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Literature survey for Sahara – Systematic analysis of health-vitals in an automated real-time atmosphere

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ABSTRACT

The world of healthcare is undergoing rapid changes with changing and emergence of new technologies. In order to maintain good health, frequent visits to healthcare centers can help us understand the current status of our internal health. In spite of investment in infrastructure and healthcare services, access to healthcare for people in rural India is still a problem. For the growth of rural healthcare, several government programs have been initiated, but but availability of quality healthcare for all is still a dream, with quality and number of doctors per capita falling well below global average. Telemedicine as a new technology has offered great hope in making healthcare accessible to all but it has not found wider acceptance. In this paper, we have carried out an extensive survey by visiting PHCs in different states, compared the existing telemedicine system in the market.

Keywords: *Healthcare, Telemedicine, PHC, Health-vitals, IoT, Real-time Data*

1. INTRODUCTION

India, a populous country, has both public healthcare services and private healthcare services. However, most of the private health-care providers are concentrated in urban India, providing secondary and tertiary care health-care services. 69% of the Indian population concentrated in rural areas. The Government of India has initiated National Health Mission (NHM) in order to provide the required healthcare to the people of India. The services provided by these healthcare centers in the rural areas have created an infrastructure of health services in the form of CHC/PHCs. These services, together with ASHA and Anganwadi workers have made it possible to provide most essential healthcare services to most of the rural and urban population of India. The National Health Mission has been working closely with state government agencies to monitor and improve upon it on a continuous basis. As of March 2020[20], there are 15328 health-care centers in India. Out of which, there are 7778 PHCs and 2760 CHCs in rural India. The works done by ASHA workers are indispensible. 1047324 ASHA workers have been employed in other to help educate the rural population. However, the availability of doctors is still much below than word average. As per the research report on "Future of India: The Winning Leap" by Price Waterhouse Coopers [22], the availability of doctors in India is only 0.67 per 1000, compared to 2.3 in US, 1.8 in China and Brazil. As per the World Health Organization (WHO) report [23] in 2016, the actual number of medical professionals at the national level is only 0.615 per thousand. It is well below the recommended figure of 1 doctor per 1000 people by WHO. With the advancement in science and technology, a telemedicine system can be devised to tackle the issues and challenges faced by the doctors and healthcare providers in rural India. This has the potential to solve the problem of accessibility and quality of care that can go a long way in providing Universal Health Coverage (UHC), as defined by the World Health Organization [14].

A telemedicine system, that addresses the need for rural India, can go a long way in making healthcare accessible to all. It will also address the skewed ratio of doctors in rural India and address the severe shortage of doctors there. According to the Health Resources and Services Administration (HRSA) of the U.S. Department of Health and Human Services, Telemedicine is defined as the use of electronic information and telecommunications technologies to support and promote long-distance clinical health care, patient and professional health-related education, public health, and health administration [1]. Implementation of such telemedicine system not only breaks the barrier but also improves the efficiency and quality of health care services. This paper provides a survey on the actual condition of healthcare in India and also identifies the specific requirements of a telemedicine system suitable for India.

The government has created a basic healthcare infrastructure as the backbone for providing necessary healthcare services to people in rural India. Primary Health care is provided to treat the people. In India, Primary Healthcare is provided through a network of Sub centres and Primary Health Centres in rural areas. The public health-care infrastructure in rural areas has been developed as a three-tier system based on the population norms as Primary Health Centres (including Sub Centres), Community Health Centres and District hospitals.

Sub Centre (SC): This is where the contact between the primary health care system and the community takes place. Services provided by sub centers are in relation to maternal and child health, family welfare, nutrition, immunization, diarrhea control and control of communicable diseases programs. It has at least one auxiliary nurse midwife (ANM) / female health worker and one male health worker. Under NRHM, one additional second ANM is given on contract basis.

Primary Health Centre (PHC): They act as a mediator between village community and the medical officer. It comes under minimum needs program (MNP)/ basic minimum services program (BMS) of State government. It is a referral unit for 6 Sub Centers. It has a medical officer supported by 14 paramedical and other staff. Under National Rural Health Mission, two additional staff nurses are given to PHCs on contract basis. The activities of PHC involve curative, preventive, primitive and family welfare services.

Secondary Health Care Centers: This is where the patients from PHC are referred to specialists in higher hospitals for treatment. In India, the health centers for secondary health care include District hospitals and Community Health Centre at block level.

Community Health Centre (CHC): It comes under Minimum Needs Program (MNP)/ Basic Minimum Services program (BMS) of State government. It is a referral unit for 4 PHCs. It has 4 medical experts, i.e. Surgeon, physician, gynecologist and pediatrician supported by 21 paramedical and other staff.

District Hospitals (DH): Every district is expected to have a district hospital. It plays a very important role in the district health system which provides curative, preventive and primitive healthcare services to the people in the district. Every district hospital is linked with the public health centers; just below the district are Sub-district/Sub-divisional hospitals, Community Health Centers, Primary Health Centers and Sub Centers.

This paper covers a decade's work of the National Health Mission in rural India. The NRHM has played a vital role in upbringing the quality of rural healthcare. With the advancement of technology, new systems have come into existence that replaced manual labor. This paper talks about the early telemedicine systems and the limitations of the existing devices. These limitations are supported by an extensive survey carried out by the team.

- ❖ Background
  - ➢ National Health Mission
  - ➢ Rural health care infrastructure
- ❖ Telemedicine system in India
  - • Early start phase
  - • Rapid development phase
  - • Technology maturity phase
  - ➢ Current Status
  - ➢ Existing Telemedicine system
  - ➢ Future direction
- ❖ Gap Analysis

2. BACKGROUND

A. National Health Mission

The Government of India launched the National Health Mission (NHM) in order to provide easy, affordable, quality healthcare services. This mission talks about the initiatives, programmes, achievements, quality of healthcare and funds released for health sector of the country. NHM comprises of two Sub mission- National Rural Health Mission (NRHM) and National Urban Health Mission (NUHM) [3].

From table 1 and table 2, we can see that NRHM employed lakhs of additional health staffs to fill the shortage of human resources in public health care sectors. AYUSH facilities by providing ASHA workers to many Primary Health Centres (PHCs), Community health centres (CHCs), District hospitals (DHs), above Sub Centres (SCs). There are approximately around 9.36 lakhs ASHAs around the country who provide community level care. Rogi Kalyan Samiti/Hospital Management Society takes care of quality of facilities provided in the hospital. Village Health Sanitation and Nutrition Committee (VHSNC) provide a grant of 10000 to each VHSNC under NRHM. Kayakalp is launched to promote hygiene in health facilities. Kilkari delivers free audio messages weekly regarding pregnancy and child birth. Including to this are Free Drugs Service Initiative, Free Diagnostics Service Initiative, Pradhan Mantri National Dialysis Programme, Comprehensive Primary Health Care, ANMOL and National Quality Assurance Framework for Health facilities and so on. According to NHM reports 2016-2020, shows the trend in the manpower utilisation of rural India [20].

Table 1: NRHM Manpower Utilisation (2012-2016)

Man Power under NRHM		**2012-13**	**2013-14**	**2014-15**	**2015-16**
No. of Staff Nurses (SNs) under NHRM		34384	38412	39559	36383
Whether AYUSH Person included in (Y/N)	Health Society	26	27	30	33
	State Health Mission	27	29	31	34
	Rogi Kalyan Samities	24	27	31	34
	ASHA Training	20	20	21	32
Number where AYUSH facilities is available as on date	DH	329	331	512	497
	CHC	2352	1885	2739	2649
	Other than CHC but below district level	512	529	572	373
	PHC	8471	8461	9112	8214
	Other health facilities above SC but below block level	3686	4465	5267	5716
	Total	15350	15671	18202	17449
Number of ASHAs selected during		22935	7730	36257	34545
Number of ASHAs in position with drug kits		800819	834902	858974	903942

Total number of monthly Village Health & Nutrition Days (VHNDs) held in the state	6478875	6471093	7494238	7969862
Number of Village Health Sanitation and Nutrition Committees (VHSNCs) constituted	511397	510442	498079	510416
No of Mahila Aarogya Samitis (MAS) formed	-	-	-	-

Table 2: NRHM Manpower Utilisation (2016-2020)

Man Power under NRHM		**2016-17**	**2017-18**	**2018-19**	**2019-20**
No. of Staff Nurses (SNs) under NHRM		41952	46783	34713	62015
Whether AYUSH Person included in (Y/N)	Health Society	29	29	29	31
	State Health Mission	30	30	30	29
	Rogi Kalyan Samities	30	30	30	30
	ASHA Training	24	24	24	24
Number where AYUSH facilities is available as on date	DH	506	495	495	497
	CHC	2871	2733	2762	2760
	Other than CHC but below district level	375	362	371	371
	PHC	8994	7944	7621	7778
	Other health facilities above SC but below block level	5720	4118	3923	3922
	Total	18466	15652	15172	15328
Number of ASHAs selected during		33197	15931	10844	11164
Number of ASHAs in position with drug kits		911388	911185	931283	936698
Total number of monthly Village Health & Nutrition Days (VHNDs) held in the state		12357956	14964315	12306149	13721304
Number of Village Health Sanitation and Nutrition Committees (VHSNCs) Constituted		522290	538588	540643	553201
No of Mahila Aarogya Samitis (MAS) formed		59099	72397	79692	80917

Funds from NHM are utilized on both the rural areas as well as urban areas. According to the NHM report 2016-2017, the Budget estimation was around 19000 Crores [2]. The actual expenditure was 11675.13 Crores. There has been a tremendous improvement in healthcare facilities in comparison with the previous decades. These improvements can be observed by the steady decline in the Crude Birth Rates, Maternal Mortality Rates and Infant Mortality Rates [15]. Meanwhile, the report from 2019-2020, the given estimation is 40000 Crores [3]. The Government of India is enhancing the quality of these healthcare facilities by a sharp margin. Currently, 27 Crores has been utilised to ensure hygienic and grade 'A' healthcare facilities [16].

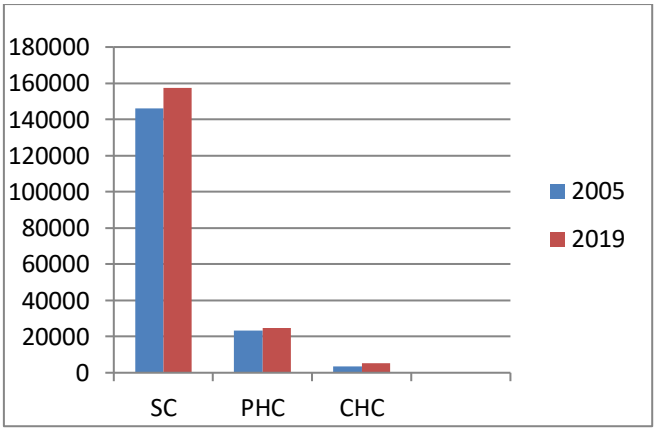

Fig. 1: The above graph shows the increase in the number of Rural Healthcare services over a period of 14 years

B. Rural Health Care Infrastructure

From Table 3, we can see that the number of PHCs have increased by 30% from 2012 to 2020. Following which, there is 17.6% increase in the number of CHCs and 8.3% increase in the SCs. Currently, there are 34 additional DHs in India, as of 2020 [20]. Figure 1 shows the graphical representation of the growth of these centers over the past 14 years. The state wise distribution of PHCs, CHCs and SCs are shown in table 4. Uttar Pradesh holds the highest number of PHCs, CHCs and SCs in India [17].

From table 5, we can see the state wise distribution of doctors, pharmacists, lab technician and specialist employed in PHCs and CHCs. In the year 2015, Bihar had a higher percentage of doctors followed by Tamil Nadu. However, in a span of 3 years, 29% of doctors reduced. The reason for this reduction can be due to the lack of poor infrastructure, lack of access to labs and test facilities, etc. In the year 2018, Rajasthan saw a massive increase in manpower in the rural health care division [18][19].

It is clear that government of India has made significant progress in creating health infrastructure and has also increased the number of healthcare professionals to meet the huge demand gap in rural India. But if we consider the gap in the availability of medical professionals in urban and rural India, 70% of the population lives in rural India. While the number of health professionals working in rural India is only 30% [24, 26]. This skews the availability of doctors in rural India much worse. It is 1.33 per thousand for urban population but only 0.30 for rural population, a difference of four times. Migration of physicians and reluctance by them to avoid working in rural India for life-style and infrastructure related issues makes this situation worse [27].

Table 3: Current Estimation Of PHCs, CHCs And DHs In India (2012-2020)

	2012-13	**2013-14**	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**2018-19**	**2019-20**
Number of SCs	148366	151684	152326	153655	155069	156231	158417	160713

Number of SCs which are functional	***In Govt. Building***	94380	99991	102319	103632	104861	104861	114333	118600
	Without ANM	4781	5099	7335	8138	8963	8963	7504	13773
	With Second ANMs	75624	73664	53290	53786	53113	53043	52599	52933
No. of health kiosks		-	-	-	-	116	100	167	553
Total APHCs, PHCs, CHCs & other Sub District facilities functional as 24X7 basis		15373	15684	16321	16299	16729	17494	17509	17511
Number of PHCs		24049	24448	25020	25308	25354	25650	25743	30045
Total number of PHCs functioning as 24x7 basis		8228	8421	9131	9197	9283	9803	9698	9459
Number of CHCs		4833	5187	5363	5396	5510	5624	5624	5684
Total number of CHCs functioning as 24x7 basis		4420	4374	4484	4530	4611	4962	4942	4961
Number of DHs		722	748	755	763	773	779	764	756

Table 4: State wise distribution of PHCs, CHCs and DHs in India

States	**2005**			**2019**		
	Sub centers	***PHC***	***CHC***	***Sub centers***	***PHC***	***CHC***
Bihar	10337	1648	101	9949	1899	150
Chhattisgarh	3818	517	116	5205	792	170
Himachal Pradesh	2068	439	66	2089	586	87
Jammu and Kashmir	1879	334	70	3025	622	84
Jharkhand	4462	561	47	3848	298	171
Madhya Pradesh	8874	1192	229	10226	1199	309
Odisha	5927	1282	231	6688	1288	377
Rajasthan	10512	1713	326	13512	2082	571
Uttar Pradesh	20521	3660	366	20782	2936	679
Andhra Pradesh	12522	1570	164	7437	1145	140
Gujarat	7274	1070	272	9166	1476	362
Haryana	2433	408	72	2604	379	115
Karnataka	8143	1681	254	9758	2127	198
Kerala	5094	911	106	5380	848	227
Maharashtra	10453	1780	382	10668	1828	364
Punjab	2858	484	116	2950	416	89
Tamil Nadu	8682	1380	35	8713	1422	385
West Bengal	10356	1173	95	10357	908	348

Table 5: State wise data of doctors, Specialists, lab technicians in PHCs & CHCs

states	2015				2018			
	Doctors at PHC	***Specialists at CHC***	***Pharmacists at PHC and CHC***	***Lab Technicians at PHC and CHC***	***Doctors at PHC***	***Specialists at CHC***	***Pharmacists at PHC and CHC***	***Lab Technicians at PHC and CHC***
Bihar	2521	63	250	611	1786	82	287	611
Chhattisgarh	368	78	844	657	359	57	936	823

Himachal Pradesh	571	7	456	157	622	4	378	131
Jammu and Kashmir	834	167	872	763	694	256	974	789
Jharkhand	372	128	305	301	340	92	241	264
Madhya Pradesh	999	263	1023	892	1112	248	1778	1238
Odisha	1008	356	1499	378	917	253	1623	567
Rajasthan	241	526	667	1930	2396	565	1172	2091
Uttar Pradesh	2209	484	2883	963	1344	192	4717	1644
Andhra Pradesh	1412	159	951	776	2045	384	1004	789
Gujarat	889	74	879	1401	1321	118	1584	1658
Haryana	489	30	508	437	491	17	397	356
Karnataka	2196	502	2521	1294	2136	498	2523	1532
Kerala	1169	39	1102	365	1169	40	1102	365
Maharashtra	999	576	2100	1387	2929	485	2055	1296
Punjab	441	173	806	482	480	105	790	585
Tamil Nadu	2375	0	1526	1314	2780	210	2097	967
West Bengal	723	114	996	448	1061	125	1422	874

Thus, it is clear that the National Rural Health Mission (NRHM) has succeeded only to a limited extent whereby, a basic care is provided to majority of population for the most common diseases like fever, cold, loose motion, cholera, diarrhea, tuberculosis (TB) etc. They also cover immunization of children against common childhood diseases like DPT, polio, etc. and basic pregnancy related services for pregnant women. However, the quality of services and for any health problem that is not the most common has been obvious to any serious researcher. This is aggravated further by lack of access to quality doctors and specialists for more complicated cases, lack of poor infrastructure, lack of access to labs and test facilities, etc. The average distance to reach a health facility in rural India is 4.94, with a quarter living within 5 to 9 KM and 18% living more than 10KM away [27]. Any serious health issue requires travel to taluk or district hospitals, which are under tremendous pressure due to the very large number of patients. Such visits often results in

loss of earning, and travel problems with very little access to ambulatory services acts as a further barrier for poor people. This often results in loss of their daily livelihood which they can ill-afford. This restricts the people living in rural communities to avail the basic services in order to maintain a healthy lifestyle. With the advancement in science and technology, a telemedicine system can be devised to tackle the issues and challenges

3. TELEMEDICINE SYSTEMS IN INDIA

The start of the twenty first century saw the emergence of new technologies like, spread of easy internet access, bio-sensor development, Internet-of-Things (IoT), cloud based services, hand-held computer devices etc. This led to an era of developing systems that could provide more personal healthcare via monitoring of health parameters, and remote delivery of healthcare service.

Any new technology goes through the classical 'S' curve of growth of initial euphoria followed by downward slide, and then reaching maturity or sustained growth phase. Technology for monitoring health parameters and remote healthcare can also be divided into three phases of development, namely

- Early start phase – This is the early phase of development that was led by development of various sensors and devices for self-monitoring of health parameters. It was led by development of various bio sensors and emergence of lab-on-chip. This can be considered to start in the beginning of 2000 and going up to the middle of first decade.
- Rapid development phase – This period represents major application of technology for health monitoring and telemedicine systems. This was the period of euphoria about telemedicine being the solution to an affordable and accessible healthcare.
- The technology maturity phase – This period saw the realization of slowdown of the spread of telemedicine system, as a result of the bottlenecks and challenges faced by researchers and developers.

The following section gives a brief overview of some of the major developments that happened in India.

1. Early start phase

Telemedicine ECG-Telemetry with Bluetooth Technology, 2001 [6]: A wireless communication protocol using the Bluetooth system for a short range (10-20m was developed which collects the short- and long term digitized ECGs with the relevant clinical data for the management of the patients.

Methodology: The prototype uses a portable digital ECG recorder, Bluetooth system and a local database to retrieve the physiological EGC analog signals from the patient.

Pros: The flow of information is bi-directional (patient-end and doctor's end). The ECG interpretation could be performed with incomplete clinical data, because the decision making is based on the re-calculated ROC (Receiver Operating Characteristic) curves of various ECG diagnoses. Since a portable ECG device is used, it is easier to carry out this operation anywhere in the network.

Cons: A Bluetooth equipped system has a very limited transmission range and it cannot guarantee data privacy since it is easier to tap into the system. It is an expensive system to carry out services in rural areas. A local database is used to store the patient's medical records which only make it harder to access from remote location. Since incomplete clinical data is used at the interpretation of ECG, correct diagnosis or the actual side effects of the diseases cannot be determined.

VitalPoll Telemedicine System, 2004 [4]: A wireless home healthcare implemented using Bluetooth, monitors real-time medical data using a client/server architecture along with a

physiologic data routing hub to collect data from different medical devices and sensors.

Methodology: The VTS was constructed with a three-layer architecture- the VitalPoll Management Center, VitalPoll Manager, VitalPoll Unit, using Celeron 500-MHz CPU, RS232, USB, Personal Computer Memory Card International Association (PCMCIA), Bluetooth module and the Client and Server side was developed using Microsoft Visual C++ and Microsoft Foundation Class development tools.

Pros: The Bluetooth has a transmission rate of 723kbps within the 100m radius because of which there is no loss of data. This helps to keep the system performance consistent.

Cons: There's delay of data transmission beyond 100m radius which shows the unreliability of the system. Treatment of diseases with incomplete data will only make it harder for diagnosis. A Bluetooth equipped system cannot guarantee data privacy since it is easier to tap into the system. It is an expensive system to carry out services in rural areas.

A Real-Time Wireless Telemedicine System Using Bluetooth , 2005 [9]: This paper aims to validate and integrate the wireless Telemedicine System for long term real-time monitoring in clinical practice by testing it with people with pacemaker patients to check if the pacemaker implant is affected by the system and also to assess the system on group of not risky heart patients with heart arrhythmia, monitoring their electrocardiogram (ECG) while carry out their daily activities both indoor and outdoor, using Global System for Mobile Communications (GSM), BLUETOOTH protocol and General Packet Radio Service (GPRS).

Methodology: It uses a patient unit (a Danica Biomedical T3300 telemetry device, a Bluetooth module and a Sony Ericsson T610 Mobile phone), GSM Network (SONOFON, Denmark), a Modem Server, and a Central Monitoring Station.

Pros: The system is highly reliable and user as well as staff friendly. Most of the patients could easily change the electrodes.

Cons: When the patients carry out their outdoor and indoor activities like driving a vehicle at various speeds, being in different landscape or building environments or probably being close to different interference sources (e.g. microwave oven at home, or other heavy electrical machines outdoor) can, significantly, influence the reliability and the performance of the system. [10, 11]. 50% of the health care professional had lesser understanding of System Function which is a major concern. Security algorithms used in GSM cannot guarantee privacy of data. GPRS speed is very low. Bluetooth can only work within a certain range and also do not provide data security.

2. Rapid development phase

Portable ECG monitoring device using Bluetooth, 2006 [8]: A prototype of a portable ECG-monitoring device has been developed for clinical and non-clinical environments as part of a telemedicine system to provide remote and continuous surveillance of patients. The device can acquire, store and/or transmit ECG signals to computer-based platforms or specially configured access points (AP) with Intranet/Internet capabilities in order to reach remote monitoring stations.

Methodology: It uses a Data Acquisition Module (DAM), Bluetooth device, Access Point (AP), USB, Local or remote Stations (used to store the patient's information), Multimedia Memory Card (MMC), Secure Digital Card (SD) and TransFlash to store the data.

Pros: There was no data loss while testing DAM for data transmissions to Bluetooth enabled local stations for all sampling frequencies. Also, it was tested using USB interface with a local station. TransFlash memory card is selected or storage because it is smaller than the others.

Cons: Bluetooth cannot transmit data after a certain range. Bluetooth are prone to lose connection which can result certain signals being lost. If USB is used, Speed at which data is transmitted is low. The lack of security during data transmission while using Bluetooth and also chances of being hacked is higher. Therefore, there can be Invasion in Data privacy. Average Battery life time of DAM under transmission modes still needs to be calculated.

Telemedicine Information Monitoring System, 2008 [13]: A telemedicine information monitoring system was proposed and prototype was designed. Zigbee protocol was given importance for data transfer. Vital sign data parameters measured were ECG, SPO2, blood pressure, glucose and body temperature, which could be transmitted to the healthcare gateway via ZigBee and then are relayed through the Internet to the health services information platform.

Methodology: The implementation initially was through Zigbee and Bluetooth but later was changed to Zigbee wireless module. OSGi and web protocols were used to develop the healthcare gateway. The OSGi-based healthcare gateway features healthcare services program remote download, lifecycle management, dynamic adjustment (additions/deletions/settings) and automated program installation and execution. Web Service technology protocols, such as SOAP, WSDL, UDDI and XML serves were used as the core of the SOA-based healthcare information platform.

Pros: Patients with cardiovascular disease and diabetes were the targeted audience and this would help them to move freely as this system was wireless and the movement would not be restricted by the wires connected.

Cons: The Zigbee wireless module can be replaced with a Wi-Fi module for faster date transmission. The system can utilise cloud virtual machines for direct access of confidential data instead of using local servers.

3. Technology maturity phase (2011-2015)

Cloud based Telemedicine Service, 2013 [7]

Methodology: The system uses a measurement device which is connected to the patient. This device uses an Ethernet connection for data transfer. Once the data is uploaded, it can be accessed from any remote area for further diagnosis.

Pros: Cloud computing can improve healthcare services to an undoubtedly large extent since it allows remote access to the data. The use of telemedicine system saves you money as it is cheaper than hospital bills. It increases productivity, allows their patient to view their medical records, contact their physician, monitor their prescription and schedule appointments from their smartphones. It is efficient as it uses real time devices like teleEEG to transmit data to distant areas.

Cons: The proposed system cannot be utilized in rural areas because the cost of the system is expensive. This wired system is not portable. The UI is complex for a layman to understand. Also the use of smartphone as a mediator of information is prone to greater threats as the confidentiality of patient's medical records is on the line. Data security and privacy is necessary to ensure that the information is not misused.

Technology maturity phase (2016-2020)

HEMAN, 2018 [5]***:*** The e-Health Care System proposed a telemedicine system to help the underprivileged population who stay in rural areas. They bridge the gap between providing expertise healthcare and lack of facility. They talk about providing and monitoring services to the elderly patients in the urban part of the nation because of the extensive use of resources.

Methodology: Uses a DAQ module to connect the pc and the micro controller AVR atmega. A third-party app called

LABview was used to display the gathered data on the computer. The storage system used is AWS and the syncing system used is Google scripts via google spreadsheets.

Pros: A single microcontroller is used to connect all the sensors. There is auto-sync of data.

Cons: AVR atmega Lacks performance compared to higher bit microcontrollers. LABview is a third-party app which doesn't have good UI, which in turn makes it harder to use. There is no usage of the data gathered (no data analysis).

Prototype Telepathology solution using Raspberry Pi, 2017 [12]

Methodology: RPi was used to host a webserver using Apache and that could be accessed with the RPi device id followed by dataplicity.io. Experiments were done to test the speed of this webserver in two ways, the first was by remote user browsing. Second was by adding microscopic image on the server and downloading those from 6 different locations across the globe. Webpagest tool was used to achieve this. Early testing showed that WLAN connection provided the fastest download speeds, followed by LTE and 3G CDMA.

Pros: The Telemedicine system is not limited to just photos; there might be need of video consulting too. Video images could be captured with a mobile phone and immediately archived on a Raspberry Pi server for remote viewing.

A. Current Status

The team visited 17 centres (PHCs and District Hospitals) in 4 states (Bihar, West Bengal, Karnataka and Uttar Pradesh). These visits were made without any prior appointments to record the ground conditions of these centres. The cost of services provided to the patients by the PHCs, SCs, CHCs and DHs in rural India are free. Around 80% of the doctors spend roughly 2 minutes with a patient during these check-ups.

Fig. 2: PHC Bhagwanpur, Bihar

The team also interviewed few patients during this survey. It was observed that patients were happy regardless of the services provided by PHCs and CHCs. From table 6, we can see that the services provided by these healthcare centers have been inadequate due to the lack of adequate and specialized doctors, infrastructure, resources, etc.

Fig. 3: Narayanpur PHC, Bengal

Because of which most of the PHCs refer the patients to a district hospital to get a detailed diagnosis of their disease. Only 2 out of the 17 centers we visited saw the use of Telemedicine system.

Fig. 4: Sonpur DH, Bihar

However, due to the complexity of the machine, such centers could only diagnose 1-2 people per day. The Kshema telemedicine system in Bihar was not in use due to lack of maintenance support and expertize needed to operate it. The Sky Health Clinic, started as a partnership between Bihar govt and Milinda Gates Foundation, opened centers in many places in Bihar and also few in Rajasthan. However, the few centers visited in Bihar, were non-functional. The telemedicine system developed by ISRO was installed in a district hospital in Mangalore. It was connected with several specialists in different govt hospitals in Karnataka. It was primarily used as a secondary consultation system for one or two patients a day. Figure 2 and 3 show the actual ground conditions of such healthcare centres in rural India.

Table 6: PHC Survey Data From 4 States (2016-2020)

STATE	Name of the PHC Centre - Place	SURVEY PARAMETERS									
		No of Doctors/ Medical Staffs Present	No of beds in the facility	Provision of Medicines	Avg No of Patients	No of People Dependant on Availing these Services	Nearest Diagnostic Centre	Services Provided by the Facility	Use of TM System	Vital Parameters taken for Diagnosis	Common Diseases
BIHAR	*DARIAPUR APHC, SARAN*	1 doc + 1 telemedicine operator	-	Availability of essential drugs	~90	Covers 2-3 villages	10km away	Common Health check-up	kshema	ECG, BP, Sugar, Temperature, Pulse	TB, Cold, Malaria, Kalajar, Leprosy, Cough, Fever

	NAYAGAON APHC, SONPUR, SARAN	7 (1 doc + 2 ayurvedic + 4 nurse)	1 labour room	Availability of basic drugs	~70	Covers 3km radius	10km away	Pregnancy, Common Health check-up	-	BP, Temperature, Pulse	Lung Infections, Cold, Fever, Cough
	BHAGWANPUR, VAISHALI	5 (3 doc + 1 nurse + 1 pharma + 1 lab tech)	6	Availability of essential drugs	~300	Covers 12km radius	40km away	Diagnostic lab, X-Ray, Labour room, Ambulance service	-	Sugar, BP, Temperature, ECG, X-Ray, Lab reports	Malaria, Typhoid, TB, Cold, Jaundice, Lung Infections, Dysentery
	SONPUR PHC + DH	16 docs (7 male + 9 female)	75 (45 in use)	Availability of all drugs	~750	Covers 2-3 villages	-	Dental, Ophthalmic, Blood test,Sugar, Albumin test, X-Ray, ECG, TB test	-	All vital parameters are measured	75% delivery cases, 25% others (viral infection, bacterial infection, lung infection, etc)
WEST BENGAL	***NARAYANPUR PHC, NARAYANPUR***	3 (1 doc + 1 nurse + 1 pharma)	-	Availability of essential drugs	100	30000 people (1 gram panchayat)	6-7km away	OPD, Antenatal Check-up, Pharmacy	-	Blood, Temperature, Pulse	Malaria, Typhoid, TB, Jaundice, Respiratory Infections, Dysentery
	CHAKMANDALA BLOCK PHC, BIRHBUM	5 (3 docs + 2 nurses)	15 (2 labour)	Availability of essential drugs	7200	1.8Lakh people	7km away	24/7 service, OPD, Diagnostic lab, Pharmacy	-	Blood, Temperature, Pulse	Diarrhoea, Chickenguny a, Fever, Malaria, Kalajar, Leprosy
	RAMPURHAT, BIRBHUM	3 (1 doc + 1 nurse + 1 pharma)	-	Availability of essential drugs	~100	Covers 2-3 villages	6km away	Common Health Check-up, Pharmacy	-	Blood , Sugar, Albumin, Temp, BP	Kalajar, Malaria, Cold, Cough, TB
	BODORA PHC, TARAPITH	No doc, 1 pharma	-	Availability of essential drugs	~20	Covers 2-3 villages	9km away	Common Health Check-up	-	BP, Temperature, Pulse	Fever, Cold, Cough
KARNATAKA	***CHC VEEREGOWDANA DODDI, RAMANGARAM***	5 (3 doc + 1 nurse + 1 pharma)	6	Availability of essential drugs	~70	Covers 10km radius	60km away	Pharmacy, OPD, Immunisation, Lab, Labour, OT, Govt programs like Pulse polio, Malaria.	-	BP, Pulse, Pregnancy, Blood Sugar test, ANC Care, PNC	Viral fever, Malaria, TB, Vaccinations
	NAYAMANGALA TALLUK, MANDYA	12 (10 docs + 2 med staff)	100	Availability of essential drugs	~600	All villages in the talluk	-	Pregnancy, Surgery, IP, OPD, LSCS	-	BP, Temperature, sugar, ECG, Ultra sound, Oxygen level	All varied cases in the Talluk are handled
	DEVALAPURA PHC, MANDYA	3 (1 doc + 2 staff)	6	Availability of essential drugs	~150	Covers 20km radius	15km away	Pregnancy, OPD, Common Health check-up	-	BP, Temperature	Fever, Asthma, Body ache, G.E. (stomach pain)
	PHC JALAMANGALA, RAMANAGARAM	6 (1 doc + 5 staff)	6	Availability of basic drugs	~40	Covers 1-2 villages	15km away	Lab testing, OPD, Day care, Immunization to kids	-	Blood, Urine, Temperature	TB, Malaria, Asthma

	GEJJAGARAGUPPE, RAMANGARAM	2 (1doc + 1 pharma)	6	Availability of basic drugs	~60	Covers 32 villages	25km away	Immunization to kids, Govt programs like Pulse polio, Malaria, OPD	-	BP, Pulse, Temperature, HIV	Respiratory Infections,Malaria, Fever, Diarrhoea
	WENLOCK, MANGALORE	*(was not disclosed)*	50	Availability of essential drugs	2-5 for TM	Covers the entire district	-	All services are provided	*Televital by ISRO*	BP, Pulse, Temperature, ECG, X-Ray	Cardiovascular, Onco
	SARASWATHINAGR PHC, BANGALORE	10 (1 doc + med staff + junior health assistants)	-	Availability of essential drugs	~40	Covers 1-2km radius	-	OPD	-	All vital parameters	

B. Existing Telemedicine System:

Telemedicine at Narayana Hrudalaya – partly funded by HP, this system focuses mainly on cardiac patients. They have cured more than 54000 patients and have a connected 150 centers worldwide.

eVaidya – Based in Hyderabad they provide telemedicine system which gives consultation with doctors over video call, phone, email, chat. It also provides health news and facts.

KSHEMA telemedicine from KTwo Global – Based in Bihar, this telemedicine costs 8L roughly which measures ECG, temperature, sugar, x-ray by manual input.

Sky Health Clinic - This network brings together public and private sector health providers, rural health workers, and local entrepreneurs through telemedicine and mobile-enabled connections that mobilize and connect existing human resources in new ways.

TeleVital telemedicine network – with over 515 installations worldwide this is a preferred system used at ISRO and has treated over 25000 patient.

e-Sanjeevani – Launched in 2009 by union IT minister in India, this system provides tele-consultation. Some of the medical diagnostic equipment interfaced with eSanjeevani include ECG machine, digital slit lamp, digital microscope, medical film scanner, etc.

C. Future Direction

In spite of so many telemedicine systems developed and also implemented (fully/partially) in different parts of India, it has still not found much acceptance so far. Because technology is growing at such a fast pace, it's been difficult for policymakers to keep up with the industry. There is great uncertainty regarding matters like reimbursement policies, privacy protection, and healthcare laws. Moreover, technology is expensive. One of the key technological challenges in India is the required internet band-width for telemedicine systems.

Security Concerns - Providers and patients alike have concerns with telemedicine due to the mass amount of sensitive information in the healthcare world. Because of telemedicine, physicians are able to communicate with their patients via video chat, text message, and phone call, but not all communication mediums are safe.

Physician Licensing - Although telemedicine itself permits physicians to treat patients nationwide, there are restrictions on who can provide services across countries.

Technical Training and Equipment - Restructuring IT staff responsibilities and purchasing equipment takes time and costs money. Training is crucial to building an effective telemedicine program. Physicians, practice managers, and other medical staff need to be trained on the new systems to ensure a solid ROI.

Reduced Care Continuity - In cases where patients are using on-demand telemedicine services that connect them with a random healthcare provider, care continuity suffers. A patient's primary care provider may not have access to records from those other visits and end up with an incomplete history for the patient. Service provider shuffling increases the risk that a doctor won't know a patient's history or have notes about care routines.

4. GAP ANALYSIS

The available telemedicine systems are good for use in select centers and in semi urban areas. But, for rural India, we need a system that is truly affordable, accessible and of adequate quality (AAA). An AAA system needs to be -

- A very low cost solution for collecting and aggregating patient data.
- It must have wireless connectivity of bio-sensors to make it very easy to use.
- It must be rugged and very easy to maintain / replace at a very low cost.
- The user interface (UI) should be simple and easy to use by semi-skilled professionals.
- It should not be dependent on electricity for its operation.
- Given India's linguistic diversity, it must provide Native Language Support (NLS) for use in local language.

5. CONCLUSIONS

The healthcare sector of rural India receives unacceptably low quality primary care due to structural constraints, lack of incentives and resources, lack of access to doctors, specialized doctors, lab facilities, etc. It is necessary to address the problems of every individual in a systematic order. The need for telemedicine system in rural areas not only improves the quality of healthcare services rendered but also has been proved to be effective in improving management of emergencies in pre-hospital care. Telemedicine can provide more expedient and more accurate diagnosis of patients, and provide tentative decisions regarding their treatment reduce the loss of golden time and cost reduction. However in rural areas, telemedicine systems have some major non-technical problems. These need to be addressed and solved, keeping in mind the local need and conditions. They are, mainly

a) Limited access to High-speed internet
b) Sustainability of the system with proper training and upkeep
c) Interoperability with other healthcare systems
d) Ease of use and low cost

e) Mistrust in Technology among rural population

Telemedicine promises unique opportunities for both patients and physicians, especially in rural communities where infrastructure and distance plays a major factor.

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