN (Body Sensor Networks), huge amount of data resources have to be fed into the solution base including basic readings of vital signs as well as complex e-Health contingency abnormal condition detections. Our architecture gateways supply the necessary features to enable resources coordination, stream loading, filtering functions and interactions with the orchestration processing engine.

A service orchestration engine will carry out service level distribution, application routing, task cycle management, meta-data model access/control, and real time execution for those required flows mandated in [12]: appointments, patient management, and processing work flows.

Most of the Standardized Workflow are formulated into the following API abstractions. New service APIs are created as the external devices grow in a pervasive e-Health environment. Workflow APIs cover Service Order, Order Response, Communication Request, Device Use Request, Device Use Statement, Process Request, Process Response, Supply Request, and Supply Delivery.

C. User Realms and Acceptance Certification

The U.S. Department of Health and Human Services has published the Final Rule [13] for Health Information Technology that includes standards of implementation and certification criteria for e-Health technology. The Final Rule has listed the functions or services and promoted enhanced interoperability, functionality, utility, and security of EHR technology.

D. Security flows and enforcement

[13] has required security context management to accommodate more types of patient data being efficiently shared and further expansion of access to patient data due to the accelerated conversion of data into useful intelligence. Our general security framework [4] is a base for further expansion and conformance in order to meet the requirements of Resource Provenance and Event Audits [12].

E. Conformance toolsets

Conformance toolsets deal with validation of development and initial deployment. The key items include terminology verification, content well form, and operational integrity including functional delivery, privacy as well as security. Implementation guides and test scripts also follow standard requirements.

Terminology:

- Value Set
- Concept Map
- Naming System

Content:

- Structure Definition

- Data Element

Operations Control:

- Conformance
- Operation Definition
- Search Parameter

A major benefit of this solution architecture plan is the flexibility in extending conformance to emerging e-Health standards as well as other external sources [14,15].

F. Operational Supports

Additional OAM&P (Operation, Admin, Management and Provision) functions are provided for operational support, administrative utilities, quality management control, and provision of new resources and service flows. Here we focus on the security aspects of the architecture.

As e-Health fast resources are deployed into the interconnected environments, the operational complexity increases as e-Health applications grow. At the operational level, additional e-Healthcare management issues have to be supported by the infrastructure. Examples of operational activities include security monitoring, configuration, service level agreement enforcement and performance monitoring, auditing and accounting.

Security Service Management provides a mechanism for patient permission preferences to be stored and maintained, and thus applied separately from a particular PHR or other mechanism used to enter such preferences. Additional (secure) interconnection and dependency relationship (i.e., secure associations) where information flows among three or more parties may be following different policies governed by HIPAA or HITECH. In other words, different members (e.g., a support provider or a secondary user) may have different authorization level from a subset of the e-Health information set.

Configuration management deals with attributes and services information for connected users, enabling temporary and permanent de-authorization of direct and third-party users when necessary, and granting emergency access capabilities.

Performance management enables threshold reporting, trend analysis and continuous capacity upgrades in order to meet a desired level of service guarantees.

Audit and reporting services are important when many parties are riding on shared interconnected e-Health networks where multiple entities are participating in a coordinated e-Healthcare process. Reports have to meet all security and privacy requirements of e-Healthcare.

G. Future Solution Roadmap

For the e-Health providers, the starting point is in validating the solution scope and to revisit set of objectives for e-Health services. The quantifiable aspects of objectives usually identify the fast resources involved and service plans.

At this initial phase, and proposed solution most cover all resources element systems of clinical, medical and patient supports, networking resources and interconnection gateways, as well as business-specific services.

Next is to make decisions on various platform or application service providers. Whether an e-Health organization decides on a pure cloud solution or a hybrid development solution, one must take into consideration of the partnership organizations in the network, the selected application systems and the privacy policy from each participant(s).

Another critical step during this process is to decide on the technology infrastructure including software, hardware, and network. We can determine whether the existing information technology infrastructure meets the requirements by validating the interconnection, security and QoS components of our e-Health solution with consideration of secure transmission of clinical data. Additional secure flows are setup to validate the differential security aspects of Data Interoperability.

In parallel to the technology selections, different e-Health application flows have to be performed and re-designed if necessary. For examples, check the flows between the lab and the pharmacy in a hospital, as well as across organizations such as between hospitals and government agencies.

When necessary, adaptation connections may be used to enable the “service centers” and “operational centers” for some internal (business) functions, so that the architecture can be prototyped before any costly operational centers are built. Existing service agreements are reviewed, and current infrastructure quality of service are measured, and projected models must be developed to accommodate foreseeable business growths. The end result can become an operational plan for the new e-Health infrastructure. Future performance plan will identify the steps to tune for optimal service and operational performance.

IV. SUMMARY

We have presented our evolution of platform architecture designs to enable efficient rollout of fast healthcare resources for rapid delivery of e-Health services. This RDeHS design streamlines standard conformance. The solution serves the purposes of rapid development of e-Health services and deployment of fast e-Health resources to reduce healthcare costs and enhance quality of care.

The key contributions of the new extension architecture plan include fast resources in the new e-Health industry, external monitoring resources and data, a new orchestration engine for flows and service routing, as well as provision and management of e-Health life cycles with logging and security controls.

When combined with our previously published security framework and operational architecture, the new platform capabilities form a foundation for a future rapid implementation of emerging standards, rapid data conversion and utilization, and a rapid deployment of new e-Health application flows.

Future research will focus more on the detail fast resources and the validation models in the orchestration engine. Another effort is to gain buy-ins from the field practitioners. Performance models may be developed to fine tune the processing rates and response times of e-Health service flows.

While the overall architecture plans are consistent with our evolution in e-Health solutions, the swift adoption of the fast resources and service flows become revolutionary as we are conforming to the latest industry trends.

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