Business Data Analytics Framework for Digital Health Informatics

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ABSTRACT

The U.S. Healthcare.gov estimates the FY2021 Healthcare-and-Medicine market to be in the neighborhood of $808 billion. By far, it is measured as the largest undisputed market in the U.S., which may pave the ground for the development of many business models based on new data frameworks and value chains.

The objective of this paper is to propose a framework for a new business model using Digital Data Analytics in the topical area of *Health Informatics*. Specifically, healthcare data for the *metabolic disease* comprised of (human) blood pressure, blood glucose/sugar, and blood cholesterol are at the center of focus. Digital medical apparatus, real-time digital health informatics, and their data analytics are discussed.

Keywords: Data Analytics, Digital Data Framework, Health Informatics, Mobile Health, Metabolic Disease, Medical Devices, Systems Analysis and Design, Internet of Things.

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INTRODUCTION

The U.S. Healthcare.gov estimates the FY2021 Healthcare-and-Medicine market to be in the neighborhood of $808 billion. By far, it is measured as the largest undisputed market in the U.S., which may pave the ground for the development of many business models based on new data frameworks and value chains.

By far, data analytics for health informatics has been less effective, relative to such systems as Electronic Commerce (*i.e.* e-Commerce), Financial Technology (*i.e.* FinTech), and/or Engineering. This is due, in part, to lack of *de-facto* standards for its digital data to be analyzed extensively. As a consequence, building sound *data frameworks* for standardizing the systems data is necessary to perform effective data analytics. Patient health cannot be comprised under any circumstances. To this end, a constructive framework for buiding a healthcare portal is suggested in this paper.

Digital Data has transformed itself from a pure technological topic for research and development to an atomic unit which is valued as an indispensable asset for many business models surrounding Big Data. By and large, evolution of information systems which has brought the era of Big Data may be summarized as:

Generation 1. Development of the Infrastructure [Y2K ~ 2009]:
- Construction of Wired and Wireless Data Communications Networks
- Advancement of Networking-Apparatus Technology, such as Servers, Routers, Gateways, Firewalls, Virtual Private Networks, *etc*. (*i.e.* Systems Software or Middleware)

Generation 2. Mobile Revolution [2010 ~ 2019]:
- Global Adoption of Personal Mobile Devices
- Synchronization of Data in *Quasi*-Real Time
- Digital Data Explosion and Digital Conversion (*e.g.* Internet of Things; IoT)

Generation 3. Digital Intelligence [2020 ~ Present]:
- Artificial Intelligence and Machine Learning (AI/ ML)
- Digital Data Compatibility and Standards
- Quantum Computing

Thus, the development of an array of digital business models founded upon Gen-3 technology above may positively support the profiles of many global industries, corporations, and governments.

The objective of this paper is to propose a framework for a new business model using Digital Data Analytics in the topical area of *Health Informatics*. The U. S. Food and Drug Administration (2022) reports *metabolic disease* to be the major cause to negatively affect both life expectancy and health expectancy for the entire population of the U. S. Hence, early intervention by physicians and prevention such as lifestyle modifications by patients are of essence. Specifically, digital healthcare data for the *metabolic disease,* comprised of (human) blood pressure, blood glucose/sugar, and blood cholesterol are at the center of focus. Digital medical apparatus, real-time digital health informatics, and their data analytics will be discussed.

This paper is organized as follows. In the subsequent sections, Business Data and Digital Gauges to measure the Blood Pressure, Blood Sugar, and Blood Cholesterol are discussed. More importantly, recent surge of adoptions of the *Wearable* Devices/Gauges/Meters by the healthcare market are reviewed. These provide the foundational mechanism and platform for *quasi*-real time intervention (by the medical professionals) for possible complications of metabolic disease. Their *pros* and *cons* in terms of building business models which may further allow data analytics are delineated. Review of literature follows in section 2. In section 3, an integrated framework to support and process the digital data produced by medical devices is presented. Specifically, an Entity-Relationship Diagram (ER-D) with accompanying Data Dictionary (DD) are presented. Further, medical portals to engage, communicate, and share these health informatics are studied. An architectural prototype is presented. Conclusion and remarks for future research follow in section 4.

Business Data

Data may be classified into a taxonomy of 2×2 matrix. Their examples are summarized and listed in Table 1 (Appendix), following the conceptualization presented in Willow (2005).

As to the types of data, there may be a mixture of structured and unstructured, often referred to as the *hybrid* types. These *encapsulated* data types provide combinations of finite numbers of both structured and unstructured data. Moving images or videos are perfect such examples of the hybrid data types, wherein virtually every data type may coexist.

Conspicuously, business values of digital data are not equal across the board. That is, some data management may opt in to secure their digital data *closed* and *local*. Unless stakes of security are high, business values of these digital data will remain relatively low until they are shared (*i.e.* open) via communications network in *quasi*-real time. Closed set of digital data, therefore, often exhibit comparable business attributes of the analog form. In essence, global Big-Data market is primarily dominated by the *shared* unstructured and hybrid digital data.

Major health indicators which cause the metabolic disease include but are not restricted to: Blood Pressure, Blood Glucose/Sugar, and Blood Cholesterol (FDA, 2022; Goldman *et al*., 2020; Lee *et al*., 2020, Lu *et al*., 2020). Historically, then, there is an urgency to trace and monitor these three (3) medical parameters from a patient on a regular time interval. Preferably, benefits from preventative medicine may be maximized by *real-time* intervention.

Digital Gauges for the Metabolic Disease

Blood glucose monitoring devices are at the forefront at the present juncture. Figure 1 (Appendix) represents a classical, state-of-the-art analog blood-sugar measuring device. These devices allow the patient to intermittently measure her/his blood glucose levels. Some may permit the measurement to be recorded and stored internally in digital form. However, data sharing may not be the option in general, since most of these devices lack or even inhibit networking capabilities.

Advanced evolved forms of blood glucose monitoring gauges, in the more recent years, have emerged. Consistent with the *digital convergence* strategy for most (digital) mobile business, these are typically the *plug-and-play* physical apparatus onto many mobile devices which support the iOS or Android platforms. Figure 2 (Appendix) depicts such an example on an Apple *i*-Phone.

Wearable devices have proven to be more effective for real-time, *continuous* monitoring of blood glucose, most recently. Close-proximity network and pairing technology such as Bluetooth allows ubiquitous access to patient data. Figure 3 (Appendix) follows to illustrate (Abbott, 2022).

With a lifespan of approximately 2 to 3 weeks, tiny patches are worn by patients. A glucose measurement-patch performs dual functions; while it estimates chemical compounds of patient blood, it simultaneously serves as a data access point to communicate with the patient's mobile device(s). One of the objectives of this research is to construct a business model to maximize the value of this continuous and overarching *digital convergence* taking shape at the patients' end by way of her/his mobile devices and App's. Further discussions follow in section 3.

Blood pressure and cardiological Beats per Minute (BpM) are also measured in real time, continuously, by using alternative mobile device which syncs with other Internet of Things (IoT). An example follows in Figure 4 (Appendix).

As to the Blood Cholesterol, there are analog lipid meters, as demonstrated in Figure 5 (Appendix).

However, chemical complications may hamper accurate measurement of the blood cholesterol levels. At the very least, three (3) sub-parameters must be monitored, simultaneously, comprised of the High-Density Lipoprotein (HDL), Low-Density Lipoprotein (LDL), and the Triglycerides (TG). Consequently, wearable devices are seldom marketable.

LITERATURE REVIEW

A review of relevant literature follows to complete the understanding of current research on the topical subject matters of this paper.

Nyein *et al.* (2021) describe a prototype for a wearable patch to monitor human perspiration. Data analytics for such an experiment may be inclusive to an extension to this paper. Medical professionals may verify and confirm that sweat analysis in real time may trigger interventions for complications of the metabolic disease. A digital data framework was not presented by Nyein *et al.* (2021), notwithstanding.

In Shan *et al.* (2019), emphasis was placed on the need for a comprehensive *healthcare portal*. They stressed that such an health-informatics approach is necessary to care for and manage diabetic patients. Although their *rationale* and set of justifications were sound, Shan *et al.* (2019) had also failed to engage themselves to present a digital data framework within reason.

Goldman *et al.* (2020) propose the notion of an Interface Data Sheet for each medical device. The underlying assumption is that the entire set of medical devices in a data network domain is operable on a single standard platform and standard. In addition, whether these devices were network-detectable Internet of Things (IoT) was unclear.

Lee *et al.* (2020) introduced a prototype for a Healthcare Portal entitled, *e-*Motivate4Change. It was designed specifically for the purpose of preventing metabolic disease for younger adults. Rather than medical intervention, however, the focus was on patient education on their lifestyle changes. This paper was well organized with a clear objective and sound designs of experiment. Perhaps the only shortcoming was the lack of its extension to include medical-device data onto Motivate4Change to implement a *real-time* data analytics. Instead, blood sample measurements were made intermittently by registered nurses, who at a later time intervals, manually entered the data.

Brief reports on government regulations for Medical Devices appear in Curfman *et al.* (2011) and Challoner *et al.* (2011).

Another Healthcare Portal to (medically) intervene premature births is presented by Cramer *et al.* (2018). Entitled GoMo Health, this portal was tested for its efficiency, acceptability (by patients, who are primarily expected mothers), fidelity or patient loyalty, and financial impact from intervention. This paper clearly provides the impetus for the design and development of a Healthcare Portal which supports real-time *medical data analytics*.

Artificial Intelligence (AI) applications to medical devices are discussed in Beckers *et al.* (2021). Their topic provides positive prospects for various medical devices. However, there was no reservation to further their discussions to transform these AI-equipped devices to workable Internet of Things (IoT).

Design of medical devices including but not restricted to end user interface are studied by Lang *et al.* (2013) and von Behr *et al.* (2021). In furtherance, the International Standard Organization (ISO) (2022) provides an excellent foundation for such designs.

INTEGRATED FRAMEWORK FOR HEALTH INFORMATICS

A preliminary framework for the proposed *Healthcare Portal* is presented in this section. To comply with global standards, a traditional Entity-Relationship Diagram (ER-D) is completed. The ER-D supports the process of *Systems Analysis and Design* as its draft blueprint. A dedicated section follows to illustrate.

Once the preliminary ER-D completes its series of □-tests, version upgrades to complete the Systems Analysis and Design are expected to pursue. Upon successful implementation of the system, the real-time Big Data (*i.e.* Health Informatics) will provide opportunities for physicians and their assistants, medical facilities, pharmaceutical firms, medical manufacturing industry, and/or educational institutions to perform multi-dimensional Data Analytics in quasi-real time, expectedly. Needless to emphasize, the caveat for this set of Data Analytics is that *data security and privacy* matters and problems for all parties are resolved and accounted for well in advance.

Entity-Relationship Diagram

Figure 6 (Appendix) represents the preliminary Entity-Relationship Diagram (ER-D) for the proposed Healthcare Portal to allow early intervention by physicians for possible patient symptomatic complications due to their metabolic disease. One of the globally-opted open-source development application, MySQL, was the apparatus. Figure 6 (Appendix) is an outcome of MySQL in that the ER-D is constructed as a WorkBench file (*.mwb*) [of MySQL].

To further comply with Data Design principles, *simplification* was necessary for the ER-D of Figure 6 (Appendix). As a consequence, a total of six (6) Entity-Tables were identified as the foundational archives for the Big Data to be collected, recorded, shared, and eventually analyzed. Thus, the set of tables includes:

Tables = {Patients, Mobile-App-1, Mobile-App-2, Mobile-App-3, Physicians, Facilities}

The Mobile-App Tables represent those which trace the Blood Glucose, Pressure, and Cholesterol measurement, respectively, and will populate entity data, as a patient downloads the relevant App on her/his mobile device and/or desktop. Attributes for each Table is summarized as a *Data Dictionary* in section III.2, similar to an Index Glossary of a textbook.

Upon completion of design for the Entity Tables, possible Data Relationships between pairs of Tables must be verified and validated. Combinatorics for this pairwise comparisons, therefore, is expressed as

$$\binom{n}{2} = {}_{n}C_{2} = \frac{n\,(n-1)}{2} \tag{1}$$

where, *n* denotes the total number of Tables. Notice we are choosing two (2) tables at a time to form a possible pair to expedite the sharing of data to allow *quasi*-real-time queries. Hence, the maximum possible pairwise comparisons for the six (6) tables is

$$\frac{6\,(5)}{2} = 15 \tag{2}$$

A total of five (5) Data Relationship Channels were identified out of the possible fifteen (15), as depicted in Figure 6 (Appendix):

- Patient-to-Blood Pressure App; a patient may choose to download zero or more Apps to trace her/his blood pressure, digitally.
- Patient-to-Blood Glucose App; a patient may choose to download zero or more Apps to trace her/his blood sugar, digitally.
- Patient-to-Blood Cholesterol App; a patient may choose to download zero or more Apps to trace her/his blood cholesterol, digitally.
- Patient-to-Doctors; a patient may choose to consult with multiple doctors, and each doctor may opt to manage multiple patients.
- Doctors-to-Facilities; a physician may opt to work with multiple medical facilities, and each facility may engage with multiple doctors.

Data Dictionary

Delineation of the complete set of *Attributes* for each Entity Table is the objective of this section. This glossary of attributes, often referred to as the Data Dictionary, is summarized in Table 2 (Appendix) through Table 7 (Appendix).

Prototype Architecture

A preliminary architecture of the proposed system is encapsulated in Figure 7 (Appendix).

Under a fault-tolerant and secure network, there are *n* number of registered patients with metabolic disease ($i = 1, \ldots, n$), who have real-time access to the portal. Assuming the three major devices to measure comprehensive blood panel (of patients), comprised of blood pressure, blood glucose, and blood cholesterol, respectively, are fully developed to function as reliable Internet of Things (IoT), real-time measurement data is collected and shared by way of synchronous digital Apps from each patient's mobile device. A physician ($j = 1, \ldots, m$) may then intervene to perform preventative medicine in real time, should the portal alert her/him for metabolic anomalies of the patients.

Most importantly, the Big Data generated by the suggested framework for healthcare portal is expected to allow meaningful sets of *Data Analytics* in multiple dimensions by business entities and professionals, alike. These may encompass the pharmaceutical industry, precision manufacturing, laboratories, and medical scientist such as pathologists, among others.

CONCLUSION

Digital Data Industries are expecting the next disruptive era of the global market. Driven by real-time Big Data, high demand is expected to transform many existing analog devices into digital Internet of Things (IoT). The *Fourth (4-th) Industrial Revolution* is operationalized by infusing Artificial Intelligence (AI) onto these IoT's.

The U. S. Healthcare and Medicine is unsurpassed by any other industry in the nation in terms of its dominant market size, measured at $808 billion in Fiscal Year 2021.

A data design framework for a new business model to implement Digital Data Analytics for *Health Informatics* was presented in this paper. Specifically, healthcare data for the *metabolic disease* comprised of (human) blood pressure, blood glucose/sugar, and blood cholesterol were at the center of focus. At the present juncture, there is an absence of standard data framework for health informatics systems. A preliminary but complete Entity-Relationship model was constructed. A Data Dictionary was appended as the glossary. A prototype architecture for preliminary analysis was suggested.

Plans to extend this research includes:

- Management of Innovation to fully digitize medical devices.
- Extensions of the medical network of Internet of Things (IoT), including but not restricted to surgery robotics.
- Development of Data-Analytics Business Model to accommodate the Pharmaceuticals to complete the Medical Industry Network as a new Value Chain for the 4-th Industrial Revolution.

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APPENDIX

Table 1. Data for Value Creation

Form \ Type	Structured	Unstructured
Analog/ Local/ Closed	Letters, Real Number Set, Symbols, Time, Date.	Pictures, Music, Rhythm, Sports Performance, Human Feelings.
Digital/ Global/ Open/ Shared	Text Message, Username, Access Code, Email Timestamp.	Digital Image Cloud, Digital Signatures, Medical Diagnosis Portals.

Table 2. Data Dictionary for Table Patients

Table	Attribute	Data Type	Example
Patients	Patient_ID	Literal (17)	USA-CNJP-1234567890
	Last_Name	Literal (100)	Doe
	First_Name	Literal (100)	John
	Middle_Name	Literal (100)	A.
	Nationality	Literal(3)	USA
	Age	Integer (3)	100
	Gender	Literal (1)	M
	Height	Integer (3)	180 (cm)
	Weight	Integer (3)	80 (kg)
	Mobile Phone Number	Literal (10)	1234567890
	MAC for SIMM card	Hex (12)	586D8FCAA7CB
	International Classification of Disease 1	Literal (45)	M35. 05
	International Classification of Disease 2	Literal (45)	J96. 00
	International Classification of Disease 3	Literal (45)	R65. 11

Table 3. Data Dictionary for Table Doctors

Table	Attribute	Data Type	Example
Doctors	Physician_ID	Literal (15)	USA-CNJD-12345678
	First_Name	Literal (100)	Jane
	Middle_Name	Literal (100)	C.
	Last_Name	Literal (100)	Wang
	License Number	Literal(10)	NJ012345678
	Access Privilege	Integer (5)	3 (Class 3)
	Specialty	Integer (20)	072 (cardiology)

Table 4. Data Dictionary for Table Medical Facilities

Table	Attribute	Data Type	Example
Facilities	Facility_ID	Literal (12)	USA-CNJF-12345
	Facility_Name	Literal (100)	Hackensack Meridian Health
	Street	Literal (100)	735 Beers St.
	City	Literal (100)	Holmdel
	State	Literal(2)	NJ
	Phone	Literal (10)	732-264-8484
	Occupancy	Integer	300 (patients)
	Emergency Room	Literal (1)	Y (Yes)

Table 5. Data Dictionary for Table Blood Pressure App

Table	Attribute	Data Type	Example
BP App	Device Serial Number	Literal (8)	BP-123456
	MAC for Mobile Device	Hex (12)	47-7C-5F-0B-54-05
	MAC for SIMM Card	Hex (12)	94-DB-BC-98-11-73
	BP Measurement Time	Time	15:00
	BP Measurement Date	Date	Dec-25-2022
	Systolic	Integer (3)	120 (mmHG)
	Diastolic	Integer (3)	80 (mmHG)
	Left Arm	Literal (1)	Y
	Right Arm	Literal (1)	N
	Mobile Phone Number	Literal (10)	1234567890

Table 6. Data Dictionary for Table Blood Cholesterol App

Table	Attribute	Data Type	Example
BC App	Device Serial Number	Literal (8)	BC-123456
	MAC for Mobile Device	Hex (12)	47-7C-5F-0B-54-05
	MAC for SIMM Card	Hex (12)	94-DB-BC-98-11-73
	BC Measurement Time	Time	07:00
	BC Measurement Date	Date	Jan-01-2022
	Cholesterol Level	Integer (3)	100 (mg/ dL)
	LDL	Literal (1)	Y
	HDL	Literal (1)	N
	Triglyceride	Literal (1)	N
	Mobile Phone Number	Literal (10)	1234567890

Table 7. Data Dictionary for Table Blood Glucose App

Table	Attribute	Data Type	Example
BG/BS App	Device Serial Number	Literal (8)	BG-123456
	MAC for Mobile Device	Hex (12)	47-7C-5F-0B-54-05
	MAC for SIMM Card	Hex (12)	94-DB-BC-98-11-73
	BG Measurement Time	Time	09:00
	BG Measurement Date	Date	Sep-09-2022
	Blood Glucose Level	Integer (3)	88 (mg/ dL)
	Fasting	Literal (1)	Y
	Post-Meal Start 1 hour	Literal (1)	N
	Post-Meal Start 2 hours	Literal (1)	N
	Post-Meal Start 3 hours	Literal (1)	N
	Hyper Sugar Level Alert	Integer (3)	200 (mg/ dL)
	Hypo Sugar Level Alert	Integer (3)	70 (mg/ dL)
	Mobile Phone Number	Literal (10)	1234567890

Figure 1. Analog Blood Glucose Monitoring Device

Figure 2. Digital Blood Glucose Monitoring Device

Figure 3. Wearable Continuous Blood Glucose Monitoring Device

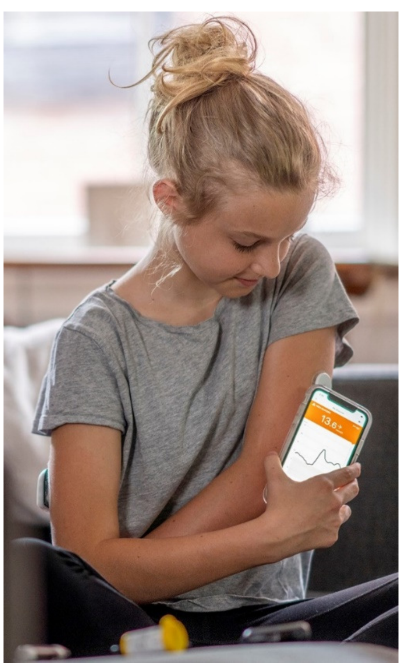

Figure 4. Wearable Continuous Blood Pressure Monitoring Device

Figure 5. Analog Blood Cholesterol Monitoring Device

Figure 6. Entity-Relationship Diagram for Healthcare Portal

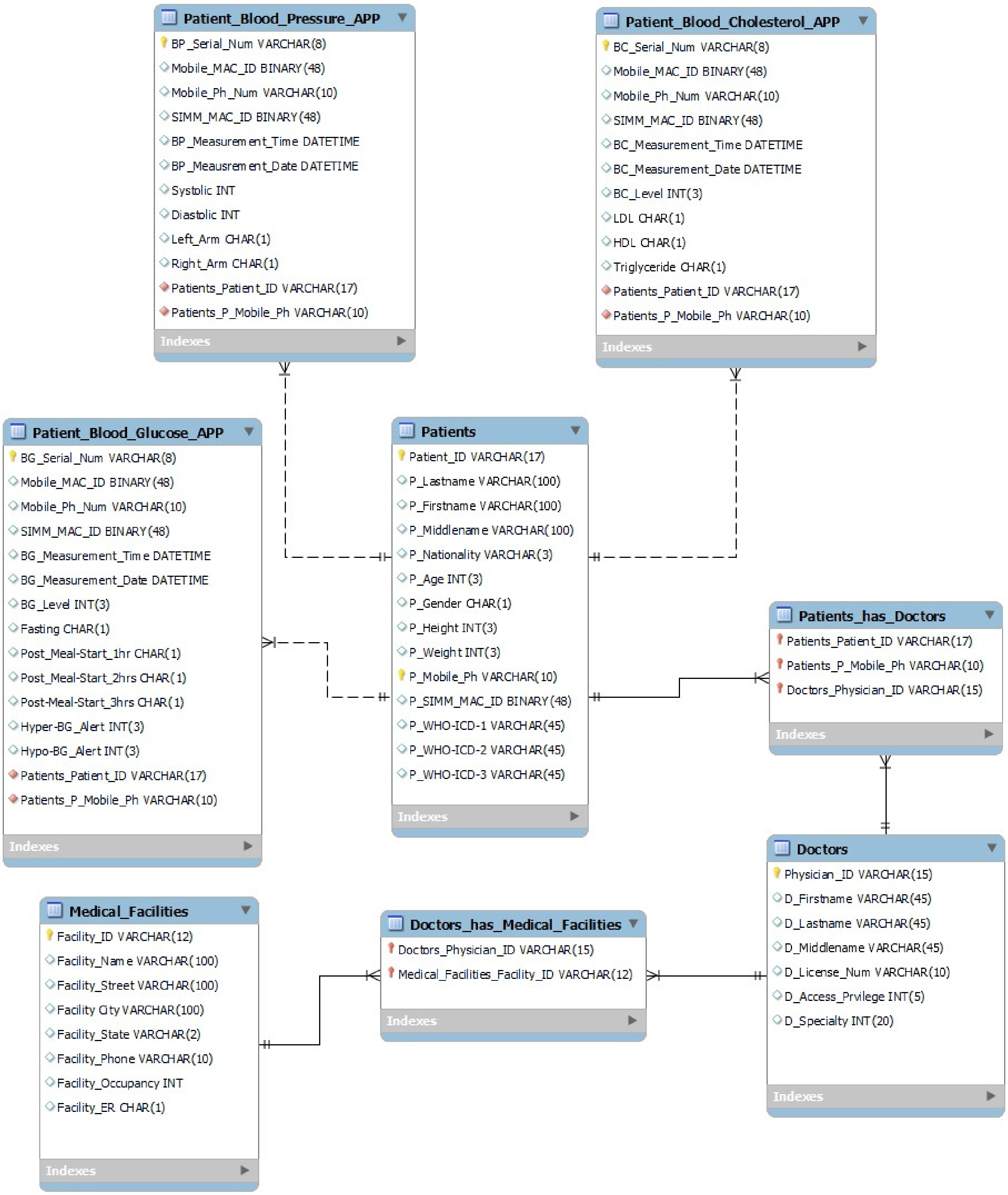

Figure 7. Prototype Architecture for Health Informatics with Standard Data