AI AND IOT POWERED HEALTHCARE SYSTEMS IN SMART CITIES OF THE FUTURE

1. What are the current trends and challenges within the healthcare systems (you can choose one or more)?

The current problems, trends and challenges of the existing healthcare system in general are as follows, which are also very well brought out on Siemens Healthineers ITT website.

Problem Statement: Almost half of the world population is lacking access to the required healthcare services

- **Trending Solution**: **Digital Health and Telemedicine** - The adoption of digital health solutions and telemedicine has seen a significant surge, especially during the COVID-19 pandemic. Virtual consultations, remote patient monitoring, and telehealth platforms have become essential components of healthcare delivery.
- **Challenge**: While telemedicine offers convenience and accessibility, there are challenges related to ensuring equitable access, data privacy, and maintaining the human touch in patient-doctor interactions.

Problem Statement: Delay in getting Healthcare and Shortage of staff

- **Trending Solution:** This is one of the most important issue and being resolved with the following multiple modular approaches Using AI, ML and IoT-
    - **Virtual Health Assistants:** AI-powered virtual health assistants will interact with patients, answer their medical queries, provide personalized health recommendations, and direct them to appropriate healthcare services.
    - **Predictive Analytics for Patient Care:** AI-driven predictive analytics will assess patient data to anticipate disease progression, patient outcomes, and potential healthcare needs. This will enable early interventions and personalized treatment plans.
    - **Smart Hospital Beds and Monitoring Systems:** IoT-enabled hospital beds will track patient movement, posture, and pressure points to prevent bedsores and enhance patient comfort. Monitoring systems will also alert nurses when assistance is required.
    - **Automated Medication Management:** Smart medication dispensing systems will accurately administer and track medications for patients, reducing the risk of medication errors and ensuring timely doses.
- **Challenge**: Integrating AI into healthcare systems requires robust data governance, ensuring the quality and privacy of patient data. Additionally, building and validating AI models for healthcare applications require extensive data and expertise. Also attracting and retaining

IT skilled healthcare workers, especially in rural and underserved areas, is a critical challenge for healthcare systems.

Problem Statement: To Improve Accuracy and Efficiency of overall Healthcare System

- **Trending Solutions**: The following are the trending solutions using AI/ML, IoT and Robotics
  - **Health Data Interoperability:** The necessary push for health data interoperability aims to enable seamless exchange of patient information between different healthcare providers and systems. Standards like FHIR (Fast Healthcare Interoperability Resources) are gaining traction to facilitate data exchange.
  - **IoT-Enabled Medical Devices:** Smart medical devices equipped with IoT capabilities will continuously monitor patients' vital signs, such as heart rate, blood pressure, and temperature. These devices will transmit real-time data to electronic health records (EHRs) and alert healthcare providers in case of any abnormalities.
  - **AI-Powered Diagnostic Tools**: AI models will be embedded in medical imaging equipment, pathology scanners, and laboratory analyzers to assist in diagnosing diseases and identifying anomalies with enhanced accuracy and efficiency.
  - **Robot-Assisted Surgery Systems:** Advanced surgical robots equipped with AI capabilities will support surgeons during complex procedures, providing precise movements and enhancing surgical outcomes.
- **Challenge:** Achieving widespread health data interoperability is complex due to varying data formats, privacy concerns, and the need for coordination among different stakeholders. The availability of 5G network speed is one of the limiting factors for connecting IoT devices. Preprocessing of dataset for accuracy of decision is vital for Machine Learning of Bots.

Problem Statement: Increasing cost of Healthcare

- **Trending Solution:** Value-Based Care and Population Health Management: There is a shift towards value-based care models that focus on improving patient outcomes through more patient-centered healthcare approach, rather than just providing services. Population health management aims to proactively address health issues in a group of patients and reducing cost.
- **Challenge:** Controlling healthcare costs while maintaining quality care requires innovative cost-saving strategies, efficiency improvements, and evidence-based decision-making. Transitioning to value-based care requires aligning financial incentives, measuring outcomes accurately, and coordinating care across different providers.

Problem Statement: Healthcare Inequities and Access Disparities

- **Trending Solution:** Seamless and Good Quality Healthcare to one and all: The disparities based on factors such as race, socioeconomic status, and geographical location continue to be a concern, which is being addressed through Medical Policies at international level for humanity with well defined protocol

- **Challenge:** Addressing health inequities requires targeted interventions, community engagement, and policy changes to improve access to healthcare services for vulnerable populations.

Problem Statement: Cybersecurity and Data Privacy

- **Trending solution:** As healthcare systems become more digitized, the threat of cyberattacks on patient data increases. Cybersecurity measures are crucial and are being implemented to protect sensitive health information. Blockchain technology is being used to enhance the security and privacy of health records, ensuring secure and tamper-proof data sharing between healthcare providers and patients.
- **Challenge:** Healthcare organizations need to invest in robust cybersecurity measures, train staff on data security practices, and stay ahead of evolving cyber threats.

Problem Statement: Pandemic Preparedness and Quick Response

- **Trending Solution:** The COVID-19 pandemic highlighted the importance of preparedness and response capabilities in healthcare systems. The importance of formation and ensure readiness through regular and automated monitoring, servicing and audits of Rapid Action Force equipped with necessary medical facilities is being implemented to ensure 24x7 readiness.
- **Challenge:** Ensuring readiness for future pandemics or public health emergencies involves improved testing, vaccine distribution, supply chain management, and healthcare infrastructure.

2. Propose what an ideal healthcare system could look like.

With an evolving concept of smart city, the healthcare system should also get upgraded to become smart by adapting emerging concept of Internet of Medical Things (IoMT) driven by efficient AI/ML technologies connected through 5G communication networks as brought out in Fig-1.
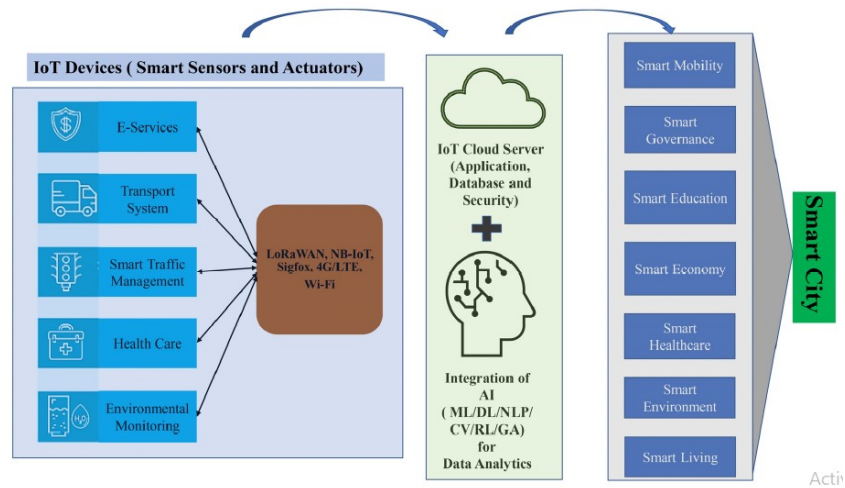
Fig-1: Healthcare and other main component of smart city and Methodology of integration

In the future healthcare centers the medical advice, specialist consultation, pathological/radiographic test/reporting, dispensary, surgical procedures, patient care, and hospital administration are becoming fully automated using intelligent machines/robots working with more accuracy. Hence, **the future Healthcare system will look the following Fig-2**.
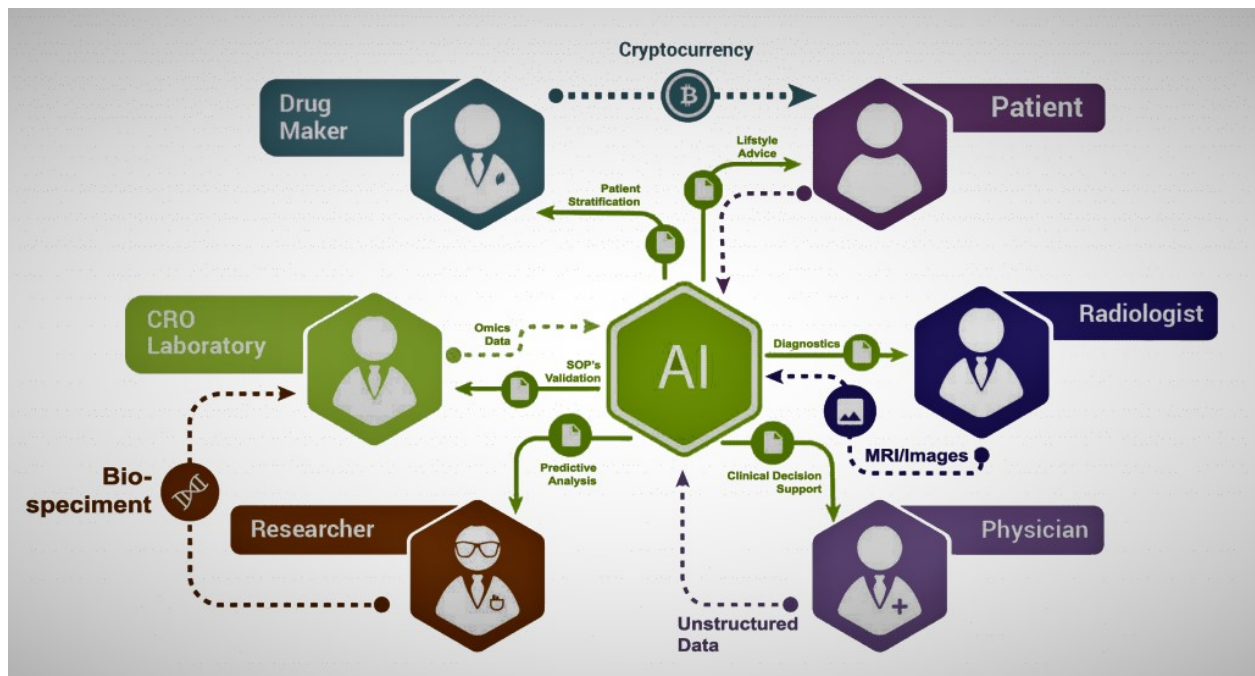

Fig-2: Future Healthcare System

3. What should it consist of? (e.*g., a collection of best practices…)*

The Smart Healthcare encompasses certain key technologies driving digital health as shown in Fig-3 along with a range of innovative technologies and solutions that aim to improve access to healthcare services, enhance patient outcomes, and increase the efficiency of healthcare delivery.

Fig-2: Key Technologies driving Digital Health

These technologies include the Internet of Things (IoT), Artificial Intelligence (AI), machine learning, wearables, and telemedicine. Hence, the proposed **future Smart healthcare system as shown in Fig-2** will enable patients to receive personalized and real-time care, regardless of location. Patients can access healthcare services remotely through telemedicine and wearable devices, enabling healthcare professionals to monitor their health conditions continuously. Smart healthcare also facilitates collecting and analyzing large amounts of patient data, providing valuable insights into patient health trends and treatment efficacy. Moreover, smart healthcare in a smart city also include using AI-powered chatbots and virtual assistants that can interact with patients, provide medical advice, schedule appointments, reducing the burden on healthcare professionals and improving the efficiency of healthcare services. The Smart healthcare offers immense potential to revolutionize healthcare delivery in a smart city, from improving patient outcomes to reducing healthcare costs and increasing access to healthcare services.

As brought out above most of the trending solutions to improve healthcare are based on AI/Ml, IoT, 5G communication and Robotics technologies contributing in different field of Smart Healthcare as shown in the following **Fig-3**.
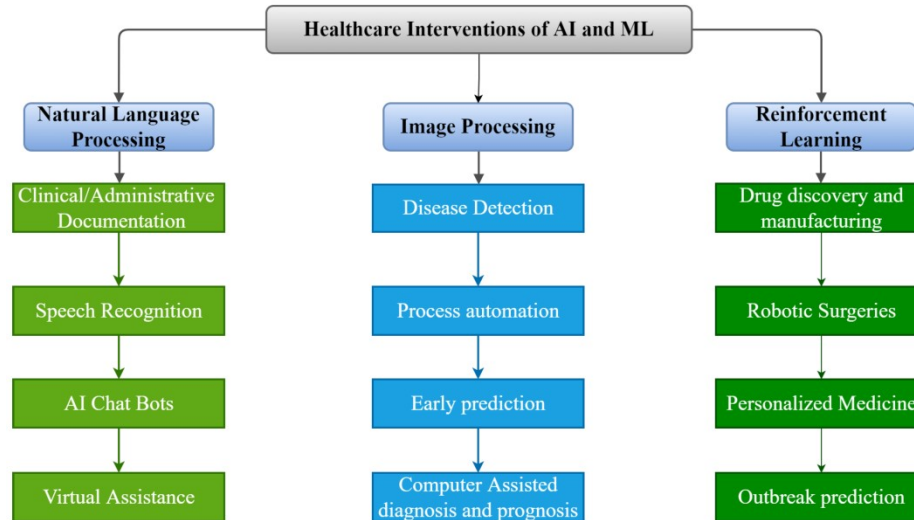
Fig-2: Application of AI and ML in Smart Healthcare System

Further, Internet of Medical Things (IoMT) and point-of-care (POC) devices will further improve healthcare in advanced areas such as cardiac measurement, cancer diagnosis, and diabetes management. AI is playing a pivotal role in improving the functionality, detection accuracy, and decision-making capabilities of IoMT devices while identifying potential risks. The frameworks based on AIoMT will monitor and diagnose patients. Integrating AI and IoMT in the healthcare industry will reduced the burden of medical processes and significantly enhanced disease diagnosis, prediction, treatment, screening, and medication. Smart health monitoring systems (SHM) are effective tool for a healthy lifestyle amidst busy work schedules. With smart and cost-effective sensors developed through electronic Industry and 5G communication infrastructure, health monitoring services have become faster, cost-effective, and reliable from remote locations. Also a model based on AI and big data analytics for m-health will accelerate the process of drug discovery and with reduce costs and improved accuracy. The researchers suggest that AI can transform drug discovery by identifying new drug candidates, predicting their efficacy and toxicity, and optimizing the drug development process. Further, with certain NLP techniques to analyze various healthcare domains, such as hospital management, clinical practice, public health, personal care, and drug development. The ML and DL techniques are also very efficient in drug discovery and predicting chronic diseases such as heart disease and kidney-related ailments.

4. How would stakeholders interact and what would the workflows look like?

The medical healthcare can be primarily divided in two categories ie Preventive and Corrective. The Preventive healthcare concept is mostly being followed by the people with higher health consciousness, wellness awareness with affordability. Whereas, the corrective healthcare is a

mandatory requirement of all including for the people taking Preventive care. As per latest trends the advancement is taking place in both the categories and associated stake holders are well connected through the network as shown above **Fig-2** depicting future smart healthcare system.

The work flow and interaction in Smart Healthcare System between the stockholders ie Patient, Doctor, Hospitals, Researchers, administration, Diagnostic Centers, Vendors can be understood with an **example of Cardiac Decease Management System for a Potential Heart Patient**. It starts with wearable IoT device in the form of a watch connected to internet through cell phone, having features of giving visual and audio warning to the individual in case his parameters crossing threshold values as per predefined stages, offer necessary first aid may be Nitrate Vasodilators (Sorbitrate), Warfarin, Asprin or Nitroglycerin, call ambulance/navigate to the nearest cardiac healthcare hospital and transmits prior information with real time vital parameters with medical history to the hospital Emergency Room to be ready to receive the Patient to avoid delay in required treatment. It will also generate an alarm and will start transmitting current state, location with medical history to the specialist. In turn the specialist can get connected to the Emergency Room to obtain real time report and to provide necessary prescription to stabiles the patient and further necessary medical test and admission to the hospital as per requirement. In smart hospital after conducting the necessary pathology /radiology test with smart machines, the necessary test reports will be transmitted by the machine to the intended specialist to prescribe correct course of treatment. Further the necessary surgical procedure will be assisted by AI powered intelligent bots and post operative care will be provided by AI powered attendant ensuring hygiene and timely medicine doses. The real time parameter monitoring will help in calibration of treatment and will ensure early recovery of the Patient. Further, the administrative facilities including billing, transport, environment control and other associated activities are also interlinked through appropriate network for proper management. On the basis of research and analysis of the acquired large data, calibration of medicine/services will be a continual process for further improvement of quality of services.

In the same manner the work flow for management for all critical illness systems may be created and made available as standard version for ready to use by all or customize/selective version as per choice depending on risk level of the individual assessed during preventive medical checkup.

Hence, the interaction and work flow between various stakeholders, including patients, healthcare providers, administrators, and technology vendors, in standard future smart healthcare system, would be through a seamless and interconnected ecosystem. The workflows would be designed to facilitate efficient communication, data exchange, and collaboration among the stakeholders. Here's how the interactions and workflows might look like:

Patient Interaction and Engagement:

- Patients would interact with the healthcare system through user-friendly mobile apps, web portals, or smart health devices.

- They can schedule appointments, access medical records, receive personalized health recommendations, and communicate with healthcare providers through secure messaging.

- Remote patient monitoring devices would continuously track health data and transmit it to the healthcare system, enabling real-time monitoring and proactive interventions.

- Patients can also participate in shared decision-making, providing feedback, and contributing to their care plans.

Healthcare Provider Collaboration:

- Healthcare providers, including doctors, nurses, specialists, and pharmacists, would have access to integrated electronic health records (EHRs).

- They can communicate with each other and share patient data securely through the health information exchange (HIE) platform.

- AI-powered decision support tools would assist healthcare providers in diagnosing and creating personalized treatment plans.

- Telemedicine platforms would enable virtual consultations and collaboration with remote specialists.

Data Analytics and Insights:

- Data analysts and healthcare administrators would use advanced data analytics tools to derive insights from large-scale health data.

- Population health management workflows would identify high-risk patient groups and implement targeted interventions.

- Predictive analytics would forecast healthcare resource needs and support evidence-based decision-making.

IoT Device Integration:

- IoT-enabled medical devices and wearables would seamlessly integrate with the healthcare system, transmitting real-time patient data to EHRs.

- Hospital beds, monitoring systems, and equipment would be connected through the Internet of Medical Things (IoMT), allowing for efficient resource management and workflow optimization.

Smart Hospital Management:

- Hospital administrators and operations managers would have access to smart dashboards that provide real-time information on patient flow, resource utilization, and staff allocation.

- Automated workflows would optimize bed management, patient transfers, and equipment maintenance.

- Smart tracking systems would enable real-time location services (RTLS) to monitor the movement of patients, staff, and assets within the hospital.

Vendor Integration and Maintenance:

- Technology vendors would provide support for software updates, security patches, and maintenance of smart healthcare systems.

- Vendor integration workflows would ensure seamless interoperability between different software and hardware components.

Patient Education and Support:

- AI-powered virtual health assistants and chatbots would deliver personalized health education and support, answering patient queries and providing self-care guidance.

- Patients can access educational resources and participate in virtual support groups through the healthcare system's patient engagement platform.

Healthcare Policy and Regulation:

- Health authorities and policymakers would use data from the smart healthcare system to inform public health policies, preventive measures, and healthcare regulations.

Overall, the workflows in a future smart healthcare system would emphasize collaboration, data-driven decision-making and patient-centered care. The integration of advanced technologies and seamless communication among stakeholders ensuring privacy and security would lead to more efficient, personalized and proactive healthcare services.

Smart Healthcare Systems powered by Artificial Intelligence and IoMT