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SPECIALIZATION: SOFTWARE ENGINEERING

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REQUIREMENT, DESIGN AND TESTING FOR TELEMEDCINE APP: MEDIK

	NAMES	MATRICULE NUMBERS
1	QUINUEL TABOT NDIP-AGBOR	FE21A300
2	INDAH RICOBELLE MBAH	FE21A204
3	SIRRI THERESIA ANYE	FE21A306
4	TSAPZE ZAMBOU ROSELINE	FE21A328
5	ENOW MYKE-AUSTINE ETA	FE21A183
6	MOKFEMBAM FABRICE KONGNYUY	FE21A240
7	MONDOA ROBERT	FE21A241
8	TAKEM JIM	FE21A309
9	KENFACK SAMEZA	FE21A213
10	FOLETIA AJONGAKUE SYNCLAIR	FE21A190

COURSE INSTRUCTOR: DR. TSAGUE ALINE

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I. INTRODUCTION

Telemedicine applications, also known as telehealth apps, have emerged as transformative tools in the healthcare landscape. With the growing need for medical attention without any latency, mobility issues and other challenges hindering the offering of quick medical services at maximum comfort, medical services through telecommunication is at high need. These mobile applications enable individuals to access healthcare services remotely, bridging geographical distances and overcoming mobility challenges. By leveraging the power of smartphones and other digital devices, telemedicine applications are revolutionizing the way healthcare is delivered and consumed.

MEDIK, a telemedicine application, stands at the forefront of this transformative movement. MEDIK offers a comprehensive suite of services designed to provide convenient and accessible healthcare to individuals from all walks of life. The application's core functionalities include:

- **Real-time video and audio consultations:** MEDIK empowers patients to connect with licensed healthcare providers via secure video or audio calls, enabling face-to-face interactions for diagnosis, treatment planning, and follow-ups.

- **Secure messaging:** MEDIK facilitates seamless communication between patients and healthcare providers through a secure messaging platform, allowing for asynchronous exchanges of information, questions, and concerns.

- **Online prescription generation:** MEDIK streamlines the prescription process by allowing healthcare providers to electronically generate and send prescriptions directly to pharmacies, eliminating the need for paper prescriptions.

- **Pharmacy services:** MEDIK integrates with partner pharmacies, enabling patients to conveniently order and receive medications directly through the application.

- **Appointment scheduling:** MEDIK simplifies appointment scheduling, allowing patients to browse available time slots and book appointments with their preferred healthcare providers directly from the app.

- **Personalized health notifications:** MEDIK goes beyond consultations and prescriptions by providing personalized health notifications based on a patient's medical history, lab test results, and diagnoses. These notifications may include health tips, medication reminders, and follow-up appointment prompts.

MEDIK's comprehensive suite of features caters to a wide range of healthcare needs, from routine checkups and prescription renewals to chronic disease management and mental health counseling. The application's user-friendly interface and secure communication protocols make it accessible to individuals of all ages and technical proficiency.

In a world where healthcare accessibility is often hindered by geographical barriers, mobility limitations, and time constraints, telemedicine applications like MEDIK are paving the way for a more equitable and inclusive healthcare system. By bridging the gap between patients and healthcare providers, these applications are empowering individuals to take control of their health and well-being.

II. PROJECT DETAILS, REQUIREMENT DESCRIPTION AND STANDARDS ANALYSIS

1) FUNCTIONAL REQUIREMENTS:

➢ **User Authentication and Security of User Data:**

- Secured user registration and login using multiple authentication factors, including username, password, and biometric fingerprint.
- Enforced password complexity and change requirements.
- Secure storage and encryption of user credentials and personal data.
- Implementation of role-based access control (RBAC) to restrict access to sensitive information.
- Regular security audits and vulnerability assessments.

➢ **Patient-Healthcare Provider Communication and Consultation:**

- Real-time video, audio, and messaging communication between patients and healthcare providers.
- Scheduling and management of virtual consultations.
- Secure file sharing for exchanging medical records, images, and other relevant documents.
- Integration with third-party communication platforms.
- Real-time translation services for multilingual communication.

➢ **Payment Processing and Transactions**

- Integration with secure payment gateways for online transactions.
- Support for multiple payment methods (credit cards, debit cards, mobile wallets).
- Generation of detailed transaction receipts for consultations, diagnosis, and medication purchases.
- Secure storage and processing of payment information.
- Compliance with relevant payment industry standards (PCI DSS).

➢ **Appointment Scheduling and Management**

- Real-time scheduling and management of appointments for both patients and healthcare providers.
- Availability of appointment slots based on healthcare providers' schedules.

- Synchronization with healthcare providers' calendars and scheduling systems.
- Automated appointment reminders and notifications.
- Waitlist management for oversubscribed appointments.
- Integration with patient calendars for seamless scheduling.

➢ **Medical Records Management**

- Secure and centralized storage of patient medical records, including test results, prescriptions, and other relevant health information.
- Patient-controlled access to their medical records.
- Sharing of medical records with healthcare providers with patient consent.
- Data encryption and access logging for audit purposes.
- Compliance with relevant data privacy regulations (HIPAA, GDPR).
- Integration with electronic health record (EHR) systems for comprehensive patient data management.

➢ **Prescription Services**

- Electronic prescription (eRx) generation and management.
- Direct transmission of prescriptions to pharmacies.
- Patient consent management for sharing prescription information with pharmacies.
- Integration with pharmacy management systems.
- Medication affordability and delivery options, including generic drug recommendations and pharmacy discounts.

2) NON-FUNCTIONAL REQUIREMENTS:

➢ **Security of telemedicine application:**

- MEDIK adheres to strict security standards (e.g., HIPAA compliance) to ensure the confidentiality, integrity, and privacy of patient data.
- MEDIK provides strongly authenticated, access controlled and sustainable database to store and backup data of patients for medical and research purposes.
- MEDIK is to provide a secured internet connection that is essential to enable video conferencing between patients and healthcare providers mainly by encryption.

➢ **Usability and User Experience:**

- MEDIK has an intuitive and user-friendly interface, making it easy for users to navigate, schedule appointments, communicate, and access their information.

- MEDIK incorporates an expert assistant to walk new users through the interface as well as provide directives to achieving patient's objective on the application.

➢ **Reliability and Availability:**

- MEDIK is reliable, ensuring consistent availability and minimal downtime to avoid.
- MEDIK incorporate error free payments and retrieval of user data at any time possible time.

➢ **Accessibility:**

- MEDIK will comply with accessibility standards to ensure that individuals with disabilities can access and use the app effectively.
- A text to speech and speech to text functionality to make it comfortable for disabled users.

➢ **Performance and Scalability:**

- MEDIK is capable of handling concurrent users and providing a smooth and responsive experience, even during peak usage times.
- MEDIK has fast response time between using action and effect hence reducing waiting time.

➢ **Compatibility and Integrations:**

- The app should be compatible with various devices, operating systems (e.g., iOS, Android), and browsers to cater to a wide range of users.
- It should also support integrations with other healthcare systems, such as electronic health records (EHR) or pharmacy systems.

➢ **Regulatory Compliance:**

- The app should adhere to relevant regulations and guidelines, such as HIPAA, GDPR, and local telemedicine practice guidelines.

➢ **Internationalization:**

  - MEDIK is multilingual and can be used across 50+ international languages.

3) ARCHITECTURAL REQUIREMENTS:

➢ **Stakeholders**

  – MEDIK will basically involve four major stakeholders i.e., the patient, healthcare center (which will consist of health experts), pharmacy and administrator.

➢ **Layers**

MEDIK consists of 3 main layers or tiers namely

- **The Presentation layer** also commonly known as the frontend or user interface using React native due to its light weight and cross platform nature.

- **The Application layer** also commonly known as the logic tier or middle tier which will be done using TypeScript due to its assured security and high-performance in integration with React native.

- **The Data layer** which will involve manipulation of data in the database which will be done using MongoDB due to its role-based access control features as well as security features like authentication, authorization, and transparent data encryption (which automatically encrypt data at rest in database).

- **User Interfaces (Clients)**
  - **Patient App**: A mobile or web app that allows patients to register, sign in, manage their profiles, schedule appointments, and communicate with healthcare providers in real-time.
  - **Healthcare Provider App**: A web app used by doctors and other healthcare providers to manage appointments, access patient records, and conduct virtual consultations.
  - **Admin Panel**: A web-based interface for system administrators to manage the platform, users, and data.

- **Communication Components**
  - **Video/Audio Streaming**: Real-time communication channels for virtual consultations.
  - **Chat Messaging**: Text-based communication for quick queries and follow-ups.

- **APIs and Logic**
  - **Authentication and Authorization**: Secure methods for user registration and access control.
  - **Appointment Management**: Functionality to schedule, modify, or cancel appointments.
  - **Medical Record Management**: Secure storage and retrieval of patient medical records.
  - **Medically Trained Expert System Model API**: for Expert System consultations and user guide through system's user interface.

- **Storage and Infrastructure Services**
  - **Database**: A secure database to store user data, medical records, appointment details, and other relevant information.
  - **File Storage:** For storing and sharing documents, images, and other files.
  - **Payment Gateway**: To process financial transactions for services rendered.

- **Security Measures**
  - **Data Encryption**: To protect sensitive data during transmission and at rest.
  - **Compliance**: Adherence to healthcare regulations like HIPAA for patient data privacy.
  - **Access Logs and Monitoring**: To track usage and detect any unauthorized access.

- **Integration with External Systems**
  - **Pharmacy Systems**: For sending prescriptions and managing medication orders.

- **Network Architecture**
  - Cloud-based architecture will be used precisely **Azure** where computations will be done over the internet (or the cloud). Azure was chosen due to it's high security, high performance (since computing will be independent on the specifications of the user's device) and it's scalability.

4) INTERNATIONAL QUALITY STANDARDS FOR TELEMEDICINE APPS

Internationally socially used standards include:

Health Insurance Portability and Accountability Act (HIPAA):

HIPAA is a well-known and popular standard for patient data privacy and security, specifically applicable in the United States. Compliance with HIPAA is crucial for telemedicine apps serving users in the U.S. to safeguard patient privacy and security. The standard is widely recognized for its comprehensive regulations and its emphasis on protecting sensitive patient health information. While not an international standard per se, HIPAA's influence extends beyond the U.S. healthcare system due to its rigorous privacy and security measures. The World Health Organization (WHO) supports the principles of HIPAA in promoting the secure handling and protection of personal health information.

To ensure compliance with HIPAA in a telemedicine app, the following considerations should be taken into account:

1. **Protected Health Information (PHI):** Implement strict controls to protect PHI, including electronic health records (EHRs) and any other sensitive patient information.

2. **Administrative Safeguards**: Establish policies and procedures to manage access to PHI, conduct risk assessments, and train staff on HIPAA compliance.

3. **Technical Safeguards**: Implement security measures such as encryption, access controls, and audit logs to ensure the confidentiality and integrity of PHI.

4. **Physical Safeguards**: Secure physical locations where PHI is stored or accessed, including data centers or mobile devices used for telemedicine consultations.

5. **Business Associate Agreements**: Establish contractual agreements with any third-party service providers who have access to PHI to ensure they also comply with HIPAA regulations.

By adhering to HIPAA's privacy and security requirements, the telemedicine app can provide a trusted environment for patients, protecting their sensitive health information and ensuring compliance with relevant regulations.

General Data Protection Regulation (GDPR):

GDPR is a standard for data protection and privacy that applies to the European Union (EU) and European Economic Area (EEA). Compliance with GDPR is essential for telemedicine apps serving users in EU/EEA countries to ensure the lawful and secure processing of personal data. GDPR has gained global acceptance due to its robust data protection principles and the recognition of privacy rights. The World Health Organization (WHO) also supports GDPR in promoting privacy and data protection.

To ensure compliance with GDPR in a telemedicine app, the following measures should be implemented:

1. **Obtain Consent**: Implement mechanisms in your app to obtain explicit user consent for data processing activities. Clearly inform users about the purpose and scope of data collection and processing.

2. **Secure Personal Data**: Implement appropriate security measures, such as encryption and access controls, to protect personal data from unauthorized access, loss, or breaches.

3. **Privacy by Design**: Incorporate privacy principles into the design and development of your app. This includes practices like data minimization, purpose limitation, and retention controls.

4. **Data Subject Rights**: Enable users to exercise their rights under GDPR. This includes providing mechanisms for users to access, rectify, erase, or restrict the processing of their personal data.

By adhering to these GDPR requirements, the telemedicine app can ensure compliance with data protection and privacy regulations, providing a secure and transparent environment for users in EU/EEA and the rest of the other countries.

International Organization for Standardization (ISO) 27001:

ISO 27001 is an internationally recognized standard for information security management systems. While not specifically focused on telemedicine, adopting ISO 27001 guidelines helps ensure that your telemedicine app implements robust security controls, risk management processes, and data protection measures on an international scale. ISO standards are widely adopted globally due to their comprehensive nature and the assurance they provide in managing information security risks. While the World Health Organization (WHO) does not explicitly endorse ISO 27001, the principles and practices align with the WHO's objective of promoting secure and reliable health information systems.

To align with ISO 27001 in your telemedicine app, consider the following:

1. **Risk Assessment**: Conduct regular risk assessments to identify potential vulnerabilities and threats to the confidentiality, integrity, and availability of information.

2. **Information Security Policies**: Develop and enforce policies and procedures that address key security areas, including access control, incident response, and data classification.

3**. Security Controls**: Implement a set of security controls based on ISO 27001 requirements, such as network security, encryption, and user access management.

4. **Continual Improvement**: Establish processes for ongoing monitoring, review, and improvement of your information security management system.

By adopting ISO 27001 principles, the telemedicine app can demonstrate a commitment to maintaining a high level of information security, protecting sensitive patient data, and mitigating potential risks.

Health Level 7 (HL7):

HL7 is an international standard for the exchange of electronic health record (EHR) data. It facilitates interoperability and data exchange between different healthcare systems globally, including telemedicine applications. HL7's standards enable seamless communication and information sharing, improving the efficiency and accuracy of healthcare delivery. While not directly endorsed by the World Health Organization (WHO), HL7's interoperability standards align with the WHO's goal of promoting health data exchange and integration.

To ensure compatibility with HL7 in your telemedicine app, consider the following:

1. **HL7 Messaging**: Implement HL7 messaging standards for the exchange of clinical and administrative data between your telemedicine app and other healthcare systems.

2. **Data Mapping**: Ensure proper mapping of data elements between your app's internal data structure and HL7 standards to facilitate accurate data exchange.

3. **Integration Capabilities**: Develop interfaces and APIs that support HL7 messaging protocols to enable seamless integration with other healthcare systems.

4. **Standards Compliance**: Regularly update your app's HL7 implementation to align with the latest version of the standard and ensure compliance with industry best practices.

By incorporating HL7 standards into the telemedicine app, it can enhance interoperability, facilitate efficient data exchange, and enable seamless integration with other healthcare systems globally.

Digital Imaging and Communications in Medicine (DICOM):

DICOM is an international standard for the exchange of medical images, such as X-rays, CT scans, and MRI scans. Telemedicine applications often rely on DICOM to transmit medical images globally for consultation or diagnostic purposes. DICOM's standardized image format and communication protocols ensure interoperability and seamless transmission of medical images between healthcare providers worldwide. While not explicitly supported by the World Health Organization (WHO), DICOM's adoption is driven by the need for standardized and reliable medical image exchange.

To support DICOM in a telemedicine app, consider the following:

1. **DICOM Image Format**: Ensure compatibility with the DICOM image format to enable proper rendering and display of medical images within your app.

2. **DICOM Communication Protocols:** Implement DICOM communication protocols, such as DICOM web or DICOM Modality Worklist, to enable secure and standardized transmission of medical images.

3. **DICOM Metadata:** Capture and store relevant DICOM metadata associated with medical images, including patient information, study details, and image acquisition parameters.

4. **Integration with DICOM Systems:** Develop interfaces or APIs to integrate your telemedicine app with DICOM-compliant Picture Archiving and Communication Systems (PACS) or other medical imaging systems.

5. **DICOM Compliance:** Regularly update your app's DICOM implementation to align with the latest version of the standard and ensure compliance with interoperability requirements.

By incorporating DICOM standards into the telemedicine app, it can facilitate the seamless exchange of medical images, enhance diagnostic capabilities, and enable collaboration among healthcare providers worldwide.

III. ANALYSIS AND RESEARCH ILLUSTRATION FOR MEDIK

1) OVERVIEW

Telemedicine is the use of telecommunications technology to provide healthcare services remotely. The telemedicine app, MEDIK, is out to provide patients with convenient and affordable access to healthcare services, especially for those in rural or underserved areas.

2) ANALYSIS

MEDIK is a telemedicine app that provides patients with a variety of services, including:

- Video, audio and messages consultations with healthcare providers
- Prescription management
- Medical records management
- Secure communication
- Appointment scheduling
- Patient education materials
- Pharmacy services

MEDIK is a user-friendly app that is easy to navigate. The app is also secure and compliant with all applicable privacy regulations.

3) RESEARCH

There is a growing body of research that supports the effectiveness of telemedicine apps. For example, a study published in the Journal of the American Medical Association found that telemedicine was as effective as in-person care for a variety of conditions, including chronic diseases and mental health conditions. And Fig 1. Below shows an illustration of MEDIK's details

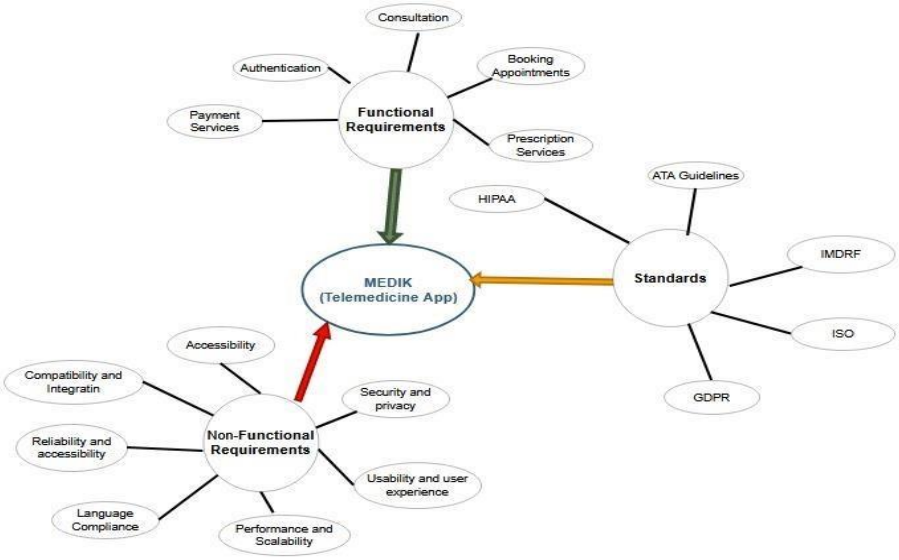

Figure 1: Illustration of requirement of MEDIK

4) ILLUSTRATION

Imagine a patient named Sarah who lives in a rural area. Sarah has a chronic disease that requires regular monitoring. In the past, Sarah had to drive for hours to see her doctor. However, now that she has MEDIK, she can schedule a video consultation with her doctor from the comfort of her own home.

IV. SYSTEM, USER INTERFACE (UI) AND DATABASE DESIGN OF MEDIK

Following the requirements, research and analysis done, the design was divided in two (2) major phases namely:

- System design
- User Interface (UI) design
- Database design

1. SYSTEM DESIGN

System Design refers to the process of defining the architecture, modules, components, interfaces, and data flow of a system to satisfy specific requirements. It involves creating a blueprint for the construction of a system that meets the requirements of the application. In achieving this design, mainly UML (Unified Modelling Language) was used which practically involved providing UML diagrams based on analysis and then describing them. The System design involved the use of four UML diagrams. That is:

- Use case diagram
- Class diagram
- Activity diagram
- Sequence diagram

❖ Use case for MEDIK

The use case diagram of MEDIK as part of the UML describes and graphically represents the actors, the different use cases (action or system services to fulfill the needs of actors) and their relationships as well a clarify scope and system boundaries of MEDIK.

Figure 2 below shows the use case diagram of MEDIK.

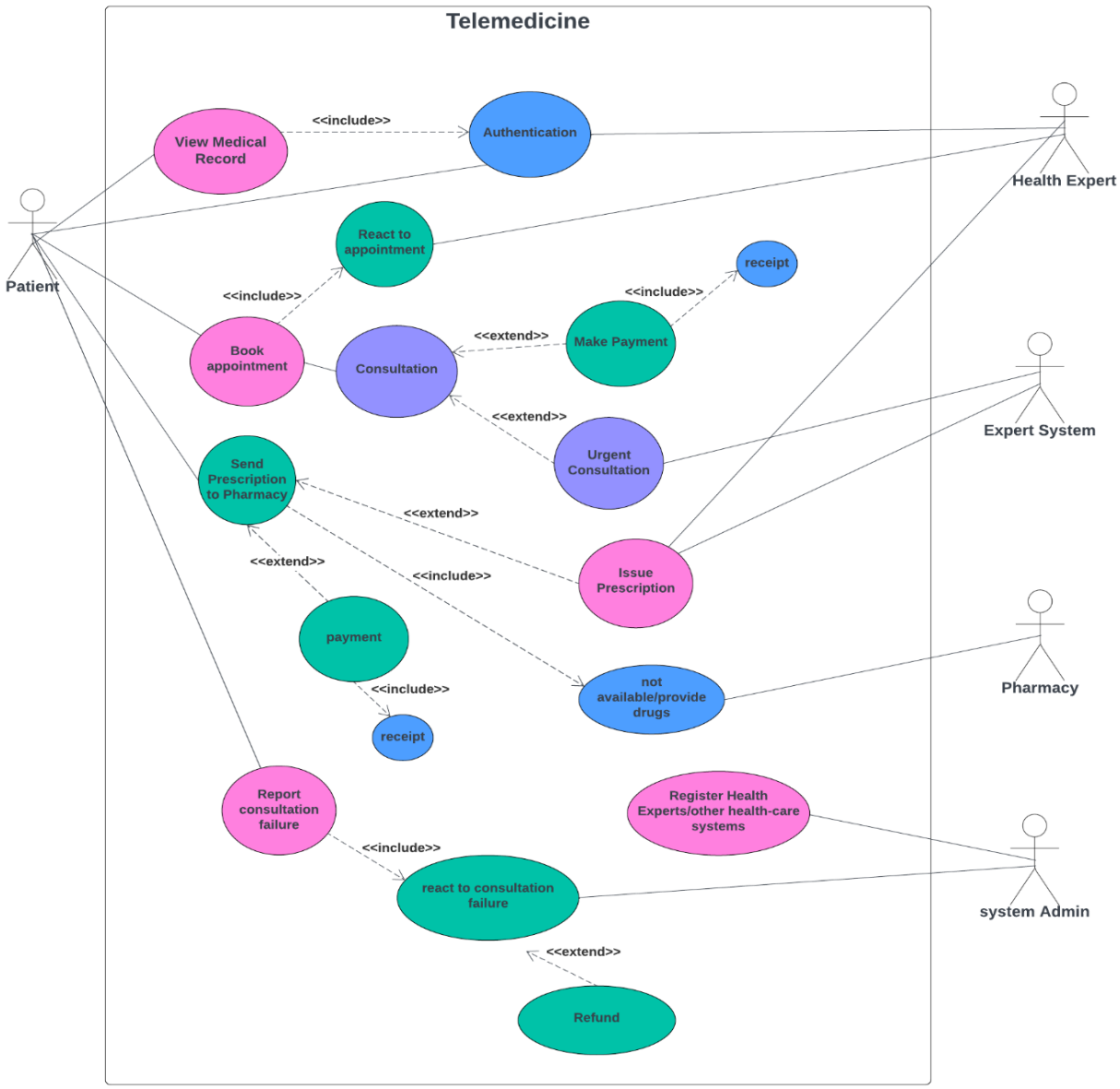

Figure 2: Use case diagram of telemedicine application MEDIK

Detailed Description of MEDIK's Use Cases

1. View Medical Record

- **Actor**: Patient

- **Goal:** To allow the patient to access and view their medical history and records.

- **Preconditions**: Patient must be logged into the system.

- **Postconditions**: Patient views the desired medical records.

- **Basic Flow**:

1. Patient requests to view medical record.
2. System verifies patient's identity and authorization.
3. System retrieves and displays the medical record.

2. React to Appointment

- **Actor**: Health Expert
- **Goal**: To respond to patient’s request to access consultation and prescription services with health expert within the telemedicine system.
- **Preconditions**: Health expert is logged in and has reviewed the patient's request.
- **Postconditions**: Patient gains access to requested services.
- **Basic Flow**:

1. Health expert receives a request for confirmation.
2. Health expert reviews schedule and the patient's medical history.
3. Health expert grants or denies authorization for consultation.

3. Consultation

- **Actor:** Patient, Health Expert
- **Goal:** To facilitate a virtual consultation and prescription between the patient and the health expert.
- **Preconditions**: Patient has been approved on request of consultation via appointment booking.
- **Postconditions**: Consultation is completed, and advice is given.
- Basic Flow:

1. Patient requests a consultation and is approved.
2. System schedules the consultation session with the health expert.
3. Health expert and patient conduct the consultation.

4. **Make Payment**

- **Actor**: Patient
- **Goal**: To process payment for the telemedicine services rendered.
- **Preconditions**: Patient has billing information after request for consultation is authorized (approved).
- **Postconditions**: Payment is processed, and receipt is generated.
- **Basic Flow**:

1. Patient selects services for payment.
2. System calculates total cost and presents it to the patient.
3. Patient confirms payment, and the system processes the transaction.

5. **Send Prescription**

- **Actor**: Patient, Pharmacy
- **Goal**: To send a prescription from the patient to the pharmacy.
- **Preconditions**: Consultation has occurred, and a prescription is needed.
- **Postconditions**: Pharmacy receives the prescription and prepares medication.
- **Basic Flow**:

1. Health expert generates a prescription.
2. Prescription is sent electronically to the chosen pharmacy by patient.
3. Pharmacy confirms receipt and prepares medication for the patient.

6. **Register Health Experts/ Health-care Provider**

- **Actor:** System Admin
- **Goal:** To register new health-care providers into the telemedicine system.

- **Preconditions:** System admin has the necessary information to register a provider.

- **Postconditions:** New health-care provider is added to the system.

- **Basic Flow:**

  1. System admin collects required information from the health-care provider.

  2. System admin inputs the information into the system.

  3. System confirms registration and notifies the health-care provider.

7. Urgent Consultation

- **Actor:** Expert System
- **Goal:** To get an instant consultation session with patient for prescription and recommendation.
- **Preconditions:** Patient has interacted with the expert system.
- **Postconditions:** Expert system provides prescription and recommendations.
- **Basic Flow:**

  1. Patient makes aware symptoms and concerns to the expert system.

  2. Expert system analyzes the information.

  3. Expert system issues prescriptions and recommendations.

8. Report Consultation Failure

- **Actor:** Patient

- **Goal:** To resolve issues with regards to consultation failure.

- **Preconditions:** Consultation scheduled for a given time didn’t push through.

- **Postconditions:** Issue is resolved and may involve a refund.

- **Basic Flow:**

  1. Patients reports failure to System admin.

2. System Admin reviews report and checks if are in line with system logs.

3.System Admin gives feedback (Reacts to report) and may involve refund.

❖ Class Diagram for MEDIK

The class diagram of MEDIK telemedicine application visualises the classes and attribute, methods and relationship between classes. The class diagram of MEDIK is shown in figure 3 below.

Figure 3: Class Diagram of MEDIK

Description of Class Diagram

Classes and Their Attributes:

- Medical Record, Patient, Doctor, Health Expert, Pharmacy, Appointment, Payment, and Prescription are the main classes represented as boxes.

- Inside each box, the attributes (properties or data members) and methods (functions or services) of the class are listed as in line with the analysis and requirements.

Relationships:

- The lines connecting the boxes indicate the **associations** between classes. For example, the Medical Record class is associated with Patient, Doctor, and Health Expert classes.

- **Associations** can represent different types of relationships, such as aggregation, composition, or inheritance, which define how objects of these classes interact with each other.

Purpose of Class Diagrams:

- Class diagrams are part of the Unified Modeling Language (UML) and are used to model the static structure of systems.

- They help developers and stakeholders understand the system's architecture and the interconnections between different components.

- They serve as a blueprint for implementing the system in code.

❖ Activity Diagram for MEDIK

The activity diagram of MEDIK telemedicine application shows the flow of action in the application. The activity diagrams of MEDIK and their description are shown below:

– **Login / Registration:**

This activity diagram effectively illustrates the steps a user must take to either log in or register for the healthcare system, as well as the possible outcomes of each action. It also highlights the different roles users can assume once they are part of the system

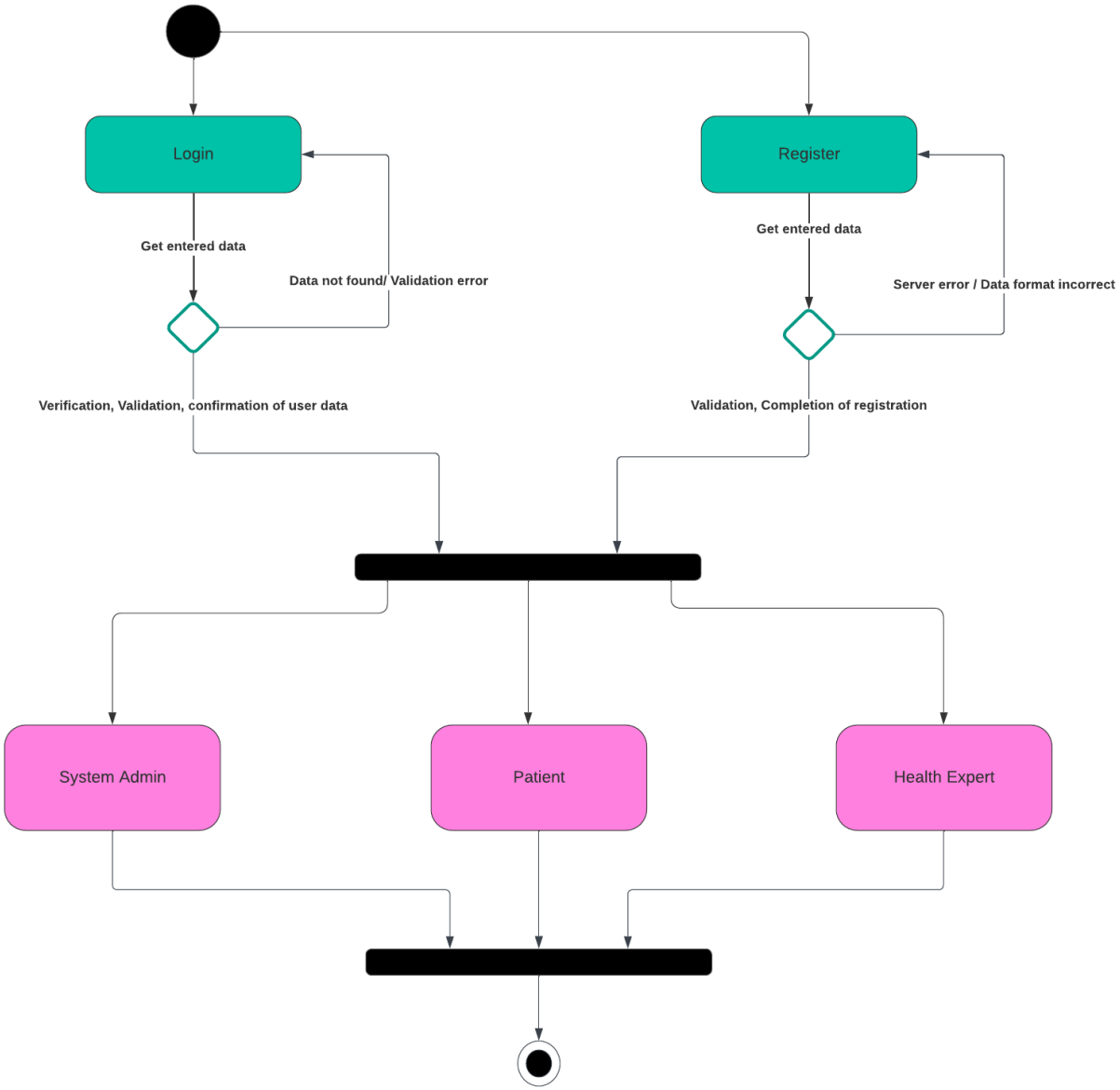

Figure 4: Activity for Login and Registration for MEDIK

Description of Diagram

Login Process:

1. **Start**: The process begins when a user attempts to log in.

2. **Enter Data**: The user enters their login credentials.

3. **Data Validation**: The system checks if the entered data is found and correct.

- If the data is not found or incorrect, the user receives an error message and is prompted to try again.

- If the data is correct, the user is verified and validated.

4. **Confirm User Data**: Upon successful validation, the user's data is confirmed, and they gain access to the system.

Registration Process:

1. **Start**: The process initiates when a user decides to register.

2. **Enter Data**: The user provides their registration details.

3. **Data Validation**: The system validates the entered data.

- If the data is incorrect, the user receives an error message and is asked to correct the details.

- If the data is correct, the user is validated.

4. **Complete Registration**: After successful validation, the user's registration is completed, and they can now log in to the system.

User Roles:

- The diagram also outlines the different roles a user can have within the system:

- **System Admin:** Responsible for managing the system's overall functionality and user accounts.

- **Patient:** Can access personal health records, schedule appointments, and communicate with health experts.

- **Health Expert:** Provides healthcare services and conducts consultations.

– **Activity for Appointment booking for consultation:**

This activity diagram illustrates the booking of appointments by patients for consultation with health expert. Figure 5 and 6 below illustrates how appointment booking occurs in MEDIK on the patient and doctor’s end respectively.

Figure 5: Patients activity for appointment booking

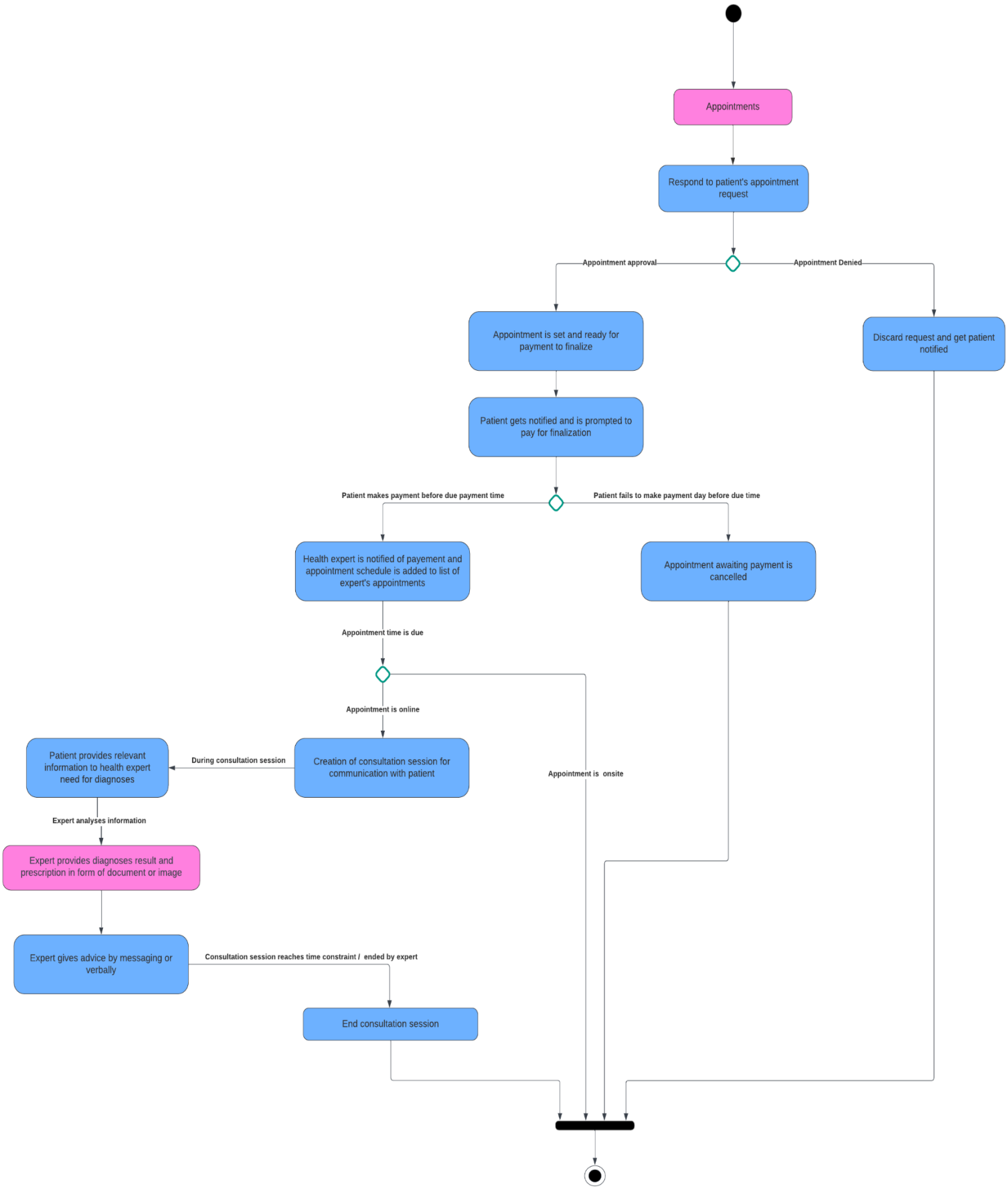

Figure 6: Health Experts activity

- **Patient Activity:**
  Beside booking appointments patients also have the ability to view their medical record, report consultation issues and send prescription they received from health expert to pharmacy. The figure below illustrates the flow of action for all these.

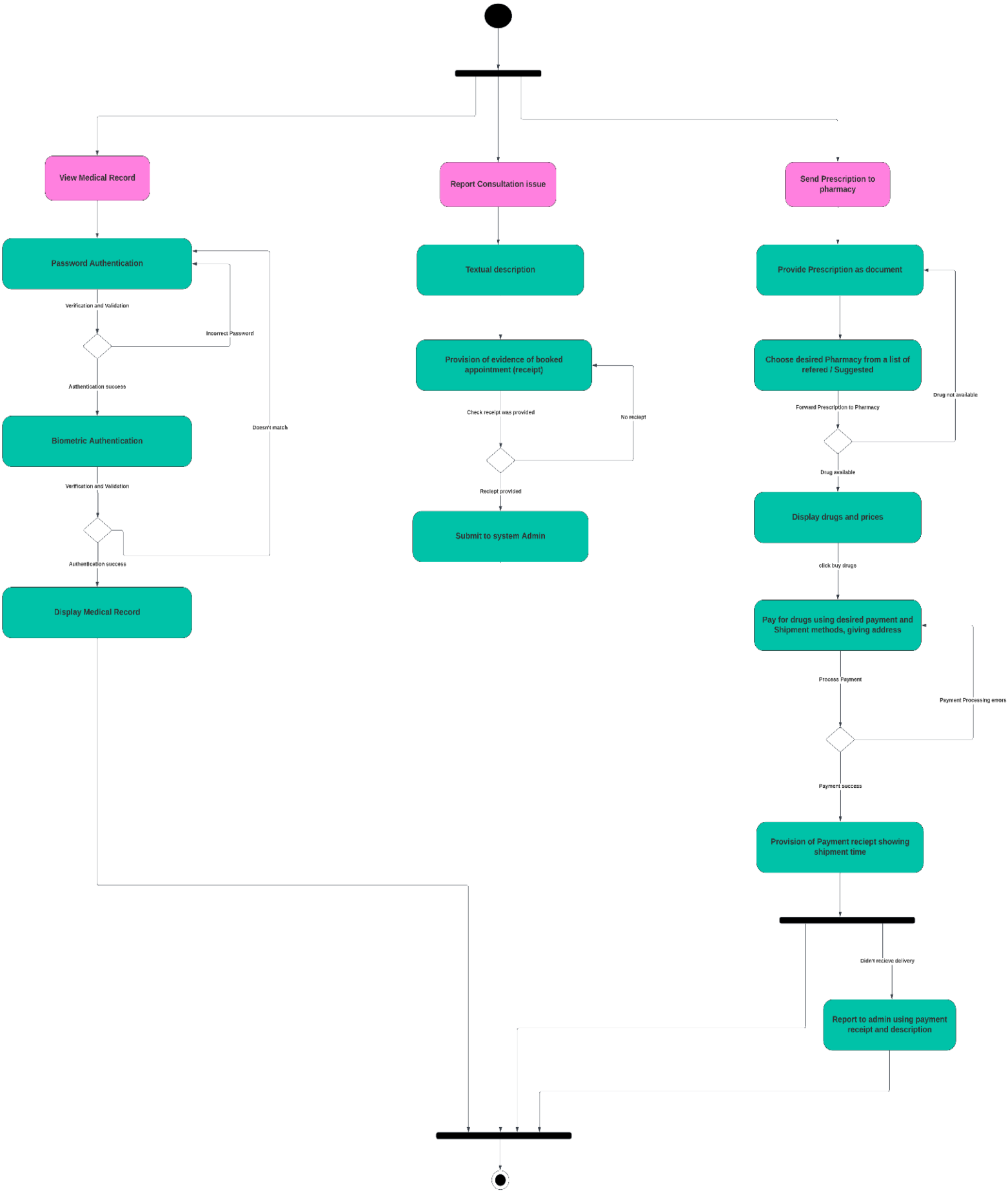

Figure 7: Patient's activity

❖ Sequence Diagram for MEDIK

The sequence diagram focuses on illustrating the dynamic behavior of the telemedicine system, showing the flow of messages and the sequence of method invocations. Illustrations are shown by figures below

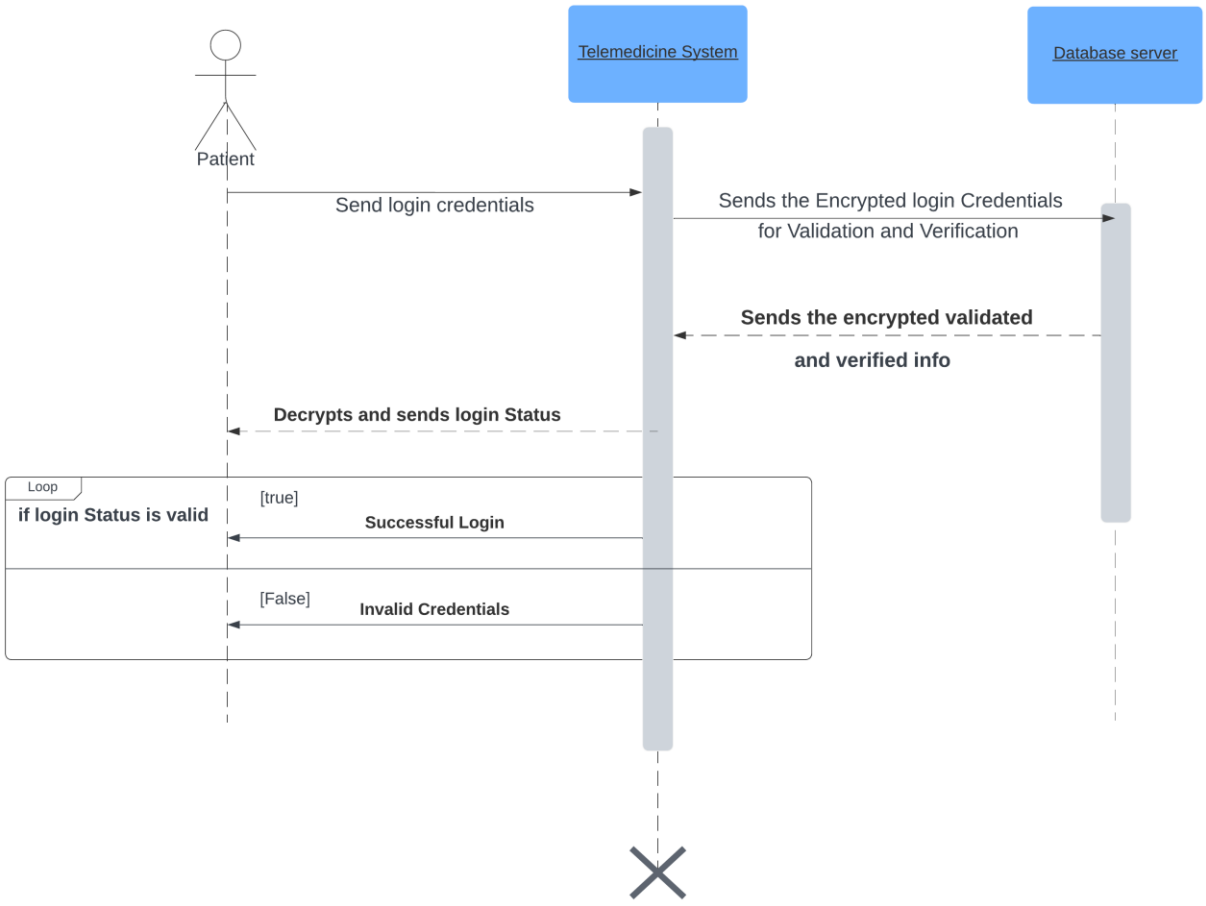

Figure 8: Sequence Diagram for authentication

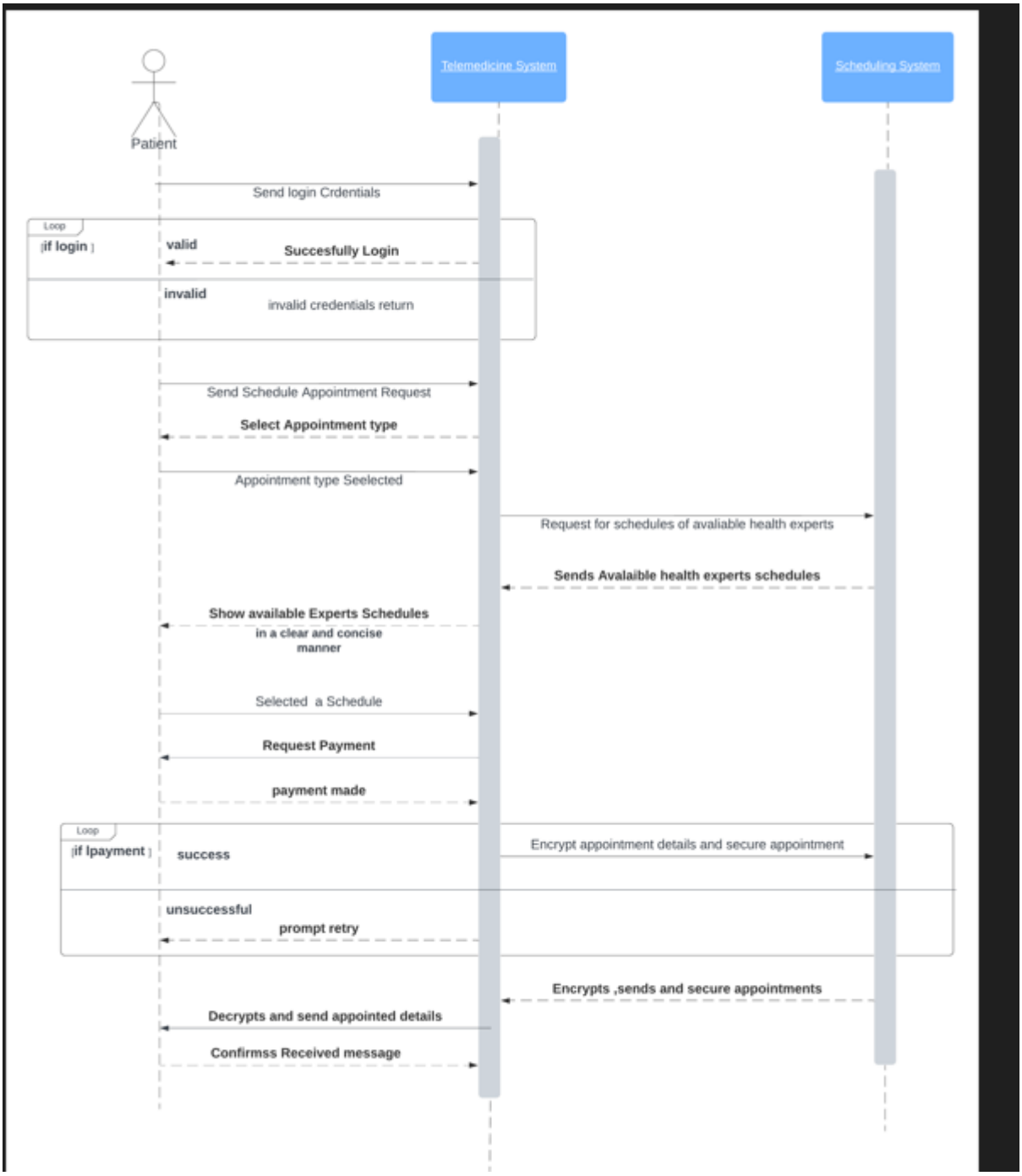

Figure 9: Sequence Diagram for appointment booking for consultation.

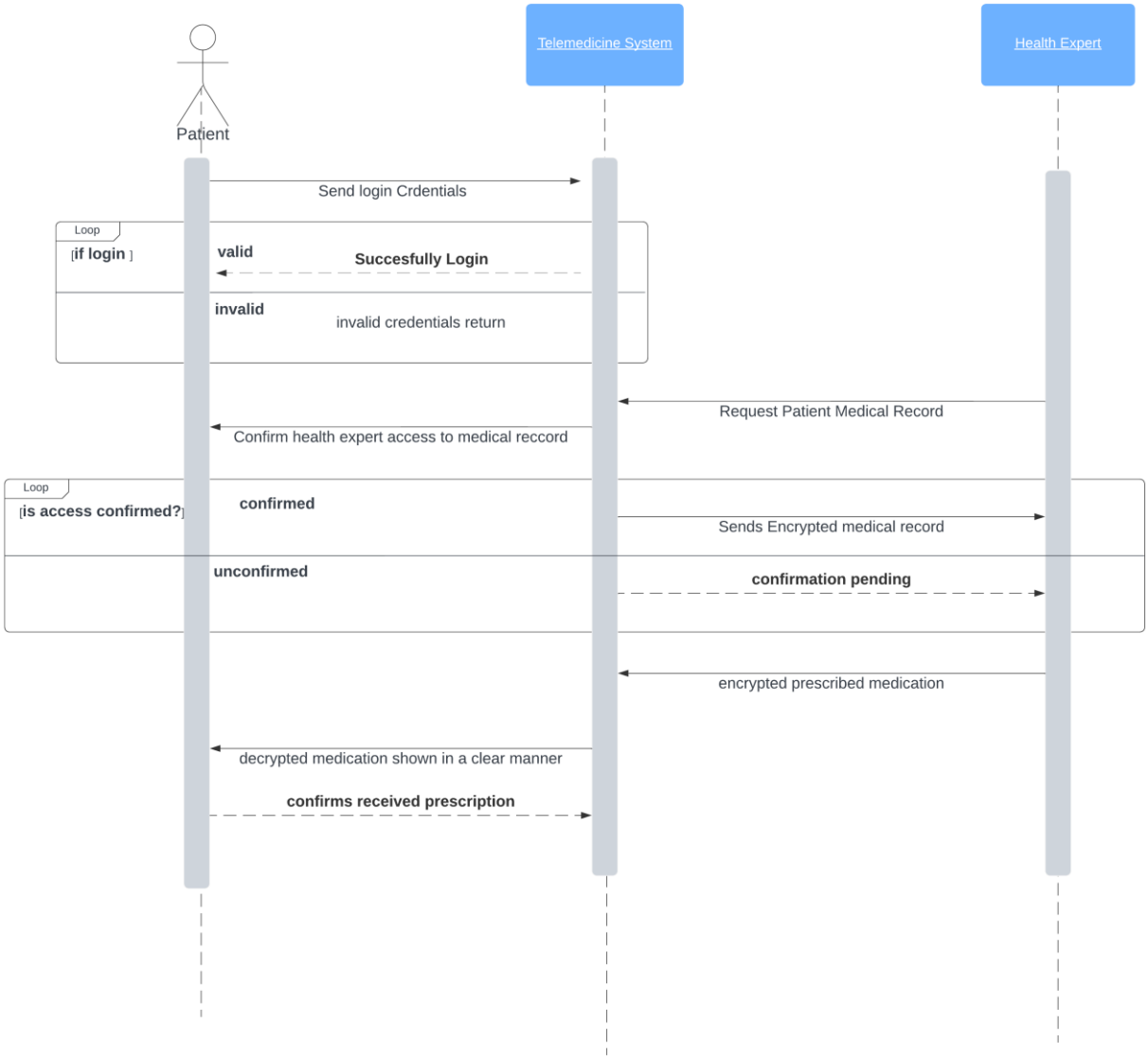

Figure 10: Sequence Diagram for prescription issuing.

Description of Sequence Diagram:

For Authentication (as on Figure 8)

- The diagram explains the login process for a patient using an intermediate (Telemedicine) system and a database server.

- The diagram consists of three columns: Patient, Intermediate (Telemedicine) System, and Database Server.
- The patient sends their login credentials to the intermediate system.
- The intermediate system sends the credentials to the database server for verification.
- If the credentials are valid, the database server sends the encrypted validated and verified info back to the intermediate system.

- If the credentials are invalid, the intermediate system sends an invalid credentials status to the patient.

HIPAA is a set of standards that regulate the use and disclosure of protected health information (PHI) [1]. The login process in the diagram is compliant with HIPAA standards, as it does not disclose any PHI.

The sequence diagram shows the process of sending a login credentials to a database server in a telemedicine system in accordance with the HIPAA standard.

Sequence:

1. The patient sends the encrypted login credentials to the database server for validation and verification.
2. The database server decrypts and validates the login credentials.
3. If the login credentials are valid, the database server sends the encrypted validated and verified info to the patient.
4. The patient decrypts and sends the login status.
5. If the login status is valid, the patient is successfully logged in. Otherwise, the patient is notified that the login credentials are invalid.

HIPAA compliance:

The sequence diagram complies with the HIPAA standard in the following ways:

- The login credentials are encrypted before they are sent over the network. This protects the confidentiality of the patient's information in case of a data breach.
- The login credentials are validated and verified by the database server before the patient is granted access to their account. This helps to ensure that only authorized individuals can access patient information.
- The patient's login status is encrypted before it is sent back to the patient. This protects the privacy of the patient's account status.

Overall, the sequence diagram shows a secure and compliant process for sending login credentials to a database server in a telemedicine system in accordance with the HIPAA standard.

For booking Appointments (as on figure 9)

The sequence diagram provided shows the flow process for a patient to book an appointment with a healthcare expert in a telemedicine system in accordance with the ISO 27001 standard:

1. The patient sends their login credentials to the telemedicine system.
2. The telemedicine system validates the patient's login credentials.
3. If the login credentials are valid, the telemedicine system displays the patient's schedule.
4. The patient selects an appointment type.
5. The telemedicine system displays a list of available healthcare experts for the selected appointment type.

6. The patient selects a healthcare expert and a schedule.
7. The telemedicine system sends a payment request to the patient.
8. The patient makes the payment.
9. The telemedicine system encrypts and secures the appointment details.
10. The telemedicine system confirms the appointment with the patient. ISO 27001 compliance:

The sequence diagram complies with the ISO 27001 standard in the following ways:

- The patient's login credentials are validated before they are granted access to the telemedicine system. This helps to ensure that only authorized individuals can access the system.
- The appointment details are encrypted and secured to protect the confidentiality of the patient's information.
- The payment process is secure and compliant with industry standards.

By implementing these security measures, the telemedicine system can help to protect the confidentiality, integrity, and availability of patient information in accordance with the ISO 27001 standard.

For prescription (Figure 10)

The sequence diagram provided shows how a doctor prescribes to a patient in a telemedicine system in accordance with the HIPAA and ISO 27001 standards:

Sequence:

1. The patient logs into the telemedicine system.
2. The doctor requests the patient's medical record to prescribe medication.
3. The patient confirms access.
4. The doctor prescribes the medication to the patient.
5. The telemedicine system encrypts the prescription.
6. The telemedicine system sends the encrypted prescription to the patient's pharmacy.
7. The patient's pharmacy decrypts the prescription and dispenses the medication to the patient.

HIPAA and ISO 27001 compliance:

The sequence diagram complies with the HIPAA and ISO 27001 standards in the following ways:

- The patient authenticates to the telemedicine system before requesting a prescription. This helps to ensure that only authorized individuals can request prescriptions.
- The telemedicine system encrypts the prescription before it is sent to the patient's pharmacy. This protects the confidentiality of the patient's prescription information in case of a data breach.

- The patient's pharmacy decrypts the prescription before it is dispensed. This protects the privacy of the patient's prescription information.
- The telemedicine system and the patient's pharmacy implement access control measures to restrict access to prescription information to authorized individuals.
- The telemedicine system and the patient's pharmacy log all activities performed to create audit trails. These audit trails can be used to investigate any suspicious activity or security incidents.
- The telemedicine system and the patient's pharmacy implement risk management processes to identify, assess, and mitigate security risks.
- The telemedicine system and the patient's pharmacy provide security awareness training to all employees who have access to prescription information.

Overall, the sequence diagram shows a secure and compliant process for the prescribing of medication by a doctor to a patient in a telemedicine system in accordance with the HIPAA and ISO 27001 standards.

2. UI DESIGN

The UI is designed to be accessible and user-friendly, with clear descriptions accompanying each button or call to action. The primary color is green for its associations with health and nature. Interactive images and icons are incorporated to enhance the visual appeal of the interface. To log in, users can use either their email or user ID along with a password, while registration requires providing a name, email, username, and password.

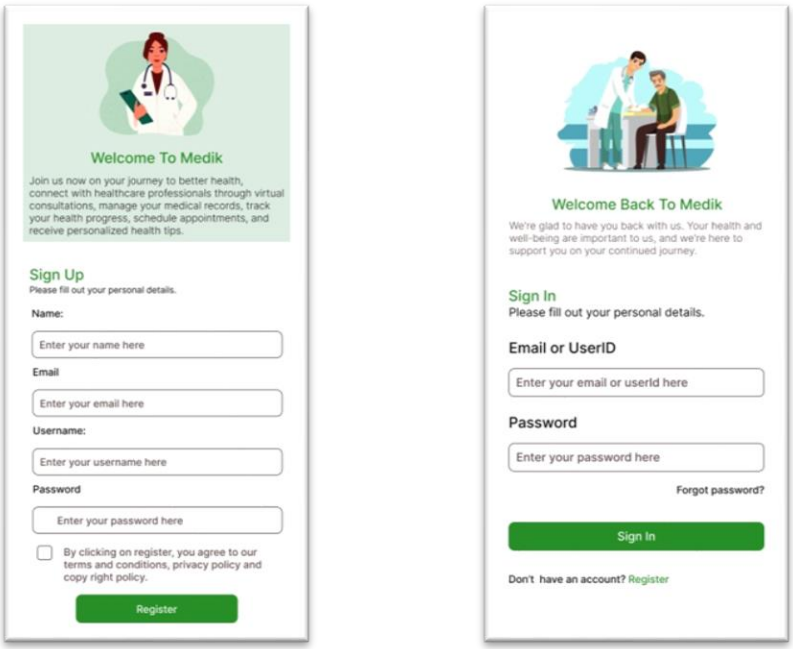

Fig 11: Mobile View of Registration and Login page

MEDIK consists of five pages: Home, Consult, Records, Facilities, and Assistant.

1. **<u>Home Page</u>**: Serving as the landing page, it provides users with notifications, upcoming consultations, reminders, articles, popular doctors, and a summary of past consultations.
2. **<u>Consult page</u>**: On this page, users can access information about their upcoming consultations and view their consultation history. They also have the option to book either a doctor or utilize the consult AI system. If they choose a doctor, they can select between an in-person or online consultation. Users are then presented with a list of available doctors, along with the option to choose the date, time, and audio or video format for the consultation.
   In order to consult, a complete registration process is required. This involves providing personal information such as your first name, biometric data, date of birth, and records, among other details.

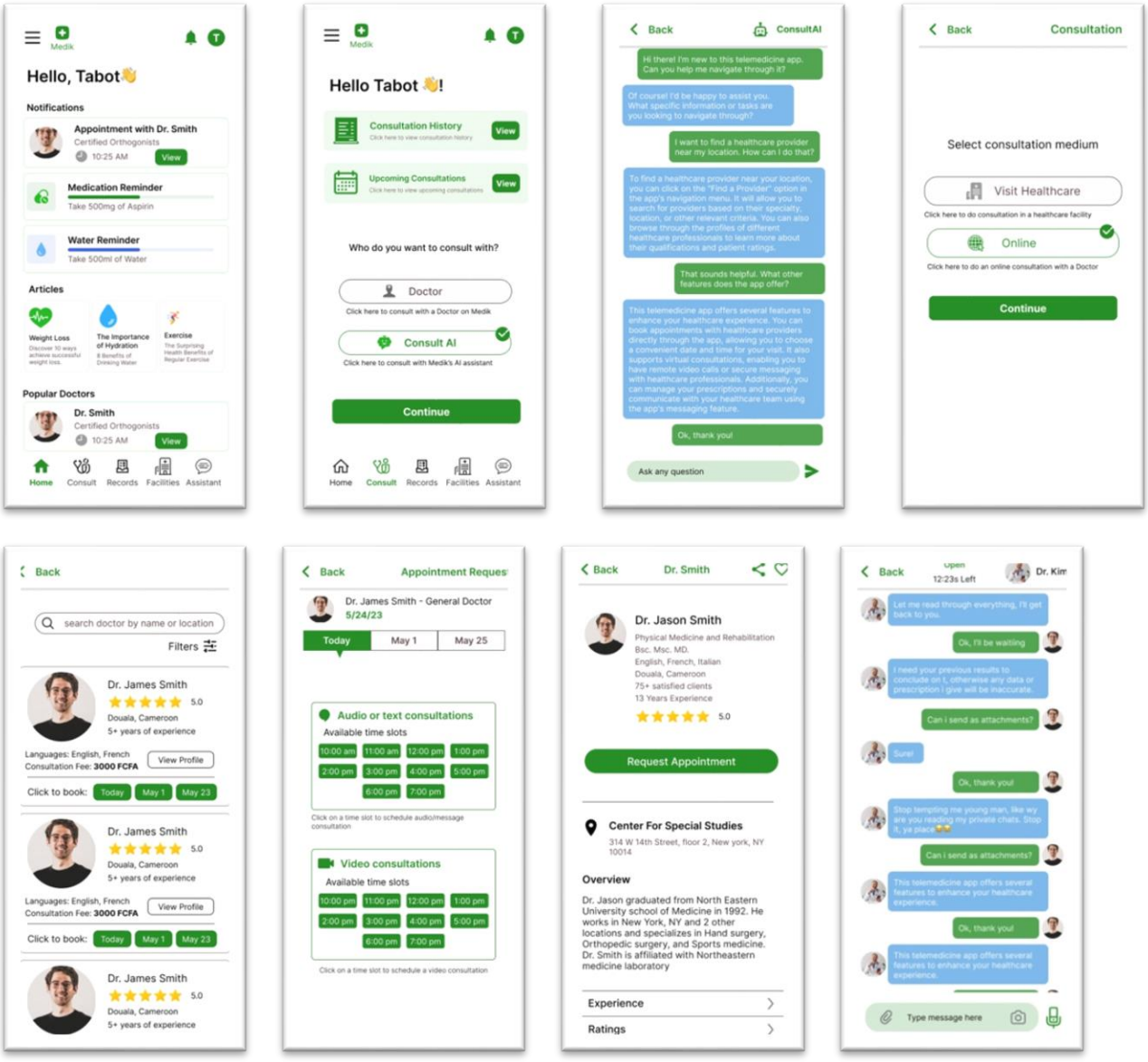

Fig 12: Mobile View of Home page, some consult pages and consultation with Expert system or Doctor.

3. **<u>Records Page</u>**: This section allows users to access their medical information. To ensure data security and privacy, users must enter their password and provide biometric authentication. The records are categorized into three tabs:

- **Personal Info**: Contains details such as height, weight, allergies, and other personal information.
- **Files**: Provides access to various medical files such as test results, prescriptions, and reports. Users can search for specific files by name, like prescriptions or test results.
- **Treatment**: Includes notes and information related to treatments, including medication details.

4. **Facilities Page**: This page displays a list of facilities, including pharmacies, hospitals, and clinics. These facilities are either partnered with the app or recommended by the app. Users can filter or search for facilities based on location, proximity, rating, and other criteria.
5. **Assistant Page**: The AI assistant is available to assist users with any inquiries they may have about the app's features, navigation, and customer support. It serves as a helpful resource for users who may need guidance or have questions while using the app.

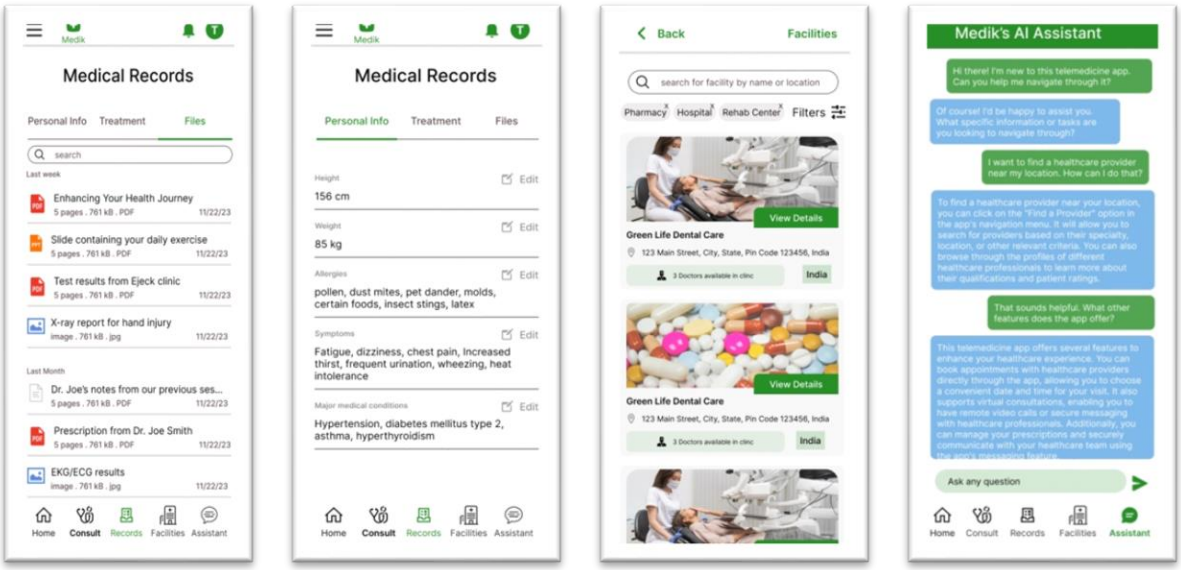

Fig 13: Mobile View of Records page, facilities page and sample chat with AI assistant.

3. DATABASE DESIGN

The design phase involves producing a conceptual and a logical model which will define detailly the database structure.

- **Conceptual Model:**

This phase of the design focused on high-level structure of data, entities and their relationship in the telemedicine application. An ER model was produced to illustrate this as shown by the figure below

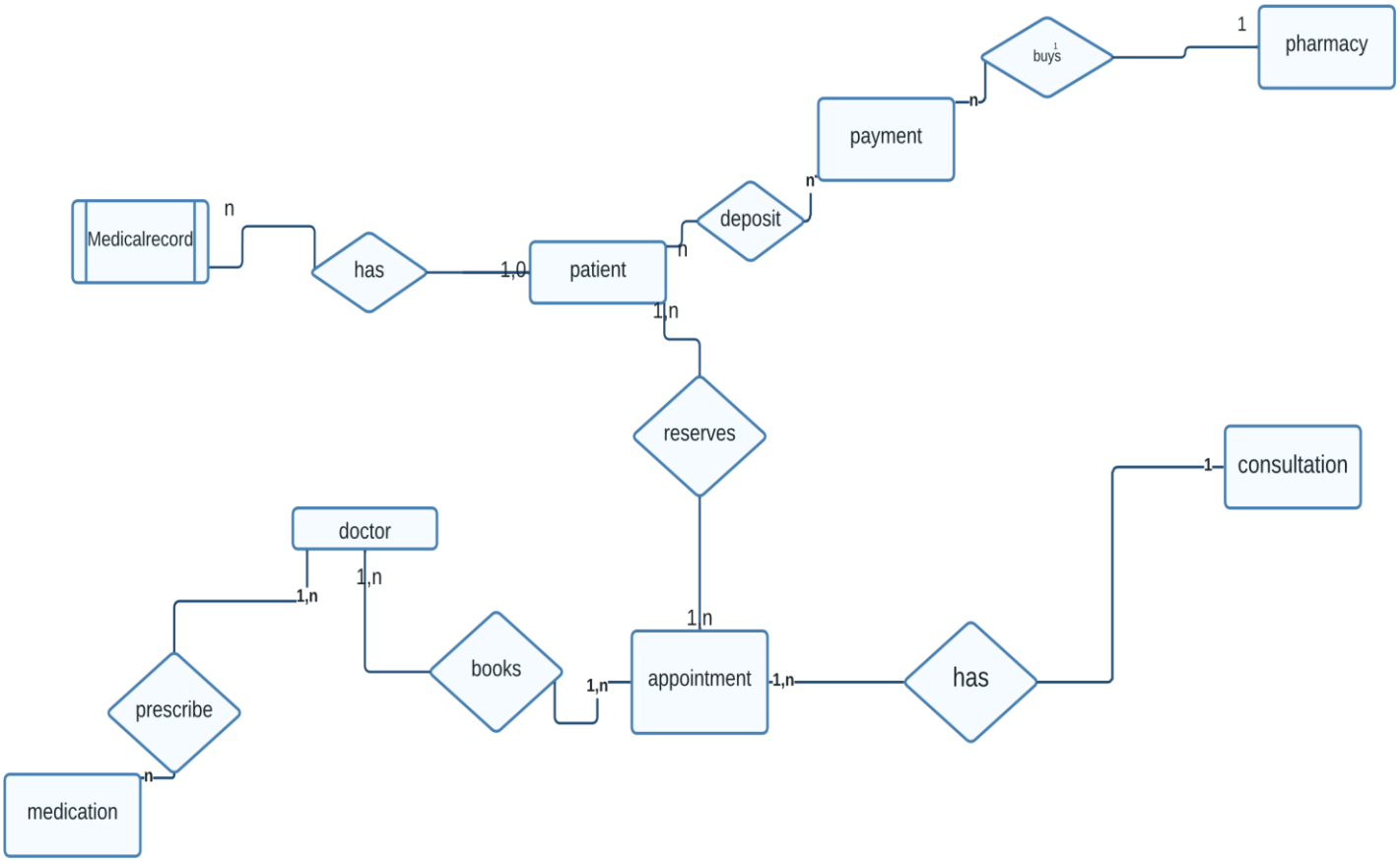

Figure 17: ER model for database

Entities:

- **Patient:** Represents individuals receiving medical care.

- **Doctor**: Represents medical professionals providing care.

- **Pharmacy**: Represents the entity where medications are dispensed.

- **Medication**: Represents the drugs prescribed to patients.

- **Appointment**: Represents scheduled consultations between patients and doctors.

- **Medical Record**: Represents the documentation of a patient's medical history and treatments.

Relationships:

- **Patient has Medical Record**: Indicates that each patient possesses a medical record.

- **Patient reserves Appointment**: Shows that patients can schedule appointments.

- **Patient buys Medication**: Reflects the transaction where patients purchase prescribed medication.

- **Doctor prescribes Medication**: Indicates that doctors are responsible for prescribing medication to patients.

- **Doctor books Appointment**: Shows that doctors can schedule appointments with patients.

- **Pharmacy has Medication**: Indicates that pharmacies stock various medications.

- **Appointment has Consultation**: Represents the actual consultation event within an appointment.

ER Model Components:

- **Entities**: Represented by rectangles, they are objects that exist independently and have a unique identity.

- **Relationships**: Represented by lines, they describe how entities are related to one another.

- **Attributes**: Not explicitly shown in your description, but typically represented by ovals, they are properties or characteristics of entities.

- **Logical Model:**
  This phase of the design focused on deep-level structure of data, database tables and their relationship in the telemedicine application. This is what to be implemented by the developers. It is illustrated using the Relational Schema as shown below

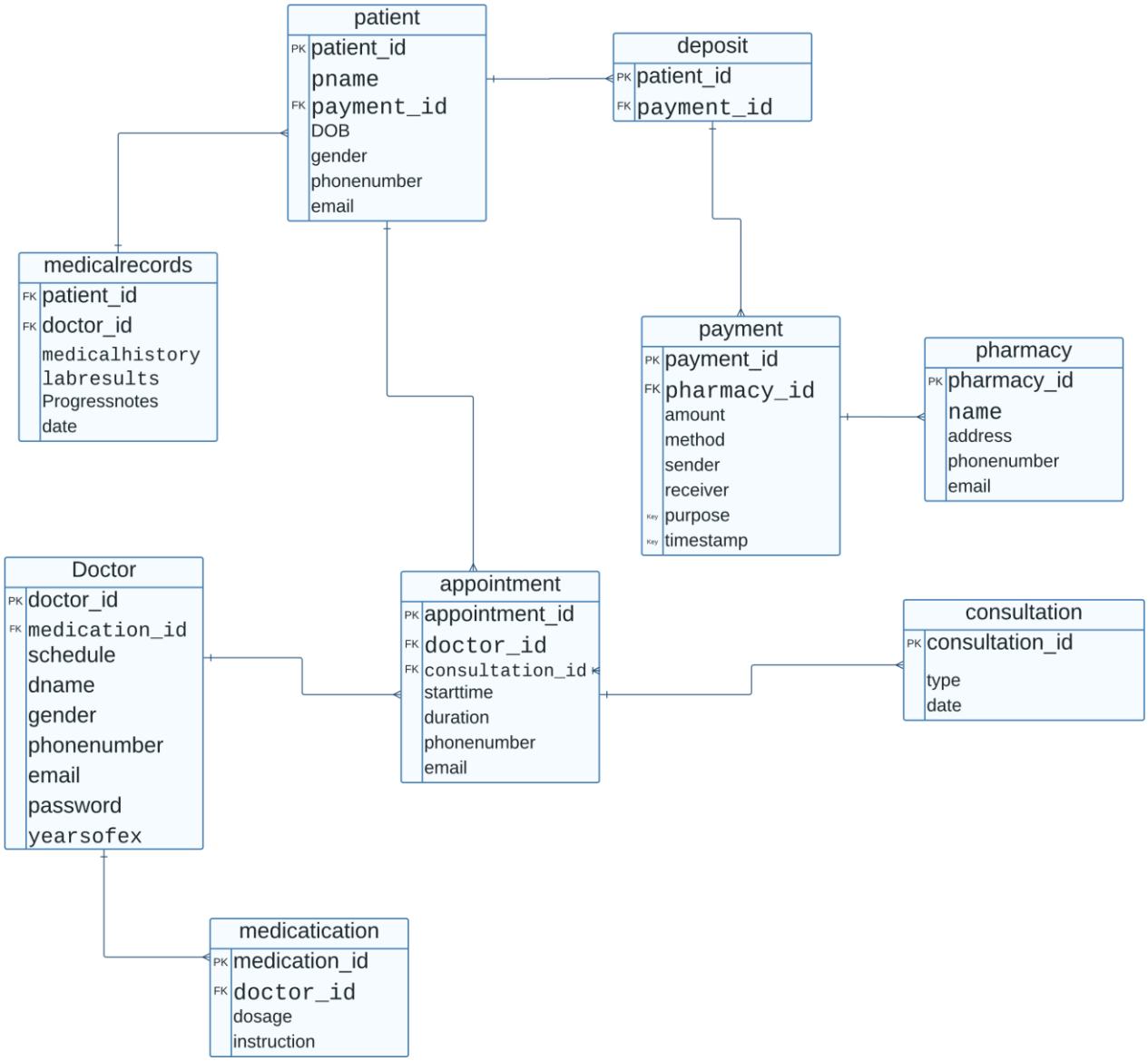

Figure 18: Logical Model for database

V. Software Quality Model for MEDIK Telemedicine App

The purpose of this software quality model is to define the quality attributes and requirements for the MEDIK telemedicine app. This model will be used to guide the development and testing of the app to ensure that it meets the needs of its users and stake holders. AdEQUATE and ISO/IEC 25010 where the models chosen for the quality development of our app.

The AdEQUATE Software Quality Evaluation Model is a quality in use model that focuses on assessing the quality of software from the user's perspective. It was developed in the 1990s and has been used to evaluate a wide range of software applications, including telemedicine apps. The model is based on the following four dimensions:

Adequacy: The software should meet the user's needs and expectations.

Usability: The software should be easy to learn, use, and understand.

Performance: The software should be responsive and efficient.

Reliability: The software should be free from defects and should be able to handle unexpected situations.

The AdEQUATE Model is a useful tool for evaluating the usability of telemedicine apps. It can help to identify areas where the app is difficult to use and can provide suggestions for improvement. The model is also relatively easy to apply, making it a good choice for organizations that are new to software quality assessment.

ISO/IEC 25010 Quality Models

The ISO/IEC 25010 Quality Models are a family of quality models that provide a comprehensive framework for assessing the quality of software systems. The models were developed by the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). The models are based on the following eight characteristics:

Functionality: The software should fulfill its specified requirements.

Reliability: The software should be free from defects and should be able to handle unexpected situations.

Usability: The software should be easy to learn, use, and understand.

Efficiency: The software should make optimal use of system resources.

Maintainability: The software should be easy to modify and maintain.

Portability: The software should be easy to transfer from one hardware or software environment to another.

Security: The software should protect user data from unauthorized access, use, disclosure, disruption, modification, or destruction.

Testability: The software should be designed in a way that makes it easy to test.

The ISO/IEC 25010 Quality Models are a valuable tool for assessing the overall quality of telemedicine apps. They can help to identify areas where the app is not meeting its requirements and can provide suggestions for improvement. The models are also a good choice for organizations that are looking to implement a quality management system for their software development process.

Comparison of the Two Models

The AdEQUATE Model and the ISO/IEC 25010 Quality Models are both useful tools for assessing the quality of telemedicine apps. However, they have different strengths and weaknesses. The AdEQUATE Model is particularly useful for evaluating usability, while the ISO/IEC 25010 Quality Models provide a more comprehensive framework for assessing software quality.

VI. SOFTWARE TESTING

Software testing is the process of checking the quality, functionality, and performance of a software product before launching. To do software testing, testers either interact with the software manually or execute test scripts to find bugs and errors, ensuring that the software works as expected. Software testing is also done to see if business logic is fulfilled, or if there are any missing gaps in requirements that need immediate tackles. Testing is categorized into two as seen below:

1.SYSTEM TESTING

This is a type of black-box testing that verifies the functionality, performance, usability, and security of a fully integrated system. It is performed after integration testing and before acceptance testing.

PURPOSE:

- **Security:** Make sure that the system is secure and that patient data is protected from unauthorised access.
- **Performance:** Make sure that the system can handle a large number of concurrent users and perform well under different network conditions.
- **Usability:** Make sure that the system is easy to use for both patients and doctors.
- **Accessibility:** Make sure that the system is accessible to users with disabilities. **Testing Scope and Strategy for the Telemedicine System Design**

  The testing scope for the telemedicine system design should include all of the system's features and functionality, as defined in the use case diagram. This includes:

- 1.**Authentication**: Users should be able to log in to the system with valid credentials and be unable to log in with invalid credentials.
- 2.**Appointment Booking:** Patients should be able to book appointments with doctors on the system, and doctors should be able to view and manage their upcoming appointments.
- 3.**Consultation:** Patients and doctors should be able to initiate and participate in video consultations through the system.
- 4.**Prescription:** Doctors should be able to send prescriptions to patients through the system, and patients should be able to view and download their prescriptions.
- 5.**Payment:** Patients should be able to pay for their consultations and prescriptions through the system.

  In addition to the above features, the testing scope should also include the following:

- **System Performance:** The system should be able to handle a large number of concurrent users and perform well under different network conditions.
- **System Security:** The system should be protected from unauthorized access and patient data should be encrypted and stored securely.

The testing strategy for the telemedicine system design should be based on a risk-based approach. This means that the most critical features and functionality should be tested more thoroughly.

Steps to Create a Test Environment for the Telemedicine System Design

1. Set up the necessary hardware and software. This includes servers, workstations, and network infrastructure.
2. Install and configure the telemedicine system under test.
3. Install and configure any necessary testing tools.
4. Create test data that represents real-world usage.
5. Configure the test environment to match the production environment as closely as possible

Test Cases and Scenarios

The following are some example test cases and scenarios for the telemedicine system design:

1.Authentication:

- Test Case: Verify that a user can successfully log in to the system with valid credentials.
- Test Scenario: A patient attempts to log in to the system using their valid username and password.

2.Appointment Booking:

Test Case: Verify that a patient can book an appointment with a doctor on the system.

- Test Case: Verify that a patient can reschedule an appointment.
- Test Case: Verify that a patient can cancel an appointment.
- Test Case: Verify that a doctor can view and manage their upcoming appointments.
- Test Scenario: A patient navigates to the appointment booking page, selects a doctor and time, and enters their contact information. They then click the "Book Appointment" button. The system should confirm that the appointment has been booked.

3.Consultation:

- Test Case: Verify that a patient and doctor can successfully initiate and participate in a video consultation.
- Test Scenario: A patient and doctor both log in to the system and navigate to their video consultation page. They then click the "Start Consultation" button. The system should initiate a video call between the patient and doctor.

4.Prescription:

- Test Case: Verify that a doctor can send a prescription to a patient through the system.
- Test Scenario: A doctor completes a patient's consultation and then clicks the "Send Prescription" button. The system should generate a prescription for the patient and send it to their email address.

5.Payment:

- Test Case: Verify that a patient can successfully pay for their consultation and prescription through the system.
- Test Scenario: A patient completes a consultation and then clicks the "Pay Now" button. The system should direct the patient to a payment processing page. The patient then enters their payment information and completes the payment. The system should confirm that the payment has been processed successfully.

For each test case or scenario:

- Review the test case or scenario and ensure that you understand the steps involved.
- Prepare the test data and configure the test environment.
- Execute the test steps and document the results.
- Compare the actual results to the expected results and identify any discrepancies.
- Report any discrepancies to the development team

Recommendations for Refining the System Design based on our review

2.UI TESTING

UI testing for a telemedicine app involves verifying the user interface elements and interactions to ensure that the app functions correctly and provides a seamless user experience. Here are some steps you can follow to perform UI testing for a telemedicine app:

i. **Understanding the requirements:** Review the requirements and specifications of the telemedicine app to gain a clear understanding of the expected behaviour and functionality.

ii. **Identify test scenarios:** Identify the key user interactions and workflows within the app. This may include tasks such as scheduling appointments, joining video consultations, accessing medical records, and sending messages to healthcare providers. Create test scenarios based on these interactions.

iii. **Prepare test data:** Set up test data that reflects different scenarios. For example, create test patient accounts with varying demographic information, medical conditions, and appointments.

iv. **Test navigation and layout:** Verify that the app's navigation flows smoothly and intuitively. Check that buttons, menus, and links are placed correctly and function as expected. Ensuring that the layout is responsive and adjusts appropriately across different screen sizes and orientations.

v. **Validate forms and input fields:** Test the input fields for patient registration, appointment scheduling, and other data entry points. Verify that input validation rules are enforced correctly, error messages are displayed when necessary, and data is saved accurately.

vi. **Check visual consistency:** Ensure that the app's design is consistent throughout, including font styles, colors, and spacing. Test the app on different devices and screen resolutions to verify that the UI elements are displayed correctly.

vii. **Test interactions and workflows:** Validate the app's functionality by executing common user workflows. For example, simulate the process of scheduling an appointment, joining a video

consultation, and sending messages to healthcare providers. Verify that each step works as intended and that data is displayed accurately.

viii. **Test error handling:** Intentionally trigger errors or exceptions during the testing process to ensure that the app handles them gracefully. Check that appropriate error messages are displayed, and the user is guided towards resolving the issue or contacting support.

ix. **Perform cross-platform testing:** Test the app on different platforms, such as iOS and Android, to identify and address any platform-specific issues or inconsistencies.

x. **Test with real devices:** Whenever possible, perform testing on real devices to ensure accurate behaviour and performance. Emulatreplicateors and simulators can be useful, but they may not always fully the real-world experience.

3.DATABASE TESTING

Unit Testing:

- Test individual CRUD operations:
  - Create test cases for each MongoDB operation (create, read, update, delete) for each collection.
  - Verify if the operations are successful and return expected results.

- Test data validation:
  - Use libraries like joi to validate data before inserting it into the database.
  - Write unit tests to ensure that invalid data is rejected.

- Test document relationships:
  - Test the relationships between documents using aggregation pipelines.
  - Verify if documents are linked correctly and data is retrieved efficiently.

Integration Testing:

- Test user registration and login:
  - Simulate user registration and login process to ensure proper authentication and authorization.

- Test appointment booking and management:
  - Test the workflow of booking appointments, including checking availability, scheduling conflicts, and cancellation.

- Test medical record creation and access:
  - Test the creation of medical records after appointments, including adding diagnosis, treatment plans, and prescriptions.
  - Verify if authorized users can access and modify medical records.

Performance Testing:

- Load testing:
  - Simulate concurrent user access and transactions to measure database performance under load.
  - Identify bottlenecks and optimize queries or indexes for better performance.

- Stress testing:

o Increase workload beyond normal usage patterns to test the database's scalability and stability.
o Ensure the database can handle high traffic without outages or performance degradation.
Security Testing:

• Test for vulnerabilities:
o Use tools like **MongoSnarf** or penetration testing services to scan for vulnerabilities like injection attacks or unauthorized access.
o Implement proper access control rules and data encryption to mitigate risks.

• Test user roles and permissions:
o Verify that users have access only to authorized data and functionalities based on their roles.
o Test for potential privilege escalation vulnerabilities.

Data Quality Testing:
• Test data consistency:
o Ensure data integrity by checking for missing values, duplicate entries, or inconsistencies between different collections.
o Implement data validation rules and cleaning scripts to maintain data quality.

• Test data backups and recovery:
o Regularly backup the database to ensure data can be restored in case of failures.
o Test the restore process to ensure it functions correctly and recovers data accurately.

Automation:
• Utilize testing frameworks like Jest or Mocha to automate unit and integration tests.
• Use performance testing tools like JMeter or Gatling for automated load and stress testing.
• Automate data validation and data quality checks using scripts or tools.

VII. BENEFITS OF MEDIK TO THE CAMEROONIAN SOCIETY

MEDIK will offer a number of benefits including:

- Increased access to healthcare: MEDIK will provide patients with access to healthcare services that they might not otherwise have. This is especially beneficial for patients in rural or underserved areas.
- Convenience: MEDIK will allow patients to see their doctor from the comfort of their own home. This can save patients time and money.
- Affordability: MEDIK will be more affordable than traditional in-person care.
- Improved quality of care: MEDIK will improve the quality of care by providing patients with more timely and convenient access to healthcare services.

VIII. CONCLUSION

In conclusion, MEDIK offers a user-friendly interface that enables patients to conveniently access virtual consultations with licensed healthcare professionals from the comfort of their homes. Through secure video calls and messaging systems, patients can receive medical advice, diagnoses, and even prescriptions, saving time and eliminating the barriers of distance and transportation.

With a strong focus on patient privacy and data security, our app complies with international professional standards such as HIPAA and GDPR. We have implemented robust encryption protocols and stringent access controls to ensure the confidentiality and integrity of patient information, instilling trust and confidence in our users.

presents a comprehensive solution that addresses the evolving needs of healthcare delivery in the digital age. By leveraging the power of technology, we aim to revolutionize the way patients and healthcare providers connect and interact, ultimately enhancing access to quality healthcare services.

Furthermore, MEDIK integrates seamlessly with existing healthcare systems through adherence to HL7 standards, enabling efficient sharing and exchange of electronic health information. This interoperability enhances care coordination and streamlines the healthcare workflow, leading to improved patient outcomes and operational efficiency.

Our team of experienced healthcare professionals, software developers, and user experience designers are collaborating for the production of MEDIK that prioritizes user satisfaction and clinical effectiveness. We have incorporated evidence-based guidelines from reputable organizations like the ATA and WHO to ensure that our app adheres to the highest industry standards.

In summary, MEDIK offers a transformative solution that empowers patients and healthcare providers alike. By embracing technology and adhering to international professional standards, we are redefining healthcare delivery, making it more accessible, efficient, and patient-centric. Join us on this journey as we shape the future of healthcare through our innovative telemedicine app.

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