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Signature of Student Date

Implementing Low Powered Smart Devices in Public Health Surveillance Systems

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Abstract:

During the past few decades, the world has seen a significant change in technology with the development of modern tools which are used to gather, disseminate and share information as never before. Use of innovative products and technologically advanced tools can help deliver better health outcomes with significant improvement in the quality of life. Smart device innovations not only deliver faster results but can also interoperate and be cost effective at the same time. However, traditionally, public health systems have not been able to keep up with the booming field of applied science, mainly due to under funded projects or their indirect approach to population health that remains unappealing to many.

The world is growing at an exponential rate and in order to meet the world's increasing health demands, it is essential that public health organizations accept and adapt to these innovative changes. Technologically advanced devices like smartphone, tablets, laptops and wearables are now virtually ubiquitous with billions of users worldwide. Thus, there is a need for public health organizations to better integrate and collaborate with technology and computer disciplines.

“Implementing low powered smart devices in public health surveillance systems” aims at finding an innovative solution by using existing hardware and software technologies to solve difficulties arising during collection, transfer and storage of surveillance data. The solution aims at using the consumer version of smartphones/ tablet/ laptops to collect data, store them locally until connectivity is achieved and send them to their operation centers for processing, all while maintaining highest level of privacy and security.

2017

# Implementing low powered smart devices in public health surveillance systems

## A TECHNOLOGICAL APPROACH TO PUBLIC HEALTH SURVEILLANCE

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DEC – 2017

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# Background:

The focus of public health is prevention rather than cure. The field has long been underappreciated and underfunded. It is a known fact that paybacks of public health programs lie in the future and are not immediately noticeable. Considering a large investment today that will potentially yield benefits in the future is not something that everyone agrees with, leading to a system which barely supports itself.

Adopting the use of modern day technology can help solve the above mentioned issue by providing fast and innovative ways of data collection, real-time data processing and speedy results generation, which can benefit the population right away.

To better understand the solution, I propose the development of an innovative solution based on two different scenarios. The conditions within the scenario are hypothetical but can easily mimic a real life situation.

## Scenario 1

*Using facial recognition technology to minimize the effect of prescription narcotic related abuse and deaths*

## Scenario 2

*Using smartphones and tablets as data collection devices in a low resource setting and in remote places with limited power and internet connectivity.*

Both of these scenarios present different challenges and associated risks and the solution aims at providing better tools to the already existing ones.

# Scenario 1 – CDC's FLU-ARTS (Flu – Advanced Research Travelers System)

## Introduction:

This scenario details a fictional project that is intended towards development of an information system to meet the requirement set by CDC in an imaginary outbreak of a new strain of viral disease using emerging technology.

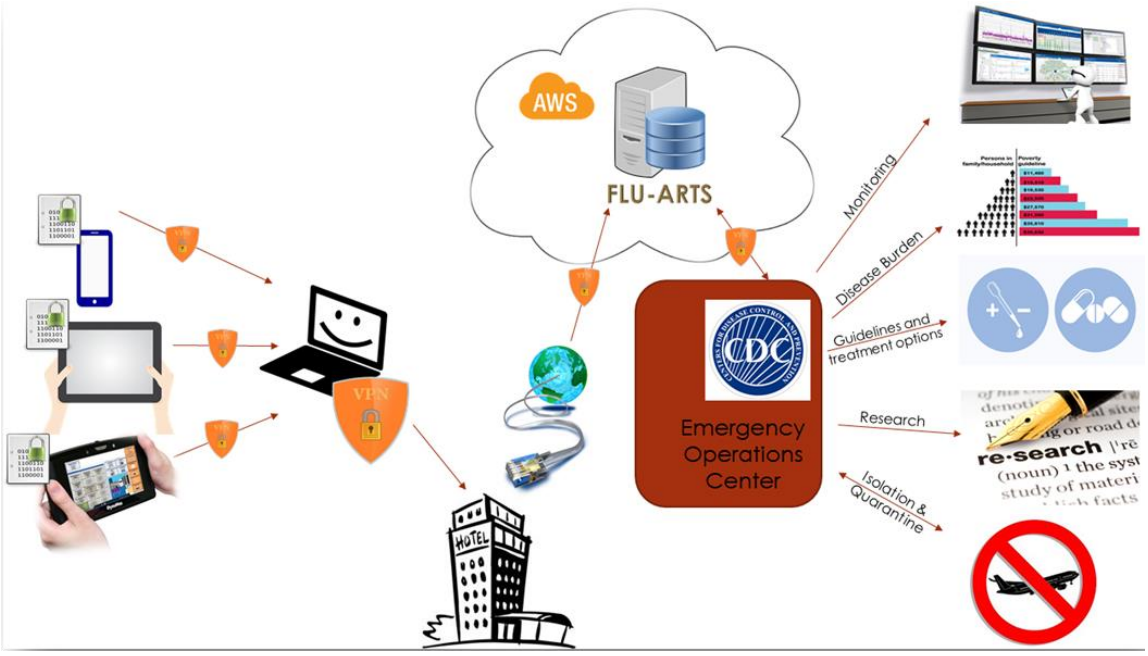
## The Problem:

A report of a new strain of influenza A virus has emerged that is rapidly spreading in parts of the southern Caribbean and a few countries in South America. The emergence of this new strain of flu is a critical issue because of its effect on population and its potential spread to other countries. A few days ago, the CDC mobilized a team of experts and since then has analyzed this remote place for samples. The samples collected confirm that this is a new strain of Influenza A virus, which was previously unknown to man. The bad news is that those infected usually die within two weeks. The CDC's team of experts were able to pinpoint the epicenter to a remote jungle area in Nicaragua.

## Solution:

Looking at this critical situation, the CDC wants to develop a surveillance system that can survive in this remote environment, even in the absence of electricity and internet. Additionally, the system must be able to work with modern technology and take advantage of low powered devices like smartphone, laptops and handheld devices.

# Solution Overview:




# Solution Requirements:

| Requirements | Explanation |
|---|---|
| **New and innovative system using new technology** | The system must have a new and innovative way of data collection using modern day devices that are readily available, low cost and reliable (like smartphones and laptops) |
| **Interoperable with other system** | The system must be able to send and receive data in standard format for interoperability. |

| | |
|---|---|
| **Highly secured** | The system must keep the data secure at all times, be it at rest or moving. The application, server, database and transfer protocol will be encrypted at all times. |
| **Off the grid data collection devices** | The system must have application interfaces that will run without network connectivity. The application will store data locally (encrypted) and transfer to the central database when connectivity is established. |
| **Use of standard data transmission languages** | The system should use messaging language and standards like HL7, LOINC, and SNOMED. |
| **Reliable and scalable** | The system must be available all the time, must be scalable for handling increasing amounts of data. |
| **Functional and intuitive interface** | The system must be able to run on most OSs like Android, iOS, Windows and Linux. Additionally, it must also work on a web browser. |

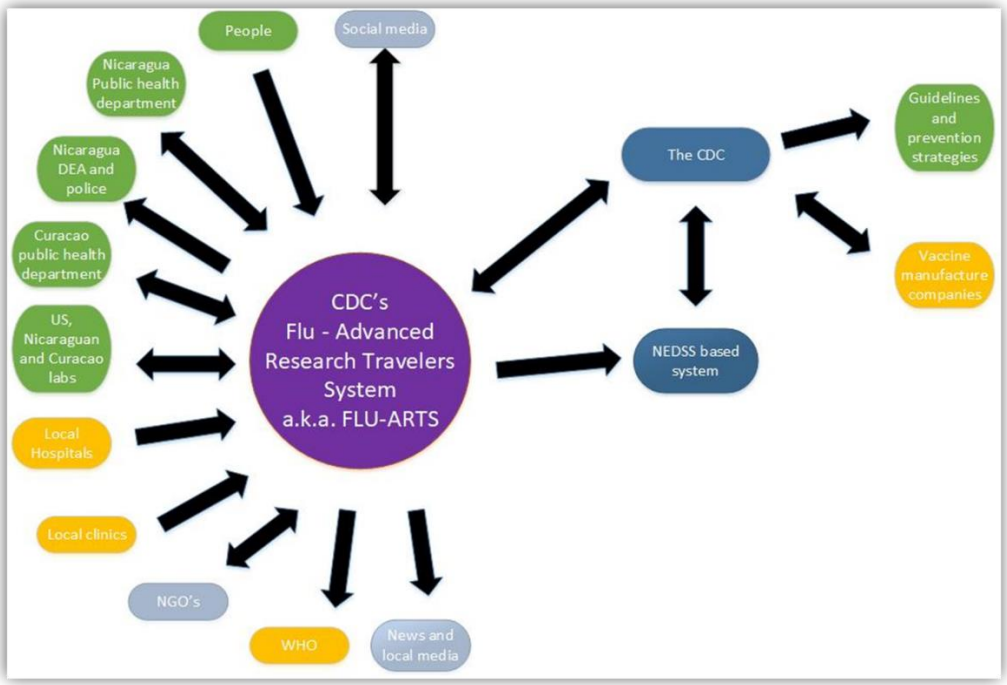
## Systems Design:

The goal is to develop a robust surveillance system that will collect ‘data field’ information regarding the number of cases, location and extent of disease, age group involved, morbidity and mortality, temperature and climatic condition, throat swabs, clinical signs and symptoms and examination data. Not only that, but it has to operate in a remote environment with very minimal resources. This surveillance data will not only help identify

many new features of the deadly strain, but will also help develop new treatment options and prevention strategies to lessen the effect on affected individuals.

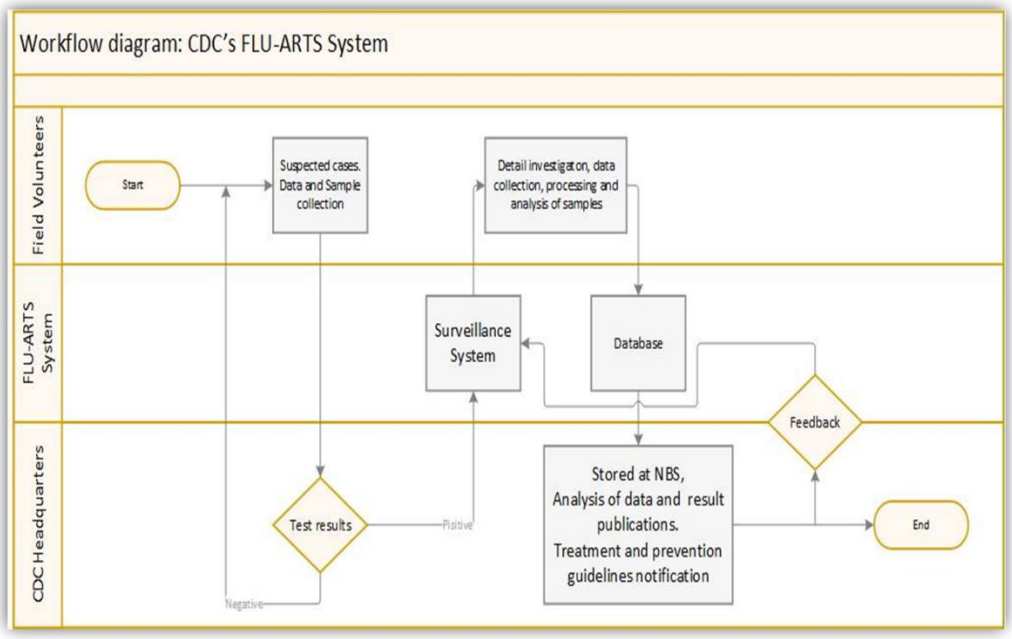
This is a two part design. The first part is the front end user interface, which is the development of a smartphone/ tablet application that will collect data for the above mentioned data fields. The second part is the back end server system (a.k.a. FLU-ARTS) where all the processing magic happens. Due to limited budget availability and a need to be scalable, the backend server will be nested within the AWS cloud platform.

The information flow diagram below gives a visual tour of how the system will collect and transmit data. The diagram also gives an idea about the stakeholders involved in this project.




Information Flow Diagram with Stakeholders

Also, presented below is a high level work flow diagram showing the systems process from start to end.




Work Flow Diagram

## Technology Architecture:

Data collection App: Since data will be collected in a remote place with no electricity and inadequate connectivity, I propose the development of a simple data collection app, which will be developed for all available operating systems. The app will use the same interface as the web-based version; however, the difference is that this app will store data locally on the device. Once the network is available the data will automatically and securely transfer to the server.

Web-based system: The interface will be similar to the app, but an internet connection will be required to use the web-based interface, typically reserved for high resource research projects.

Server: The server will be located on the AWS cloud for added security and protection. Data transfer will occur securely on a 256-bit AES encryption level. The server will be scalable on demand, but will scale down most of the time when the data is not being transmitted.

Operating System: The choice will be Linux based system as it is open source and a perfect fit for our budget.

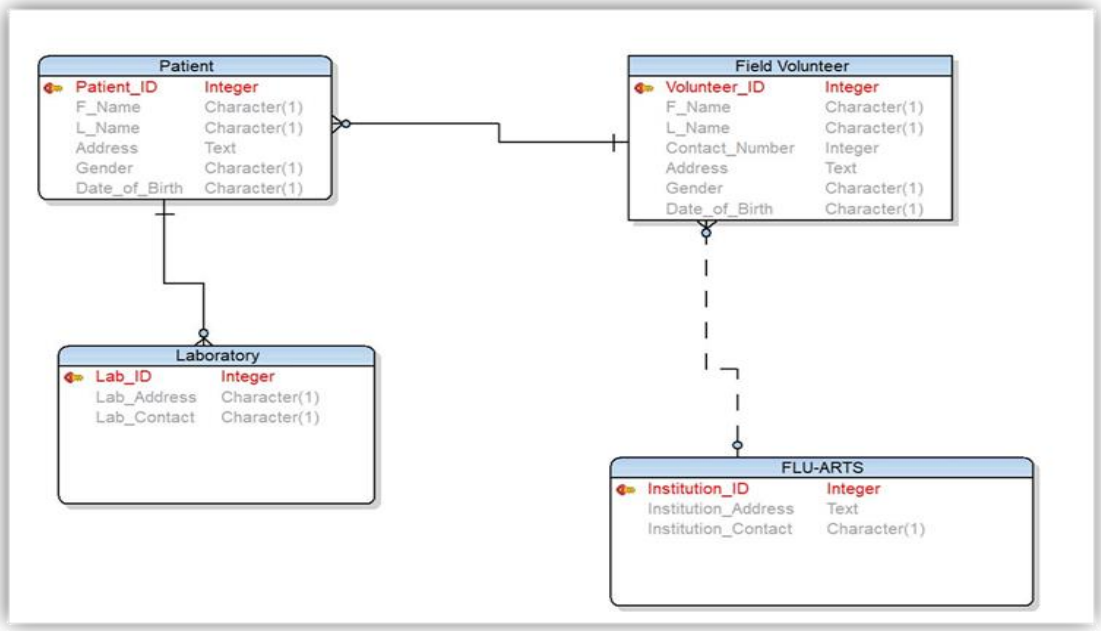
Security: Devices used will be secured biometrically. All data stored locally on the device will be stored encrypted and will be containerized so that it does not interfere with other software components.

## Critical Components | Data Structures:

| Critical Components | Applications | Data sources |
|---|---|---|
| **Hand held devices/ low resource devices** | Smartphone and devices app | Interview with patients, local hospitals, clinics and labs. |
| **Web browser** | Web-based interface | Health agencies, PH departments, DEA, NGO's, social media, local news. |

| | | |
|---|---|---|
| **Server** | Linux based OS | Hand held device data collection. |
| **CDC** | NBS | FLU-ARTS |

The diagram below shows one section on data schema that will define the database within our system. For this project the database schema was created using Toad Data Modeler®.




## Risk management:

| Emerging technology | Possible Risk | Risk mitigation |
|---|---|---|
| **Low resource hand held devices (smartphones/laptops/ tablets)** | Lost device | A GPS that is always on will help find the device |
| | Lost data/ data corruption | Local backup on a removable SD card every hour |
| | App not working | Switch to a backup device |

| | | |
|---|---|---|
| | Device stolen | Data is encrypted and containerized, device data wipe activated on more than 3 failed attempts to login |
| **Web based interface** | Failed to load page | IT service team available on the helpline number |
| | Unable to login | Reset functionality available |
| | Data stolen | Web interface will logout with 5 minutes of inactivity on the page |
| **Server** | Server not responding | Backup server activated |
| | Data corrupted | Data is always backed up on multiple cloud drives.<br>Data can also be recovered from the hand held devices |
| | Slow connection | HL7 messaging system transmits well with a slower connection |

# System in Brief:

| **Data sources and Stakeholders** | **FLU-ARTS System** | | | | **NBS** |
|---|---|---|---|---|---|
| | **Raw Data Recording and storage** | **Partially Processed Data** | **Data transfer** | **Data processing and storage** | |
| **-Field volunteers that are collecting information from local people.**<br><br>**-Nicaragua and Curacao PH dept.**<br><br>**-Local hospitals, clinics and labs, Social media.** | -Patient demographics<br><br>-Signs and symptoms.<br><br>-Physical examination findings like body temperature and respiratory sounds.<br><br>-Throat swabs and sputum samples<br>All data is collected on a smartphone app and transferred to a local computer when in a remote location. | -Lab results, demographics and examination findings tabulated into a remote server database. | Data is transferred to NBS using HL7 messaging system. | The data seamlessly integrates into NBS database. This data is then processed at the CDC for potential case identification, locating the affected area and predicting the spread of disease. | Data stored at NBS can be used for research purposes. Potential stakeholders include pharmaceutical industry for vaccine development, local hospitals and PH departments in South American countries that are affected by this new strain of flu and many more. |

# Scenario 2 - MINIMIZING PRESCRIPTION NARCOTIC ABUSE

(Model Organization of Choice – Oregon States PH department)

## The Problem:

Citizens in the United States benefit a lot from pain medications but the abuse of narcotics is a serious problem. As per CDC, 91 Americans die every day from an opioid overdose and more than 40 deaths are attributed to prescription opioids.

In the past it was easy to obtain multiple prescription from different physicians by individuals who merely travelled to another city or state to obtain them. These individuals, also known as “doctor shoppers” were the main abusers/misusers falling victim to substance abuse and death by overdosing.

Prescription drug abuse is termed as an epidemic in the United States and to counteract this situation, the Prescription Drug Monitoring Program (PDMP) was established. Although the program has led to a decrease in the number of physician prescribing unnecessary opioids to individuals, the number has not yet reached significantly low levels, especially considering that the program has been an integral part of the electronic medical system.

The PDMP is an excellent system. However, like any technologically advanced system, this one also has some drawbacks. The program has essentially two different issues. First is that the physicians often do not have enough time to dig into and verify the records on recently prescribed narcotics and would rather prescribe another set instead. The second problem is that the registration process for the physicians is again time consuming and

requires licensure verification with other legal documentation to be fulfilled which is often discouraging.

## Solution Proposed:

My proposal is to develop a system that will use a smart technology platform, which can not only track drug abusers movement/pattern in real-time, but also allow the PDMP registration process to be easy for the healthcare professionals. This system will also be extended to pharmacists, another source of drug distribution. This system will reside within the state department's public health branch, and will be extended to other states for interoperability.

The system is two part design. First is the development of a smartphone app that will capture image data using the built-in camera and transmit it securely to our central server in the cloud. The image data is then processed and converted into to hash values to create our database. The second part deals with easing the process of PDMP account access to physicians, pharmacists and nurses.

**Part 1:**

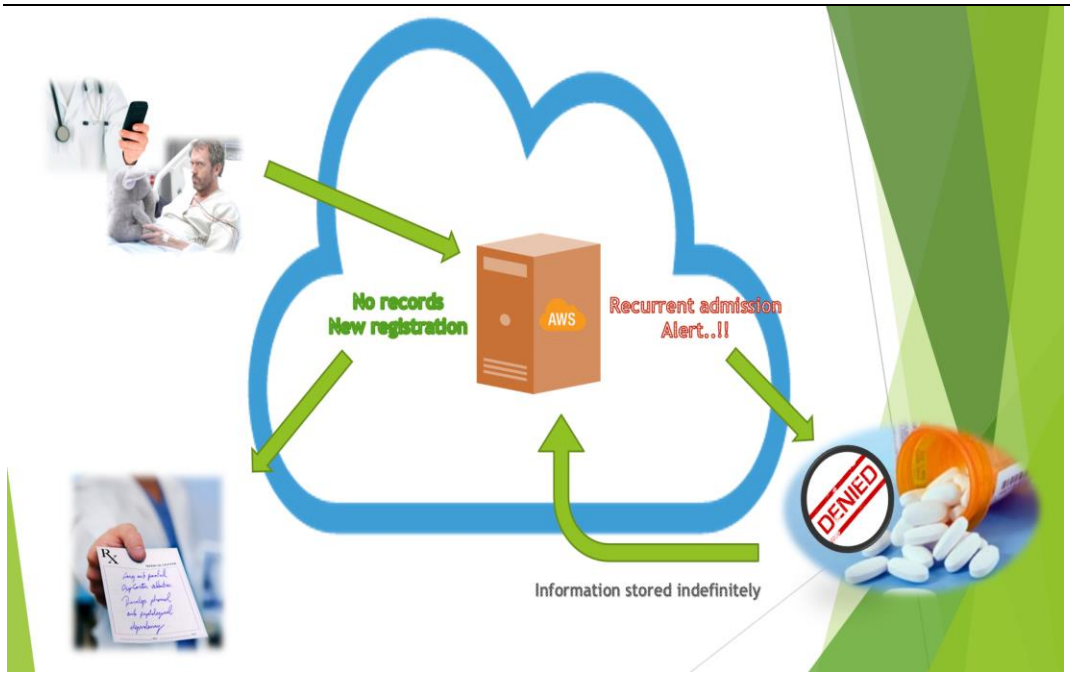
The app and the server program will be developed in-house with the help of our team members and some commercially available off-the-self software (COTS like Amazon Rekognition, running on top of our Linux based operating system). The smartphone app will be designed to have integration with most common EMR's available in the market. The process kicks in when a patient (a potential drug misuser) visits the ER, or gets admitted with the intention of obtaining a prescription narcotic. Here, the physician assigned to the patient will use their smartphone to take a picture when they realize that the

patient is seeking or is in need of a narcotic. The app, when opened, will guide the user step-by-step, asking to scan the patient's face and a scan of patient's barcode connecting the MPN. This collective data will be sent to the server for processing. If the results are returned by the server saying "individual not found" it will create a new profile with additional permission to capture current location. By using the device's GPS, the app will detect the current healthcare facility. Navigating through the app, it will ask you to take few more pictures of the patient's face (this is for facial recognition software that will work on our remote server). Finally, it will ask the user to select or type the drug prescribed to him/her during this current visit. All the information sent to our server will be data encrypted, following HIPAA guidelines. The server will generate a hash value that includes a combination of patient's static demographic values (like name, date of birth etc.) and facial image data. If this patient is trying to seek drugs at a different facility, the app will immediately alert the healthcare professional about the possibility of prescription misuse.

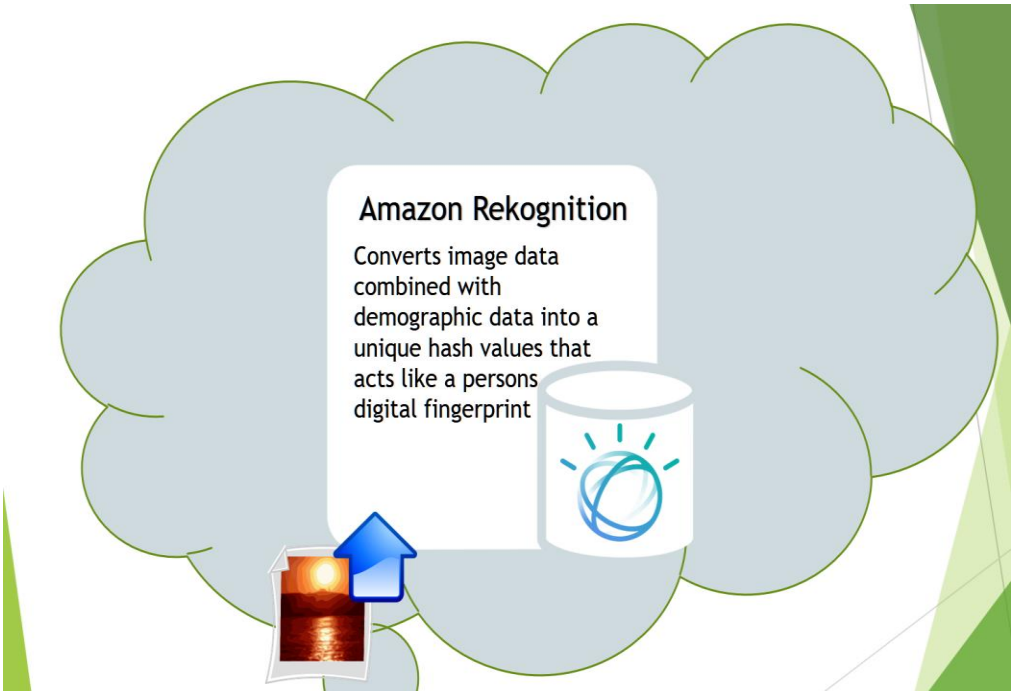
**Part 2:**

The aim here is to meet with the PDMP team and discuss the registration process for physicians and pharmacists. My recommendation is that all physicians and pharmacists should have access to the PDMP registry by default when they receive their license to practice medicine. This will help eliminate users who are otherwise discouraged by the process (or, as they say, hassle) of registration. It will also be useful for those physicians who prefer to give a prescription rather than searching for records.

# Solution Overview:



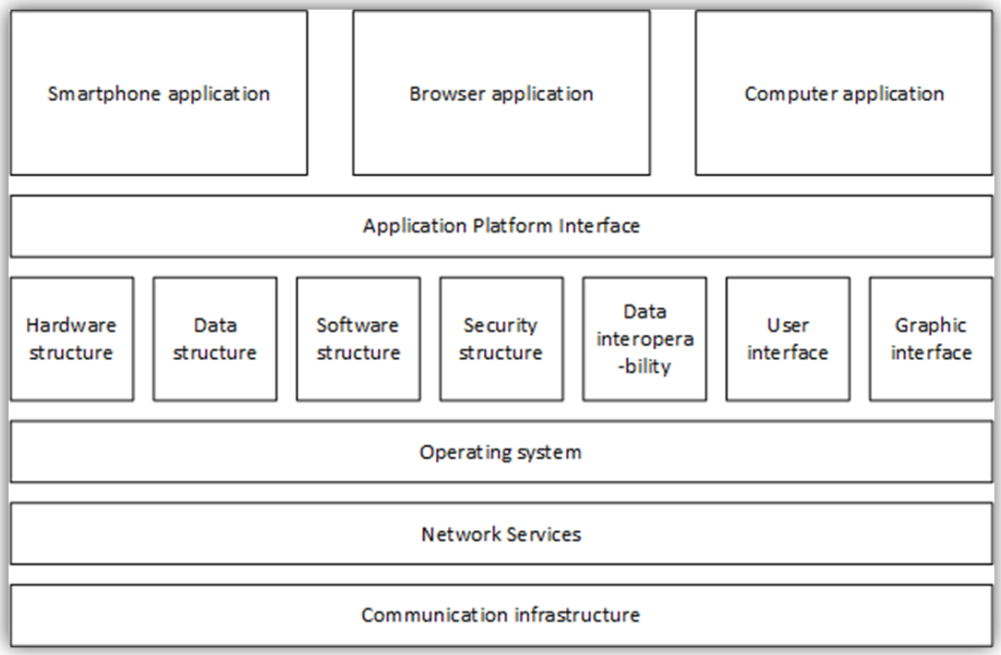

The image below shows what lies at the heart of this solution. Its Amazon Rekognition, the facial recognition technology by AWS.



# Business Architecture:

| Process | Description |
|---|---|
| **Procurement** | Startup material and infrastructure needed to start the project, including legal paperwork and licenses |
| **Notify the PDMP** | Contacting the team for registry integration and project development |
| **Agreement** | Includes creating legal terms and conditions |
| **Create project team** | Assembling the project team |
| **Create Application** | Smartphone and web application development |
| **Create database** | Creation of the database and generation of our own registry that will match drug misusers |
| **Create API** | Creating API for interoperability and free use of this app |
| **Link EMR with app and database** | Using standards and messaging languages to develop data transfer protocols and easy interoperability |
| **Process and analyze data** | Analyze data and use it for our research purposes |
| **Notifying Healthcare provider and issue training guide** | Notifying and educating the healthcare workforce about the project so that they can be prepared for its use. This will also help decrease anxiety with the use of new technology. |
| **App installation, browser integration** | Deploying the application on smartphones and setting up browser integration in HTML |
| **App debugging maintenance and support** | Post deployment support and maintenance. Debugging problematic codes and long term support for persistent functioning of the system |

# Information Architecture:




Above is the high-level view of the information architecture. It starts with communication as the base and the network services binding it with the operating system layer. Then using our OS as the base platform, we will build our system with all the tools necessary for its functioning.

# Technology Architecture:

## Service Access and Delivery:

- Access Channels:

  The web browser will be used for web interface for data entry and to take pictures via the webcam. It also serves as a backup service in case the mobile app does not work.

- Delivery Channels:

  Internet: This is required by the entire system to work.

  VPN: All data throughput will be encrypted by AES-256 Bit encryption level.

  Intranet: For local functioning within the project teams premises.

- Service Requirements:

  Legislative/Compliance: Includes all legal paperwork and HIPAA compliance procedures.

  Authentication/Single Sign On: First time authentication will be required, then phones features like biometrics can take over.

- Service Transport:

  Constant data transfer takes 24x7x365 except for downtime and maintenance.

## Service Platform and Infrastructure:

- Software Platform: Will need to create apps for all possible platforms.

- Software Engineering:

  Will need to use off-the-shelf applications and some in-house for this system

- Delivery Servers:

  Will use servers for the system to work, preferred is amazon’s gov cloud.

- Database/Storage:

Database: A new database will be created to store all data and create our own database.

- Storage: Data will be stored in amazon's S3 cloud storage drives.
- Hardware/Infrastructure:

  Servers/Computers: Servers will be running constantly for consistent service.

- Local Area Network: Traffic throughput for data transfer.

### Component Framework:

- Security:

  Certificates/Digital Signatures: MD5 hashes will be used.

- Data Interchange:

  Data Exchange: Standard messaging language over encryption will be used.

### Service Interface and Integration:

- Interoperability:

  Data types, format and integration will be affected.

## Emerging technologies | Needs and requirements:

Emerging technologies definitely play an important role when it comes to defining needs and requirements. In this age of the internet of things and social connectivity, unconventional sources are equally important as conventional ones. For example, the

model I propose takes advantage of smartphones that are already owned by physicians/nurses/pharmacists. It goes into effect when a snapshots of the persons face is taken by the phones camera, of the individual who is about to receive the prescription and is uploaded to the server by the app. The server in the cloud will receive image data and use facial recognition technology to identifying a potential narcotic misuser. Other sources may be considered in the future if they become enough reliable to produce minimal error and maximum productivity.

### Requirements:

- Development of project charter and Business case
- Assembly of Project team
- Development of Application platform
- Legal paperwork and contracts
- Training and Research
- Testing and Deployment
- Support services, debugging and risk management plans
- Post market research and long-term impacts

## Technology Uses

- Smartphones and laptops: Low power consuming but high performance devices are now-a-days easy to procure. This project will take advantage of such devices and their APIs to develop applications that will be used as tools.

- Data communication and storage protocols: This project records highly sensitive demographic data, which is vulnerable to hackers and ransomwares. The app will run in a containerized environment on devices so the data will be isolated from the devices' operating system. It will feature a 256-bit AES encryption while the data is in rest and in motion (transfer to the server via VPN). The server will be running in AWS cloud environment which is a one-stop-shop for all required services. Once images are converted to hash values, they will be deleted permanently.

- Data processing AI: This project takes advantage of AWS's "Amazon Rekognition" facial recognition technology for image processing and hash value generation.

## Strategic Implementation Plan:

| Action or Step to be Completed<br>Method for Completion | Timeline | Milestones | Person(s) Responsible (Role) | Status/ Completion Date |
|---|---|---|---|---|
| **Team Assembly:**<br>**Assemble a team to initiate the thought process. Define aims and objectives and present to the team** | 2 weeks | Team assemble completion | Project manager | TBD |
| **Systems Design: Develop blue prints of the system with the help of the team** | 2 weeks | Business case finalized | Project manager, PDMP team member and Physician | TBD |
| **Legal: Develop and design contracts, look for legal issues and HIPAA regulations.** | 1 week | Contract and guideline | Project manager | TBD |

| | | | | |
|---|---|---|---|---|
| | | documents produced | | |
| **Acquisitions: Start the acquisition process, that includes sub contracts to other parties** | Ongoing | Material and services acquired | Project manager | TBD |
| **App design: Start the application development process and web interface modeling** | 3 months | Smartphone and web applications developed | Software Engineers, Informatician (me) | TBD |
| **Server design:** | Ongoing with app design process.<br>OR<br>1week | Cloud server ready | Software Engineers, Informatician (me) | TBD |
| **Database design: database modeling and services integrations** | Ongoing with app design process.<br>OR<br>1 month | Database ready to accept data | Software Engineers, Informatician (me) | TBD |
| **PDMP registration process easement design** | Ongoing with legal contract development.<br>OR<br>6 months | New, easy and hassle free registration process | Informatician (me), Physician and PDMP team member | TBD |
| **Internal testing** | 4 weeks | Systems correct functioning and stability | All team members | TBD |
| **Beta testing** | 6 weeks | Initialized with one hospital | All team members | TBD |

| | | | | |
|---|---|---|---|---|
| **Public release** | 2 weeks | Expanded to all possible healthcare facilities | All team members | TBD |
| **Training** | Ongoing after release | Staff trained | All team members | TBD |
| **Feedback** | Ongoing after release | Software stats collected | All team members | TBD |
| **Troubleshoot and maintenance** | Ongoing after release | Release maintenance patches | All team members | TBD |

# Risk Management:

- Risk categorization:

The plan is to be able to categorize risk as high, medium and low. High risks ranges from data breaches and information exposure to total lockdown (like a ransomware), whereas medium to low are more manageable and less of a threat to the system.

- Risk mitigation:

The plan is to develop standard procedures that need to be in place if a threat has occurred.

- Risk Contingency

Plans and procedures that need to be developed in case the project is in jeopardy, like exceeding the budget or if funding is decreased.

Below is the tabulated list of risk level, mitigations and contingencies for this project.

| | HIGH | MEDIUM | LOW |
|---|---|---|---|
| **RISK** | 1.Data leak, data stolen, data lost, loss of systems functionality, infected by a virus or ransomware.<br>2.Patients may not agree to take their pictures once they are informed and consented. | 1.System unresponsive, loss of connectivity, system overload.<br>2.Picture may not be clear due to lighting conditions. | 1.Slow running system, unable to process data and return results in time. |
| **MITIGATION PLANS** | 1.Reporting of breach to the authorities.<br>2.The picture may not be on the app but remaining data may be still useful. | 1.Immediate conception of a support team to get the problem solved.<br>2.The app will have an alert feature that will ask the user to retake the pictures. If still it doesn't work then remaining data should be good enough | 1.Needs upgrade to a faster server and connectivity |
| **CONTINGENCY PLANS** | 1.Offer affected individuals credit monitoring in case of a breach | 1.Project team with the help of support team, will improve the system over time | 1.User feedback will help improve the experience |

# Timelines and Measurement Plans:

| **Priority: App development and AI integration**<br>**Strategy: Hire experienced engineers and explore AI software vendors** | | | | |
|---|---|---|---|---|
| **Programs Activities**<br>**Interventions** | Person/Group<br>Responsible | Timeline | Process Indicator | Outcome Indicator |
| **Hiring Engineers** | Project manager and Informatician | 2 Weeks | 1. Online posting of job requirement and qualifications<br>2. Analyze resumes or recipients<br>3. Conduct interviews<br>4. Hire qualified personals<br>5. Start app development process | Functional application ready for use |
| **Explore Artificial Intelligence vendors** | Project manager and Informatician | 4 weeks | 1. Research vendors for similar technology<br>2. Select the best suit for our business needs<br>3. Acquire contract and manage licensing.<br>4. Initiate software integration and start deployment<br>5. Measure success in testing phase | Functional facial recognition software integrated in the app. |

# Conclusion:

With the help of these two projects, I am trying to demonstrate the importance of using smartphones and tablets, replacing proprietary devices and increasing productivity. It can also improve community health by providing real-time disease surveillance data making a dramatic change in individuals' lives.

The small size, versatility and state of art security features are just the tip of the iceberg. Other important features include capturing a wide range of data, including audio, video, camera, GPS and text can help avoid unnecessary and expensive equipment purchase.

A cloud based platform reduces upfront costs on hardware while being much more flexible than the traditional in-house server. Other benefits include 24x7 availability, negligible maintenance costs and better use of resources.

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