Telehealth Meets Cloud

How Cloud, AI, and ML Technologies are Transforming Telemedicine and Remote Care Delivery

January 2021

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Abstract

Telehealth has revolutionized the delivery of healthcare by improving patient access to care, resulting in better care outcomes, fewer hospital readmissions, happier patients, and more profitable practices. Recent events with COVID-19 have further accentuated the need for telehealth by forcing healthcare organizations to deliver care without in-person contact. A number of countries and organizations are adapting to the changes by keeping vulnerable citizens away from hospital visits while providing the routine care they need using telemedicine. For example, the department of Veterans Affairs (VA), which operates the largest integrated healthcare delivery network in the US, delivered over 9 million telehealth episodes in fiscal year (FY) 2020 as of the date of this publication, compared to 2 million in FY 2019.[1] As the need for remote care grows, the US telehealth market is expected to witness 80% year-over-year (YOY) growth in 2020.[2]

This whitepaper discusses some of the benefits, use cases, and challenges with telemedicine, and outlines a framework for providers, hospitals, and payers to deliver remote care at large scale using cloud, Artificial Intelligence (AI), and Machine Learning (ML) technologies.

Introduction

Telehealth (sometimes referred to as telemedicine) includes real-time audio/video services that physicians and patients use to communicate for healthcare delivery. These tools can include mobile health (mHealth) applications on a computer, tablet, or other electronic device. Telehealth can be provided in multiple areas, including:

- Remote oncology/radiology (such as cancer diagnosis)
- Ophthalmology screening (such as diabetes checks)
- Obstetrical services (such as high risk pregnancy monitoring)
- Remote patient monitoring of vital stats to support better management of chronic illnesses such as heart failure, diabetes, and hypertension

Healthcare organizations and agencies that deal with telehealth, such as the VA and the Department of Defense (DOD), have a critical mission of ensuring patient safety and privacy, and providing timely and accurate care.

The federal government has focused on relaxing restrictions on telehealth, including allowing beneficiaries from any geographic location to access services remotely. For example, the CONNECT for health act[3] expands Medicare coverage for telehealth services. With the recent executive order on rural and telehealth access[4], the department of Health and Human Services (HHS) and Center for Medicare and Medicaid Services (CMS) provided policy updates on telemedicine.[5] At the state level, many agencies have focused on expanding telehealth in their Medicaid programs, and on relaxing state-level restrictions. These measures, together with the recent pandemic, have resulted in increased adoption rates for telehealth. Some of these trends are presented in Figure 1.

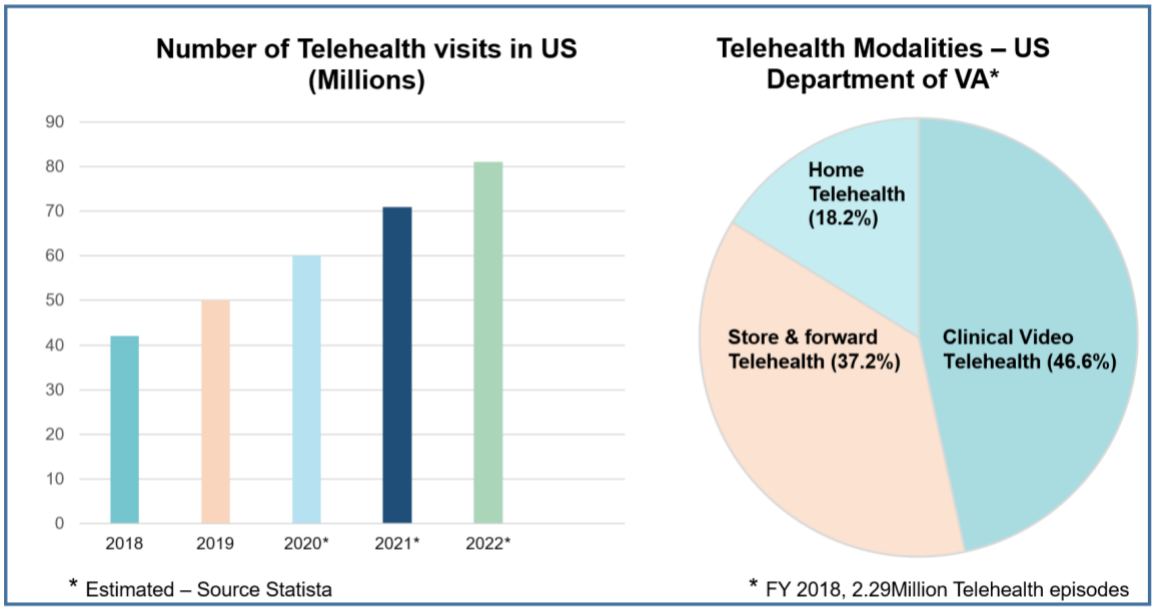

Figure 1 – Telehealth trends

Telehealth Benefits and Outcomes

The following section outlines some of the major benefits and outcomes of telehealth.

- **Access to quality care** — Many rural and remote communities face provider shortages, have limited transportation options, and lack access to timely and quality care.[6] When the nearest physicians are hours away, patients may delay their visits or skip routine screening. They might risk ignoring disease symptoms until the problem becomes more serious. Hospital visits and in-person physician consultations may not be feasible in other situations, such as the COVID-19 outbreak. In these cases, rather than forcing at-risk patients such as disabled veterans to travel, telehealth is an excellent alternative. It provides an effective way to deliver care by bringing care to the patient's location.
- **Provide timely and urgent care** — Telemedicine can potentially help save lives in the critical moments after a stroke or a heart attack, where physicians can provide remote care while paramedics arrive. In other cases, where it isn't clear whether an emergency visit is required or not, patients can conduct remote consultations with a physician to determine the best course of action. These steps can help save lives, reduce the cost of emergency room (ER) visits, and limit the spread of disease.

- **Improve provider productivity** — Physicians not only spend time on care and diagnosis, they also spend significant time on detailed entry of information into electronic health record (EHR) systems, and travel between clinical locations. Telehealth reduces travel for physicians, which in turn can help increase the number of patient appointments. With the advent of modern technologies such as AI and ML, telehealth solutions can also help boost provider productivity by assisting with medical diagnosis and clinical notes.
- **Reduce overall healthcare costs** — Studies in the UK have found that 20% of people who go to the doctor don't really need to be there.[7] Telehealth can help reduce healthcare costs by minimizing routine doctor visits, ER visits, and hospitalizations by using techniques such as remote patient monitoring. For example, the VA estimated an average annual savings of $1billion with patients who participated in telehealth programs.[8] Other cost savings include reduction of medical transportation and patient travel reimbursement costs.

Telehealth Modalities and Use Cases

This section provides the different types of telehealth delivery, and outlines some of the technologies used.

- **Real-time/Clinical Video Telehealth (CVT)** — This mode uses real-time audio/video conferencing to deliver remote care to patients. This mode has two-way communication via live video between a patient and a provider. It can be used for consultative, diagnostic, and treatment services. This method is also known as *synchronous modality*, and it can be used to substitute in-person visits.
- **Remote patient monitoring (RPM)** — RPM uses digital devices and technologies to collect healthcare data from patients at their homes or at other locations. The data is then electronically and securely transmitted to providers at a different location for diagnosis. The explosive growth of the Internet of Things (IoT) has enabled the use of connected healthcare devices, which are an essential part of effective telehealth delivery. This modality allows for automated actions such as notifications for routine care delivery (for example, daily medication reminders).

This mode enables providers to continuously monitor patients that are discharged to their homes or to care facilities so that readmissions can be minimized. These monitoring programs collect a variety of healthcare data such as vital signs, weight, blood pressure, blood sugar, heart rate, and so on. RPM can help reduce overall healthcare costs by reducing the number of hospitalizations, length of hospital stays, and number of readmissions.

- **Store and forward** — The store and forward method utilizes asynchronous modes of communication, where providers and medical professionals exchange healthcare records for patient diagnosis. This modality involves collection of data from the patient, and transmission of the data via secure communication to a centralized or cloud-based platform. The data can include x-rays, MRIs, videos, or other healthcare records from consultations. Store and forward technologies are most commonly used in radiology, pathology, dermatology, and ophthalmology.
- **Mobile Health (mHealth)** — mHealth expands clinical care beyond office visits via software applications (apps) on mobile devices, tablets, or other personal devices. mHealth refers to the concept of self-care via apps. These apps can range from providing personalized care and reminders for routine healthcare to alerts on disease outbreaks. mHealth apps are subject to oversight from the Food and Drug Administration (FDA)[9] if they store, transmit, display, or analyze patient data.

Challenges with Telehealth Implementation

There are a number of challenges that healthcare organizations face when implementing telehealth systems:

- **Communications and collaboration platforms** — Telehealth providers need to provision a highly scalable, available, and reliable communications and collaboration platform to serve millions of patients. These capabilities include audio/video communications, contact centers, virtual assistants and chatbots, and email or text messages. Amazon Web Services (AWS) provides multiple services to address this challenge, including Amazon Chime, AWS Media Services, Amazon Connect, Amazon Lex, and Amazon Pinpoint.

- **Data scale, size, and formats** — Millions of patients utilizing telehealth services results in tens of millions of healthcare documents, and hundreds of terabytes (TBs) of data in multiple formats. These formats include structured and unstructured documents such as radiology images, EHRs, audio/video recordings, and streaming data originating from multiple systems. Identifying a common storage option to host these disparate data types at scale is a major challenge for many healthcare organizations. AWS provides multiple storage options, including Amazon Simple Storage Service (Amazon S3), to address this challenge.
- **Data ingestion, processing and analysis** — Data ingestion, processing, and analysis of real-time streaming data from IoT devices (such as wearables) and batch data at scale is a major challenge. Medical documents have complex terminology that requires time and effort for semantic analysis and processing. This processing is often manual, which is error prone and requires healthcare expertise. AWS has multiple services, including Amazon Kinesis and Amazon Comprehend Medical, to address these challenges.
- **Accuracy of diagnosis** — Timely and accurate medical diagnosis is critical to the wellbeing of patients; however, the growing volume of patients and healthcare records increase diagnosis time and lead to physician burnout. For example, radiologist burnout is prevalent globally[10]. These challenges provide a perfect opportunity to utilize AI and ML. These technologies utilize machines that learn from existing data without being explicitly programmed to aid in medical diagnosis. AWS provides a number of AI and ML services, such as Amazon SageMaker, to address these challenges.
- **Security and compliance** — Healthcare data consists of sensitive patient, drug, provider, and payer information that must be protected and be complaint with local, state, and federal laws, including HIPAA. Any data breach could lead to serious consequences for patients and providers[11]. AWS provides a number of security services for data protection, and identity and access management.

High-level Framework

The AWS Cloud offers a number of services and capabilities to address the challenges discussed in the previous section. A high-level framework for a telehealth platform in the cloud is presented in Figure 2.

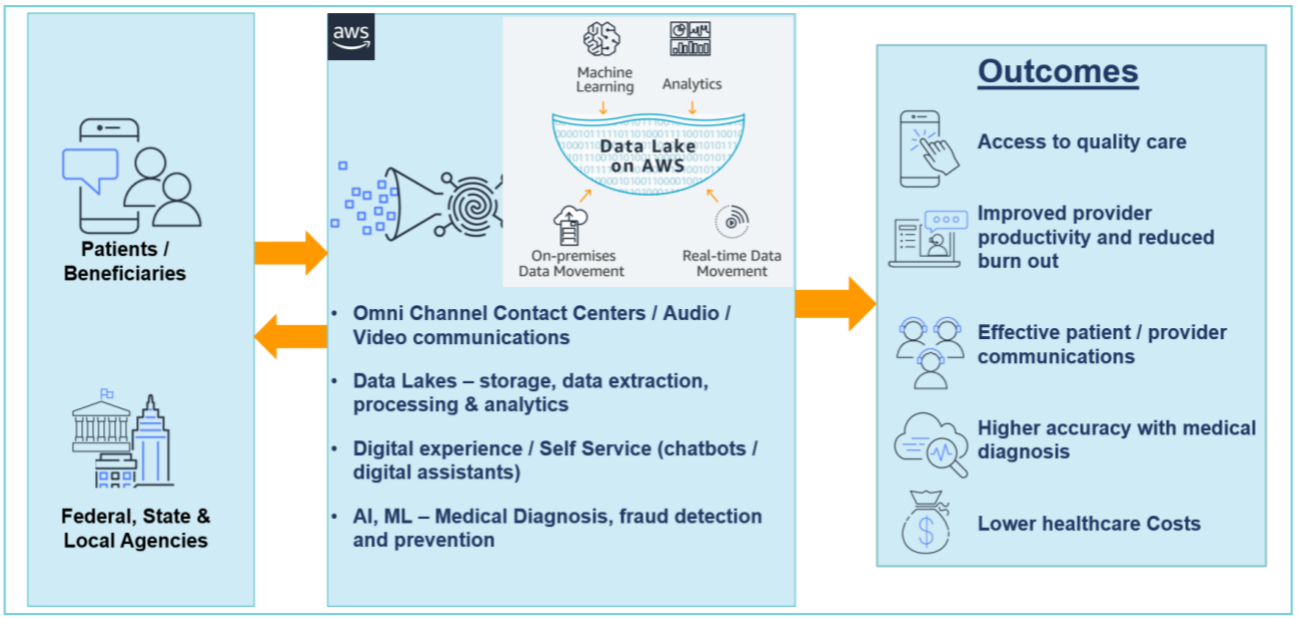

Figure 2 – High-level framework to address challenges with telehealth

Key Aspects of the Framework

The following sections provide key aspects of the framework presented, and the relevant AWS Services.

Improve Access to Quality Care

Enhance access to quality care by providing a framework with end-to-end digital capabilities such as audio/video communications, virtual nurse assistants, and chatbots. Telehealth organizations can provide secure communications and contact centers for remote care delivery using AWS services such as Amazon Chime and Amazon Connect.

- **Amazon Chime** enables patients and providers to meet, chat, and place phone calls with a single, secure application. For example, Cerner is using Amazon Chime to enhance its virtual health strategy. Using the Amazon Chime SDK, Cerner integrated video collaboration into its consumer engagement applications, so that patients can consult with clinicians on health issues remotely.
- **Amazon Connect** is an easy-to-use, omnichannel cloud contact center that helps companies provide superior customer service at a lower cost. Organizations can enable self-service and automated communications such as email, SMS on the web, mobile, and other devices using Amazon Pinpoint, Amazon Lex and Amazon Polly. Using these capabilities, patients can schedule their visits, receive care, and obtain their medical history.

Provide Centralized Storage with Data Lakes

Identifying a solution to store healthcare data in multiple formats and at scale is a challenge. The proposed framework enables data ingestion from multiple sources in disparate formats, and stores information in centralized data lakes. There are a variety of options to gather the data from patients or other sources such as medical devices or mHealth apps. These options include:

- Standard web and mobile communications combined with AWS Services such as Amazon API Gateway, Amazon Kinesis Data Streams and Amazon Kinesis Data Firehose for transactional and streaming data
- The AWS Transfer Family of services for batch data ingestion and storage into data lakes

AWS provides a number of services to enable integration with IoT medical devices, including AWS IoT Core, which is a managed cloud service that enables connected devices to easily and securely interact with cloud applications and other devices.

The AWS Data Lake solution automatically crawls data sources, identifies data formats, and then suggests schemas and transformations, so organizations don't have to spend time hand-coding data flows. For example, if a user uploads a series of EHRs to Amazon S3, AWS Glue, a fully managed extract, transform and load (ETL) tool, can scan these documents to identify the schema and data types present in the files. This metadata is then stored in a catalog to be used in subsequent transforms and queries. For example, Bristol Myers Squibb, a global biopharmaceutical company, is leveraging AWS Glue to build out a scalable infrastructure to ingest data faster, and transform it to get faster insights.

The AWS Lake Formation service builds on the existing data lake solution by enabling organizations to set up a secure data lake within days. Once a user defines where their data lake is located, AWS Lake Formation collects and catalogs this data, moves the data into S3 for secure access, and cleans and classifies the data using ML algorithms.

Some healthcare systems may have interfaces that are either proprietary or that conform to older standards, such as Health Level 7 (HL7). These systems can fail to achieve healthcare interoperability. This leads to a situation where data is digitally available, but not generally accessible. Fast Healthcare Interoperability Resources (FHIR), which is an interoperability standard for the electronic exchange of healthcare information, addresses this issue. An open-source project called FHIR Works on AWS is available to organizations to integrate with their products.

To summarize, S3 combined with AWS Glue and AWS Lake Formation act as a centralized data lake for storing documents from multiple sources with disparate data formats. FHIR provides data interoperability. Amazon DynamoDB, a key-value document database, provides fast access to these documents by storing the document metadata such as patient ID, document location in S3, and so on.

Improve Provider Productivity and Minimize Burnout

Following the implementation of the Health Information Technology for Economic and Clinical Health (HITECH) Act, physicians are required to conduct detailed data entry into EHR systems. Clinicians can spend up to six additional hours per day[12], on top of existing medical tasks, just writing notes for EHR data entry. Not only is this process time consuming and exhausting for physicians, it is also a leading factor of workplace burnout and stress that distracts physicians from engaging patients attentively, resulting in poorer patient care and rushed visits. AWS AI and ML technologies can help assist physicians with some of the EHR tasks, including data extraction, transcriptions, and comprehension.

Healthcare documents can be of different formats, including PDF, MRI or x-ray images, audio (patient/physician conversations), or EHR. Amazon Textract can extract text and data from scanned medical records and images without the need for custom coding. Amazon Comprehend Medical can be used to quickly and accurately gather information, such as medical condition, medication, dosage, strength, and frequency, from a variety of sources, including doctors' notes, clinical trial reports, and patient health records. Amazon Comprehend Medical can link the detected information to medical ontologies such as ICD-10-CM or RxNorm so it can be used by downstream healthcare applications.

Amazon Transcribe Medical can add speech-to-text capabilities to accurately transcribe medical terminologies such as medicine names, procedures, and even conditions or diseases. Amazon Transcribe Medical can serve a diverse range of use cases, from transcribing physician-patient conversations that enhance clinical documentation, to capturing phone calls in pharmacovigilance, to subtitling telemedicine consultations. For example, CareMonitor is transforming the healthcare space with its unified platform for health management that utilizes Amazon Transcribe Medical to quickly generate accurate transcriptions from medical consultations between patients and physicians.

The extracted information from healthcare records can be stored in lookup databases such as DynamoDB, Amazon Elasticsearch, or Amazon Kendra, to enable physicians with query capabilities.

Improve Accuracy of Diagnosis

One of the major challenges with telemedicine and healthcare in general is to provide a high level of accuracy with diagnosis, especially in areas such as radiology cancer diagnosis. According to the Agency for Healthcare Research and Quality (AHRQ), diagnostic errors occur in all care settings, contribute to about ten percent of patient deaths, and are the primary reason for medical liability claims.[13]

With the advancements in AI and ML, computer vision can aid physicians with medical diagnosis in a number of areas, including radiology, oncology, and ophthalmology. ML is making huge progress in improving prediction accuracies. There are a number of studies that show how ML could improve diagnostic performance and prediction accuracy, and in some cases, even outperform the human reader.[14]

Physicians can interpret and evaluate predictions from the ML models, and further validate their own diagnosis. AWS has a number of services to help with AI and ML, including Amazon SageMaker, which is a fully managed service that provides capabilities to quickly build, train, and deploy ML models. SageMaker removes the undifferentiated heavy lifting from each step of the ML process to make it easier to develop high quality models. Data labelling is an important step in training ML models. Amazon SageMaker Ground Truth is a fully managed data labeling service for building highly accurate training datasets for ML.

The diagnosis workflow can also include human review of low confidence ML models for further evaluation and re-training to improve accuracy. This workflow can be implemented using augmented AI techniques. For example, Amazon Augmented AI (A2I) enables users to build process automation and workflows required for human review of ML predictions. Amazon A2I provides built-in human review workflows for

common machine learning use cases, such as text extraction from medical documents. Using this service, clinics and organizations can enlist human reviewers when a model is unable to make a high-confidence prediction, or to audit its predictions on an ongoing basis. For example, Propeller Health developed a digital health platform on AWS using SageMaker and other services to improve outcomes for people with asthma and chronic obstructive pulmonary disease (COPD). The platform enables providers to monitor their patients remotely, stratify patients based on risk, and make data-driven decisions on treatment.

Enable Telehealth Organizations to Improve Operational Efficiencies

Healthcare organizations are often faced with operational challenges, including budget and enrollment model forecasting, fraud, waste, and abuse. This framework helps provide high visibility into program operations via real-time and batch analytics, using services such as Amazon Kinesis Data Analytics and Amazon Athena. Program leadership can get deep insights via operational dashboards built using Amazon QuickSight, which is a cloud-powered business intelligence service. Amazon Forecast can be used to forecast patient enrollment models and budgets. Using these capabilities, agencies can reduce forecasting from months to hours. Agencies can also proactively identify fraud, waste, and abuse within telehealth programs using a number of ML options that AWS provides, including Amazon SageMaker.

Provide Data Security and Privacy

Security and privacy are a top priority for organizations and agencies dealing with telehealth, due to federal regulatory and compliance frameworks such as HIPAA,[15] HITRUST, and The Federal Risk and Authorization Management Program (FedRAMP). AWS provides a number of capabilities to enable data privacy and security for protecting customer data, including encrypting data in transit and data at rest. HIPAA compliance deals with privacy and security when storing and processing protected health information (PHI), such as patient information, diagnosis data, lab results, and so on. In addition, HIPAA regulates notification of security breaches. HIPAA applies to covered entities (for example, health care providers, health plans, and health care clearinghouses) as well as business associates such as entities that provide services to a covered entity involving the processing, storage, and transmission of PHI. The Reference Architecture for HIPAA on AWS deploys a model environment that can help organizations with workloads that fall within the scope of HIPAA.

AWS also has a quick-start reference deployment for Standardized Architecture for NIST-based Assurance Frameworks on the AWS Cloud. This quick start reference

includes AWS CloudFormation templates to build a standardized reference architecture that aligns with the requirements within the controls listed above. It also includes a security controls matrix, which maps the security controls and requirements to architecture decisions, features, and configuration of the baseline to enhance an organization's ability to understand and assess the system security configuration.

For more information on AWS security capabilities, see the AWS Cloud Security page.

Other Capabilities for Telehealth Implementation

- **Develop self service capabilities for patients** — Self service capabilities help minimize the burden on providers by minimizing the number of calls and appointments. Amazon Lex is a service for building conversational interfaces into any application using voice and text. Amazon Lex provides the advanced deep learning functionalities of automatic speech recognition for converting speech to text, and natural language understanding to recognize the intent of the text. This enables organizations to build applications with highly engaging user experiences and lifelike conversational interactions.

  With Amazon Lex, the same deep learning technologies that power Amazon Alexa enable users to build sophisticated, natural language, conversational bots (chatbots). These chatbots can be integrated into healthcare applications, and provide additional self-help capabilities.

- **Provide language translation capabilities** — Amazon Translate can be used to convert text from one language to another (for example, Spanish to English). Using Amazon Transcribe and Amazon Translate together, calls in one language can be first transcribed, and then translated into a different language. This enables medical transcription in multiple languages.

- **Build effective campaign management strategies** — Campaign management and effective communication with patients is critical during a crisis (such as COVID-19), or during an open enrollment period for healthcare. Amazon Pinpoint helps organizations to engage with patients by sending them personalized, timely, and relevant communications via email, SMS, and other channels.

Reference Architecture and Best Practices

Figure 3 outlines a reference architecture for utilizing Cloud, AI, and ML technologies to implement a telehealth system.

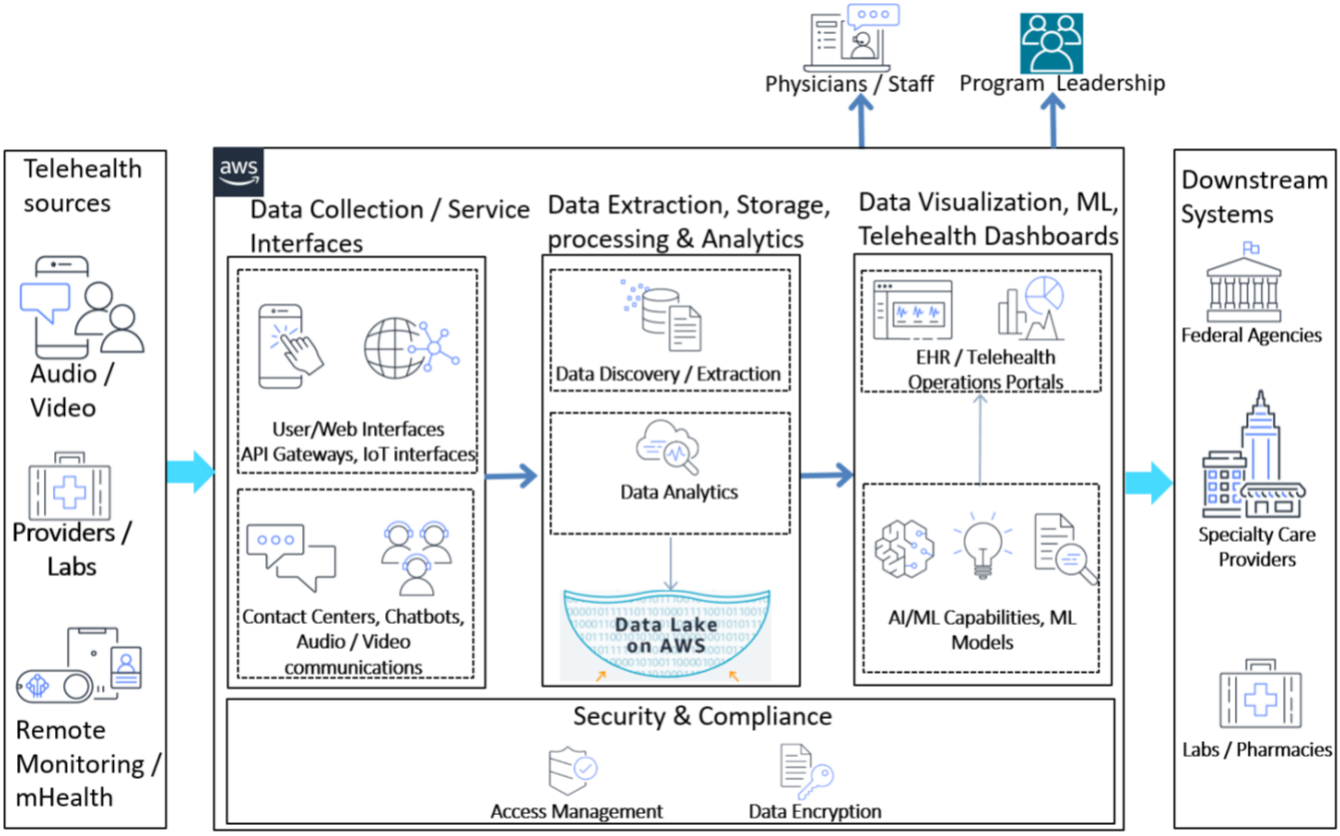

Figure 3 – Reference architecture for a telehealth system implementation

There are four main components of the architecture are:

1. Data collection and service interfaces to communicate with the patients, remote devices and providers/labs
2. Data extraction, storage (data lakes), processing and analytics
3. Data visualization and dashboards, AI/ML capabilities
4. Security and compliance

The physician or clinical staff consume the services using EHR and telehealth portals. Program leadership gets insights into program operations via the dashboards. Data is exchanged with downstream systems, including government entities, specialty care providers, and labs/pharmacies.

The following table shows the various AWS Services to implement this architecture.

Table 1: Objectives within the telehealth reference architecture and AWS Service mapping

Objective	Services / Options
Data collection / UI / mobile interfaces	Amazon CloudFront (content delivery) AWS Transfer Family (batch/file transfer) Amazon API Gateway (support for data exchange via APIs) Amazon IoT Core / AWS IoT Greengrass (integration with devices)
Data lake / storage / databases	Amazon S3 (object storage) AWS Lake Formation (data lake formation) Amazon DynamoDB (NoSQL database)
Data extraction / data processing and analytics	AWS Glue (schema discovery, ETL) Amazon Textract (extract information from documents) Amazon Comprehend Medical (relationships within text) Amazon Transcribe Medical (medical transcriptions) Amazon Translate (language translation) Amazon Kinesis Data Analytics (real-time analytics) Amazon EMR (batch analytics) Amazon Athena (interactive query and analytics)
Workflow automation, data visualization, program operations	Amazon SageMaker (ML model build, train and deploy) Amazon Augmented AI (diagnosis review workflows) Amazon Quicksight (data visualization) Amazon Forecast (forecasting budgets, enrollment models)
Security management	Amazon Key Management Service AWS Identity and Access Management
Audio/video, contact centers / campaign management	Amazon Connect (contact centers) Amazon Lex (build chatbots for self service) Amazon Transcribe (voice recording/transcriptions) Amazon Pinpoint (campaign management

Reference Telehealth Workflows

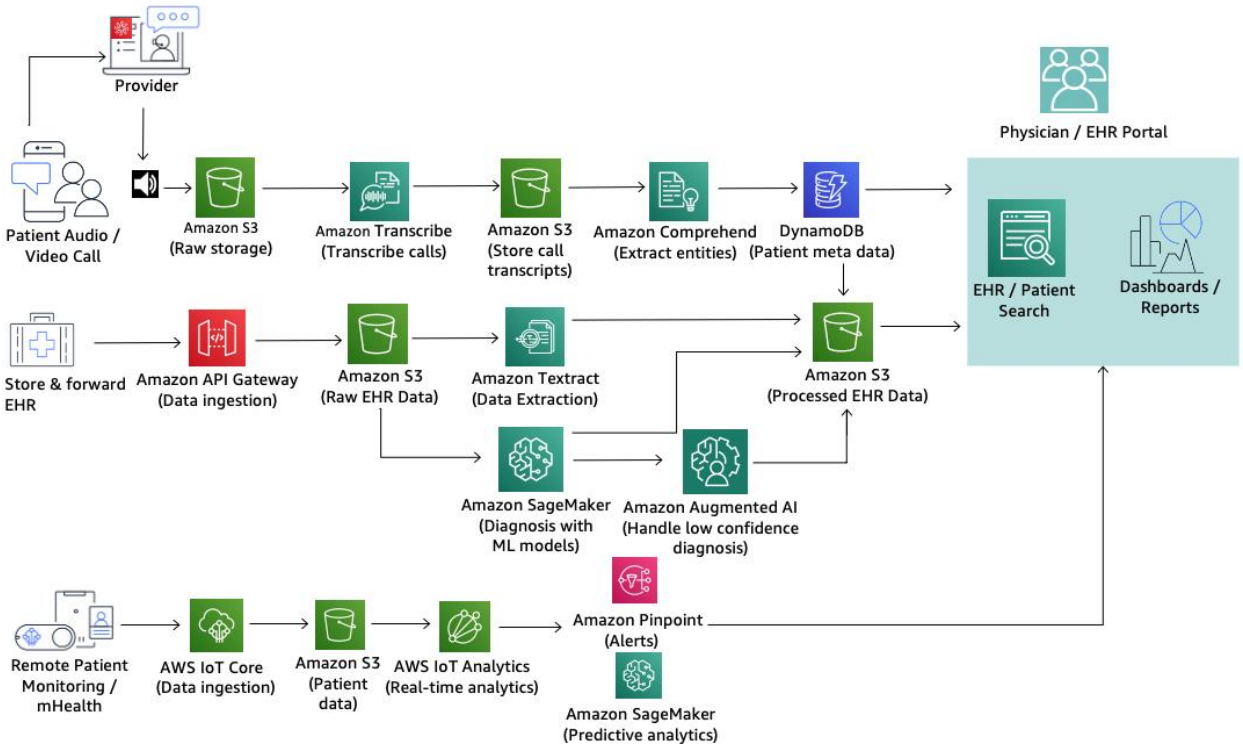

Figure 4 – Reference telehealth workflows

Figure 4 outlines reference telehealth workflows for each of the following modalities:

- **Video Telehealth**
  - Raw audio/video files are stored in an S3 bucket.
  - The files are transcribed to get the text transcripts.
  - With an AWS Lambda trigger, analysis is done on these transcripts using Amazon Comprehend Medical to extract patient conditions, medications, treatments, and so on.
  - Patient metadata is stored in DynamoDB.
  - Custom ML models can be trained using SageMaker to identify and extract key information from transcripts.
  - Physicians can search and retrieve this information and get reports from the portal using Elasticsearch and Quicksight dashboards.
- **Store and forward**

  - EHR data is ingested using batch/API modes and stored in S3.
  - Data is extracted from the documents using Amazon Textract.
  - ML models are trained using SageMaker and used for predictions on patient data.
  - Amazon A2I is used for further review of the output from these models and the results are stored back into S3. These predictions can be consumed by physicians for diagnosis and care.

- **Remote patient monitoring/mHealth**
  - Data is ingested using AWS IoT Core and stored in S3 buckets.
  - The data is sent to Amazon Kinesis Data Firehose.
  - The data is analyzed in real time using AWS IoT Analytics / AWS Kinesis Data Analytics.
  - Predictive analytics is done using ML models, and notifications are sent to patients in real-time.

Conclusion

With the rapid advancement in technology including mobile communications, cloud, and AI and ML, telehealth is the future of medicine and delivery of care. Patients and providers can benefit from remote healthcare services with better care outcomes and lower healthcare costs. This whitepaper introduced a framework for implementing a telehealth platform, and outlined techniques to address some of the implementation challenges.

Next Steps

Adopting the AWS Cloud can provide you with sustainable advantages for telehealth systems. Our customers in the healthcare space include the Center for Medicare and Medicaid Services, Center for Disease Control , Cerner and GE Healthcare, among others. AWS works together with your team and your chosen member of the AWS Partner Network (APN) to execute your enterprise cloud computing initiatives. You can reach out to an AWS partner through the AWS Partner Network. Get started on AI and ML by visiting AWS Machine Learning, AWS Machine Learning Embark Program, or the ML Solutions Lab.

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Further Reading

For additional information, see:

- AWS Healthcare and Lifesciences
- AWS Telehealth Blogs
- AWS Machine Learning Blog

Document Revisions

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December 2020	First publication

Notes

[1] https://federalnewsnetwork.com/veterans-affairs/2020/06/how-va-drastically-expanded-telehealth-during-the-pandemic/

[2] https://www.businesswire.com/news/home/20200427005249/en/Telehealth-Market-Sees-Increase-Demand-Telehealth-Services

[3] https://www.congress.gov/bill/116th-congress/senate-bill/2741

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[6] https://www.ruralhealth.va.gov/docs/ORH_Telehealth_Fact_Sheet.pdf

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