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Technology for Predictive Health Monitoring of Elderly and Vulnerable Citizens in Kenya using Healthcare 4.0: A Theoretical Review

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Abstract— *The traditional critical healthcare planning is based on periodic routine checks and a reactive strategy of interventions whenever the individuals have entered high risk states (such as heart attacks or strokes). The Healthcare 4.0 design is based on the principle of continuous predictive health monitoring such that the buildup process towards high risk states of individuals can be identified much before their critical levels thus ensuring proactive interventions by the hospitals. Kenya has significant potential to adopt Healthcare 4.0 technology using traditional information and networking components. This research investigates how Healthcare 4.0 can be used in predictive health monitoring of the elderly and vulnerable citizens that individual hospitals can adopt for operational excellence. Desktop review methodology was used. The technical literature review was used to define an operations algorithm. The results suggest that several customizations are needed in the traditional information and networking components to make them fit for predictive health monitoring. The individuals under critical monitoring should not be allowed high mobility as it has a negative effect on monitoring reliability and effectiveness. Healthcare 4.0 adoption in Kenya is feasible. Its operational details need to be defined with several tiers of customized solutions for different patient classes. There are some limitations found in this research, which should be kept in mind while designing and operating Healthcare 4.0 networks in Kenya.*

Keywords— *Healthcare 4.0, Healthcare Internet of Things, Smart Healthcare, predictive health monitoring*

I. INTRODUCTION

The Kenya's new constitution in 2010 has the aim to institutionalize mechanisms for equal opportunities and human growth in the esteemed nation [1]. Institutional systems and governance frameworks with a carefully design system of centralization and decentralization of power structures have been established to make Kenya an established economy with persistent growth path. The vision 2030 of Kenya is to achieve an industrialized middle income economy status promising prosperity and global competitiveness, high wellbeing standards for the people, and ensuring security and peace. The three pillars of Kenya are: political, social, and economical.

One of the significant future plans in the vision 2030 of Kenya is Universal Health Coverage (UHC) [2]. UHC is a vision to provide universal healthcare services to all Kenyan nationals under the direct stewardship of the government. This requires systematic and technological improvements to be committed and achieved by the organizations in the healthcare sector covering a wide range of supplies and services. UHC shall ensure a

significant boost to the productivity of the people of Kenya, which is expected to bring positive results for meeting the 2030 economic goals of the country. The UHC policy of Kenya has been designed keeping in mind people centric approaches, social integration, contributions required from multiple sectors, and equity. The functional responsibilities shall be divided between national and county level governments. Success of UHC in Kenya requires integrated development of social infrastructure, energy, electricity, transportation, education, skill-building, and advancements in information and communication technology (ICT). Integrated multi-sector services and adoption of technological advancements are new developments planned in the 2030 vision for achieving UHC in Kenya.

COVID 19 caused a global healthcare crisis, which affected Kenya significantly. The flaws and limitations of the existing healthcare capabilities of Kenya were manifested amidst extreme pressures during the pandemic ([3], [4]). Kenya requires effective multi-sector integration of assets, systems, and information to respond to future healthcare crises by increasing collective capacities and capabilities. The goals in Kenya are to provide curative, preventive, rehabilitative, palliative, and promotive health services under UHC coverage to every county. Converging with global advancements and solutions, Kenya needs to adopt latest predictive technologies evolving in the Healthcare sector to meet the goals.

In this research, the emerging Healthcare 4.0 technologies for predictive healthcare through proactive monitoring of patients have been studied. Simply stated, predictive healthcare involves collection and monitoring of relevant data related to patients such that they can be treated timely using appropriate treatment methods before the health anomalies grow in their bodies ([5], [6], [7]). This strategy can reduce pressures on hospitals, ensure better efficiency of healthcare services, reduce healthcare costs, and enable better well being to the patients being monitored. It has a significant value for extending UHC to the elderly and vulnerable citizens of Kenya by monitoring and treating them remotely. The experts can be better advised on the predictive health status of the elderly and vulnerable citizens using explainable artificial intelligence algorithms running automated learning-based scenario tests on the data collected from the citizens monitored [8]. Edge computing and cloud computing based data consolidation of the monitored cases can help in widening the scope of monitoring of elderly and vulnerable citizens based on patterns analysis instead of the current practice of case-by-case analysis [9].

The data collection can be done using body wearable sensors powered by Healthcare Internet of Things (HIoT) [10]. The sensors can be designed to collect time series data about critical health parameters, similar to the continuous monitoring systems used in an intensive care unit (ICU). The data can be consolidated for continuous monitoring and analysis such that interventions or hospital admissions can be initiated through collaborated healthcare processes and teamwork when the data suggests the needs ([11], [12]). These new technology enhancements are viewed as the new revolution in healthcare called the Healthcare 4.0 [5]. Given the value it proposes for remote and predictive healthcare, it can be of value to provide effective and low cost services to the elderly and vulnerable citizens. This research investigates the technical design of Healthcare 4.0 for remote and predictive health monitoring of the citizens of elderly and vulnerable citizens in Kenya.

II. Aim

To investigate the Healthcare 4.0 technology and its implementation for predictive health monitoring of elderly and vulnerable citizens in Kenya.

III. OBJECTIVES

This research was conducted to:

- 1) Study Healthcare 4.0 technologies for predictive healthcare.
- 2) Analyze predictive healthcare implementation in Healthcare 4.0 technologies.

The research questions investigated are the following:

- 1) What are the predictive healthcare requirements for elderly and vulnerable citizens in Kenya?
- 2) What are the Healthcare 4.0 technologies and how predictive healthcare can be implemented using them?

The highlights of the research are the following:

- 1) A comprehensive analysis of requirements of predictive health monitoring of elderly and vulnerability citizens.
- 2) A comprehensive review of predictive health monitoring and Healthcare 4.0 technologies.
- 3) Recommendations on design, operational details, and limitations of predictive health monitoring of elderly and vulnerable citizens in the nation of Kenya.

IV. LITERATURE REVIEW ON CURRENT REQUIREMENTS AND OPPORTUNITIES RELATED TO PREDICTIVE HEALTH MONITORING AND THE HEALTHCARE 4.0 ADOPTION IN KENYA

The Kenyan healthcare sector is running four major programs and several sub-programs. Among the major programs, several technological and practice enhancements are sought in the key sub-programs involving

disease surveillance, epidemic response, radiation safety, nuclear safety, communicable and non-communicable control of disease, health infrastructure and equipment, social protection related to healthcare, and health technologies and product in the Kenyan healthcare sector [4]. Currently, Kenya requires technological enhancements in data collection, integration, and analysis for building transparency, intelligence, knowledge, advisory, reporting, monitoring, and control systems in the healthcare domain. In the context of UHC, Kenyan healthcare policy has a strong commitment to elderly citizens and vulnerable citizens such as children) ([3], [2]). The policy clearly states the keywords: no one left behind, reducing or eliminating financial hardship (especially the out of pocket expenses), and multi-disciplinary networks for healthcare services delivery. This policy implies that Kenyan government is working towards major healthcare reforms, systemic changes, and adoption of new capabilities. The ultimate vision is to ensure primary healthcare services delivery through primary care networking (PCN) comprising of networked points of care (POC) managed by sub-county teams for health management.

To operate the PCN in cost effective and efficient ways, one of the options is predictive health monitoring. It is not yet recognized in Kenyan healthcare sector, but can be pursued under the quest for technological advancements as identified as a broad goal by the Kenya Health Sector Working Group (KHSWG). This strategy can be very helpful for elderly and vulnerable citizens as continuous monitoring can instigate timely diagnosis, timely interventions, and thus timely and cost effective prevention and cure of the health anomalies. The strategy can be implemented using HIoT ([10], [13]). HIoT devices are miniaturized body sensors capable of sensing and recording critical health parameters. For example, a wrist watch and other body attachable sensors can record heart rate, blood pressure, oxygen levels, motion, electrocardiogram, and body temperature on a time series and communicate with a mobile smart phone within its range ([14], [15]). Such data when correlated with environmental forecasting data (such as temperature, rains, humidity, etc.) can reveal chances of emergencies among the patients monitored leading to interventions of varying levels; from a simple follow up to readying for emergency admissions.

The data collected can be transmitted to centralized data consolidation servers hosted in end computing systems of hospital networks popularly known as fog computing ([16], [17], [18], [19], [20]). Fog computing is a virtualized computing and data storage architecture deployed in edge computing infrastructures hosted by the participating organization and integrated through Internet for collaborating computing. It is different from cloud computing as it is formed through multi-party collaboration and not offered as a service by global cloud computing vendors, such as Microsoft, Amazon, and Google. However, the design is service-oriented and follows the same principles as those used in cloud computing. It can host big data systems and artificial intelligence analytical applications employing selected machine learning algorithms. The edge computing design with these components for healthcare has been referred to as Healthcare 4.0 as they have been adopted from the generic framework of Industry 4.0. This design is expected to deliver predictive health monitoring as reviewed in the next section.

V. LITERATURE REVIEW ON HEALTHCARE 4.0

Broadly speaking, Healthcare 4.0 is a new framework of healthcare systems and services in the information age riding on technological evolutions of smart devices (HIoT), fog computing (supported by applications on cloud computing), big data analytics, and machine learning ([16], [21], [21], [22]). It is driven by data and visualization on time series and predictions made by deep machine learning. The evolution of Healthcare 4.0 started from Healthcare 2.0 that witnessed global advancements in medical electronics for instrumentation and measurements, and then of electronic health records evolving in Healthcare 3.0 stored on large scale relational databases for relational health analytics [22]. Healthcare 4.0 has taken it to the next level when electronic health records maintained by entire networks of healthcare organizations can be used to train machine learning to deliver deep data driven analytics for predicting serious health anomalies way before they actually occur [16], [21], [22], [23]. In the Healthcare 4.0 era, doctors and nurses of several hospitals can make use of predictive analytics to ensure timely healthcare intervention and admissions to the patients wherever they are present physically in a country [24]. Any signs of stress and risks can be quickly identified through remote monitoring using HIoT sensors, cameras, microphones, and other devices, and comparing the specific health data of a patient with similar patients living in similar scenarios and having similar health statuses.

Healthcare 4.0 is not only about data collection and analysis. It also incorporates strategies for empowering local communities of doctors, nurses, first responders, mobile staff, and hospital support staff through new technological advancements, building their innovation capabilities, and developing standards and procedures compatible with the local healthcare needs ([25], [26]). These strategies are defined to develop technical, behavioral, and situation handling skills in the local healthcare communities and also extending better confidence among the patients through knowledge of the systems and people supporting them and the better healthcare capabilities assuring safety and risk mitigation during their emergency conditions. A sense of being continuously monitored by experts and availability of immediate interventions required can improve the sense of confidence and reduce panic attacks among the patients. The local healthcare communities should be engaged

in pre-defined models of interventions and trained through several mock drills to boost their confidence. Mobile intervention units can be deployed at remote locations and other equipment and medicines can be fetched through drones to facilitate rapid responses at the ground zero ([25], [27]).

The mobile smart phone devices owned by the patients can be used effectively for delivering timely and reliable healthcare services to rural communities [28]. A large number of mobile healthcare (mHealth) apps are developed to assist patients in both urban and rural locations. The apps can help in making quick call with doctors for visual examination on video for prescriptive medical care. The remote data collected from the patients can provide the doctors essential diagnostic information. The medicines and other care units (such as a nebulizer) can be provided in pre-established rural storages or can be delivered by drones. Mobile Internet networks have proliferated well in both developed and developing economies. Proliferation of 5G mobile Internet is expected to cause major advancements in real time monitoring capabilities and instant remote intervention invoking new patterns of emergency care with and without admissions ([29], [30]).

VI. CONCLUSION

In This section presents the concluding points and recommendations on design, operational details, and limitations of predictive health monitoring of elderly and vulnerable citizens in Kenya.

Overall, it appears that Healthcare 4.0 adoption in Kenya is feasible if the local hospitals deploy private fog/edge computing networks for their patients. The network should be considered as limited extension of their ICU facilities and not as large scale wide area networks. The operational details of the fog/edge computing networks need to be defined with several tiers of customized solutions for different patient class. The patient classes and monitoring specifications should be defined by the doctors and the corresponding designs need to be created by information technologists ensuring careful mapping of features, their functionalities, and their capacities with each of the specification defined by the doctors. There are limitations caused by patients' mobility found in this research, which should be kept in mind while designing and operating Healthcare 4.0 networks in Kenya.

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