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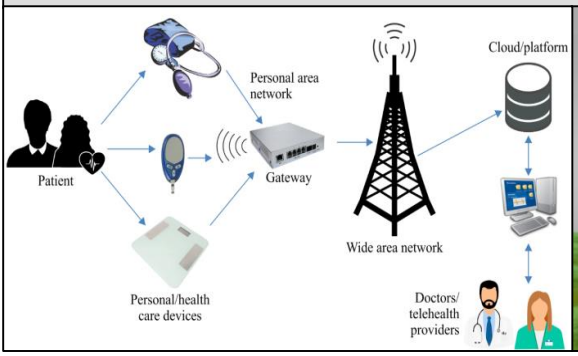
TECHNICAL REPORT

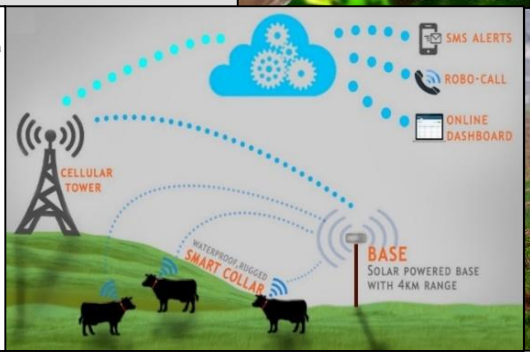
IoT/ ICT ENABLEMENT IN

SMART VILLAGE and AGRICULTURE

TEC 31158:2021

SMART VILLAGE & AGRICULTURE WORKING GROUP





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TELECOMMUNICATION ENGINEERING CENTRE
DEPARTMENT OF TELECOMMUNICATIONS
MINISTRY OF COMMUNICATIONS
GOVERNMENT OF INDIA

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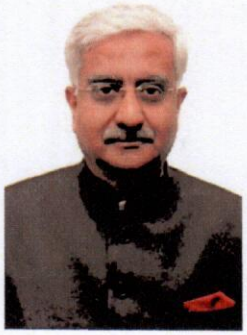
अंशु प्रकाश, आई.ए.एस.
सचिव
Anshu Prakash, I.A.S
Secretary

सत्यमेव जयते

भारत सरकार
संचार मंत्रालय
दूरसंचार विभाग
Government of India
Ministry of Communications
Department of Telecommunications



Message

I am happy to learn that Telecommunication Engineering Centre (TEC) has prepared a Technical Report on **"IoT/ICT enablement in Smart Village & Agriculture"** which is being released as a document for guidance of all relevant stakeholders.

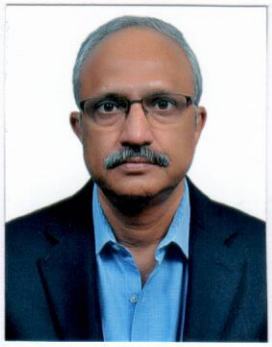
The IoT division, TEC has already released thirteen Technical Reports covering various verticals including Automotive, Power, Health, Safety & Surveillance, Smart Homes, Smart Cities and Communication Technologies in M2M/IoT domain, M2M/IoT Security etc. The current document will add to the series of Expert Reports. Technology applications to provide smart services in the areas of, inter-alia, remote health care, tele-education, e-Governance, agriculture, animal husbandry, fisheries etc. are critical for development of rural areas. Broadband Network being provisioned under BharatNet should also be appropriately leveraged for extending such services.

My best wishes to TEC for the success of their endevour to disseminate expert knowledge and guidance on important technology applications related to Telecommunication and Digital technologies.

(Anshu Prakash)

संचार भवन, 20, अशोक रोड़, नई दिल्ली-110 001 / Sanchar Bhawan, 20, Ashoka Road, New Delhi-110 001
Tel. : +91-11-23719898, Fax : +91-11-23711514, E-mail ; secy-dot@nic.in

के. रामचन्द
सदस्य (प्रौद्योगिकी)
K. RAMCHAND
Member (Technology)



सत्यमेव जयते

भारत सरकार
संचार मंत्रालय
दूरसंचार विभाग, डिजिटल संचार आयोग
संचार भवन, 20, अशोका रोड़, नई दिल्ली-110001
Government of India
Ministry of Communications
Department of Telecommunications
Digital Communications Commission
Sanchar Bhawan, 20, Ashoka Road,
New Delhi - 110001
Ph.: 23372307 Fax : 23372353
E-mail : membert-dot@nic.in

Message

I am pleased to note that Telecommunication Engineering Centre (TEC) is bringing out a Technical Report on "***IoT/ICT enablement in Smart Village & Agriculture***". This report is in continuation to the various technical reports already released by TEC in M2M/ IoT domain.

As smart cities are being created, there is a strong need to extend Smart services in the rural areas also. Connectivity being created in the BharatNet project may be used for providing smart services.

TEC has also carried out the work for adoption of oneM2M Release 2 specifications as National Standards; an important step towards providing standards based M2M/ IoT solutions.

This technical report has also covered diverse issues related with health care, agriculture, animal husbandry, fisheries, water management and resolving these issues with IoT/ ICT having cellular / non-cellular communication technologies.

I appreciate the efforts of Telecommunication Engineering Centre specially its IoT Division and the members of the Working Group for bringing out this technical report in a very timely manner. I wish them success in all their endeavours.

(K.Ramchand)

भरत कुमार जोग
सदस्य (सेवाएं)
Bharat Kumar Jog
Member (Services)

सत्यमेव जयते

भारत सरकार
संचार मंत्रालय
दूरसंचार विभाग, डिजिटल संचार आयोग
संचार भवन, 20, अशोक रोड़, नई दिल्ली–110001
Government of India
Ministry of Communications
Department of Telecommunications
Digital Communications Commission
Sanchar Bhawan, 20, Ashoka Road,
New Delhi – 110001
Ph.: 23714644 Fax: 011-23755172
Email: members-dot@nic.in

Message

I am happy to note that Telecommunication Engineering Centre (TEC) is bringing out a Technical Report on "***IoT/ICT enablement in Smart Village & Agriculture***".

I feel good that TEC has continued the excellent work in M2M/ IoT domain, as thirteen Technical Reports have already been released in the last 3-4 years, covering various verticals viz. Automotive, Power, Health, Smart Homes, Smart cities etc. as well as horizontal layers like M2M Gateway & Architecture, Communication technologies in M2M/ IoT domain, M2M/ IoT Security. A number of actionable points that emerged from these reports are part of standards / policies; enabling the development of M2M/ IoT eco-system in India.

I am glad to note that this technical report has elaborated the IoT/ ICT challenges & requirement in rural areas and also covered related use cases in various verticals namely health care, agriculture, animal husbandry, fisheries, water management, energy conservation etc. for provisioning of smart services. These smart services will help in improving the quality of life and will be quite useful in a pandemic like Covid19 scenario.

This technical report of TEC is a good reference for related organizations in developing the smart infrastructure in rural areas, which will help in improving the quality of life.

I appreciate the efforts put in by Telecommunication Engineering Centre in bringing out this report. I wish them success in all their endeavours.

Bharat Kumar Jog

(Bharat Kumar Jog)

दीपा त्यागी
DEEPA TYAGI
वरिष्ठ उप महानिदेशक एवं प्रमुख
Sr. Deputy Director General & Head

सत्यमेव जयते

भारत सरकार
दूरसंचार विभाग
दूरसंचार अभियांत्रिकी केन्द्र
खुर्शीद लाल भवन, जनपथ, नई दिल्ली–110001
Government of India
Department of Telecommunications
Telecom Engineering Centre
Khurshid Lal Bhawan, Janpath, New Delhi-110 001

Foreword

TEC is the National Standardization Body (NSB) for telecommunication in India and the national enquiry point for WTO –TBT (Technical Barrier to Trade) for telecom sector. TEC has also been mandated to interact with various international standardization bodies like ITU, APT, ETSI, IEEE, oneM2M, 3GPP etc. for standardization works.

TEC takes up development of standards based on study, continuous participation / submitting contributions in the meetings of standardization bodies and interaction with stakeholders. Certification of telecom products as per essential requirements (ERs) is also one of the major activities under MTCTE, which is being implemented in a phased manner by TEC.

M2M/ IoT is one of the most emerging technologies and it is being used to create smart infrastructure. As per NDCP 2018, eco-system is to be developed for connecting five Billion devices by 2022. TEC has already released thirteen Technical Reports covering various verticals viz. Automotive, Power, Health, Safety & Surveillance, Smart Homes, Smart cities and also in horizontal layer, the documents namely V2V/V2I Radio communication & Embedded SIM, Communication Technologies in M2M/ IoT domain, M2M Gateway & Architecture, M2M/ IoT security etc. All the technical reports are available on TEC website (https://tec.gov.in/M2M-IoT-technical-reports).

A number of actionable points emerged from these reports. Few important ones are 13-digit numbering scheme for SIM based devices/ gateways, Embedded SIM, IPv6 for devices / gateways to be connected to PSTN/ PLMN, Spectrum for low power wireless communication technologies, Common services layer- important for sharing of data.

TEC has recently adopted oneM2M Release 2 standards (transposed by TSDSI) as National standards. Details are available on TEC website (https://tec.gov.in/onem2m).

The TEC Working group on Smart Village & Agriculture is having members from Government, industry, academia and start-ups. An effort has been made to address the various issues related to humans, animals and agriculture, by providing smart solutions using emerging technologies (IoT /ICT). Around 16 virtual meetings and a number of informal discussions have already been held in drafting and finalizing the content of this document named "***IoT/ ICT Enablement in Smart Village & Agriculture***". This document has also been uploaded on TEC website (https://tec.gov.in/M2M-IoT-technical-reports).

This technical report provides relevant and reliable guidance to industry stakeholders by mentioning practical use cases that can be applied in related applications in the rural areas. I hope the working group members will continue to provide their support to TEC in carrying out further study in M2M/ IoT domain for the holistic development of smart & sustainable infrastructure in the country.

(Deepa Tyagi)

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List of Contributors

A. Joint Working Group (JWG) Chairman:

Name	Designation	Organisation	E-mail Address
Ms. Deepa Tyagi	Sr. DDG & Head TEC	Telecommunication Engineering Centre (TEC)	srddg.tec@gov.in

B. Joint Working Group (JWG) Vice-Chairman:

Name	Designation	Organisation	E-mail Address
Sushil Kumar	DDG (IoT)	Telecommunication Engineering Centre (TEC)	ddgsd.tec@gov.in

C. Drafting Committee:

S. No.	Name	Organisation	E-mail Address
1.	Sushil Kumar	TEC	ddgsd.tec@gov.in, sushil.kumar20@gov.in
2.	Ekram Khan	Aligarh Muslim University (AMU), Aligarh	ekhan.el@amu.ac.in
3.	Bharghava Rajaram	Mahindra Ecole Centrale college, Hyderabad	Bharghava.rajaram@mechyd.ac.in
4.	Raunaque Mujeeb QUAISER	STMicroelectronics, Greater Noida	raunaque.quaiser@st.com
5.	Ms. Namrata Singh	TEC	namrata.singh51@gov.in

D. Contributors:

S. No.	Name	Organisation	E-mail Address
1.	Sushil Kumar	TEC	ddgsd.tec@gov.in
2.	Ekram Khan	Aligarh Muslim University (AMU)	ekhan.el@amu.ac.in
3.	Ms. Namrata Singh	TEC	namrata.singh51@gov.in
4.	Bharghava Rajaram	Mahindra Ecole centrale college	bharghava.rajaram@mechyd.ac.in
5.	Ms. Pooja Immadi	Bayer Crop Science	pooja.immadi06@gmail.com
6.	Raunaque M. QUAISER	STMicroelectronics	raunaque.quaiser@st.com
7.	Ravindra	Agenttech Bangalore	ravindra@agenttech.org
8.	Rajeev Kumar Tyagi	TEC	rktyagiyss@gmail.com
9.	Ms. Ashima	TEC	dirsd1.tec@gov.in
10.	Om Gangwar	Ex- Adani group	om.opiitr@gmail.com
11.	Alok Kumar Mittal	STMicroelectronics	alok.mittal@st.com

12.	Rajkumar Murugesan	VIT Chennai	rajkumar.murugesan@vit.ac.in
13.	Prof Jaya Vignesh	VIT Chennai	jayavignesh.t@vit.ac.in
14.	Balamurugan MS	VIT Chennai	balamurugan.ms@vit.ac.in
15.	Dr. Subashini	Ex-professor VIT Chennai	subasundararajan@gmail.com
16.	Dr. Vydeki	VIT Chennai	vydeki.d@vit.ac.in
17.	Sriganesh Rao	Calligo Technologies Pvt Ltd	sriganesh_rao@hotmail.com
18.	Prof R. S. Chauhan	Department of Veterinary Pathology, G B Pant University of Agriculture & Technology, Pant Nagar	profchauhan58@gmail.com
19.	Prof R. S. Chauhan	College of Fisheries G.B. Pant Uni. of Agri. & Technology, Pant Nagar	rikhi812chauhan@gmail.com
20.	Dr. Lenin Raja	Scholar-EMC Compliance & RF	leninaucbe@gmail.com
21.	Narendra Bhooshan	Ex- JS IT, Ministry of Agriculture & farmers welfare, New Delhi	narendra.bhooshan@gov.in
22.	Pavan Kumar Gupta	Ex- Director IT, Ministry of Agriculture & farmers welfare, New Delhi	pavan.gupta@gov.in
23.	Bipin Pradeep Kumar	Subconscious Compute Pvt. Ltd.	bipin.pradeep@gmail.com
24.	Dinesh Chand Sharma	ETSI/ SESEI	dinesh.chand.sharma@eustandards.in
25.	Nitin Sharma	ETSI/ SESEI	nitin.sharma@sesei.eu
26.	Sharad Arora	Sensorise Digital Services Pvt Ltd	sharad.arora@sensorise.net
27.	Dr. Vinosh James	Qualcomm	vinosh@qti.qualcomm.com
28.	Ms. Shanthala K. V.	JSS Academy of Technical Education, Bengaluru	kv.shan76@gmail.com
29.	Divyesh Butala	Prompt dairy tech (Prompt Group)	divyesh.butala@promptdairytech.com
30.	Parag Kulkarni	John Deere	kulkarniparag@johndeere.com
31.	Anand Raj	John Deere	rajanand@johndeere.com
32.	Deepak Sharma	Go4Life Organic Milk Pvt Ltd	deepak.sharma@Go4Life.in
33.	Saikat Mondal	MSQUBE Technology Solutions Pvt Ltd	saikat.mondal@msqube.com
34.	Soumik Roy	MSQUBE Technology Solutions Pvt Ltd	Soumik.roy@msqube.com
35.	Anirban Chanda	MSQUBE Technology Solutions Pvt Ltd	Anirban.chanda@msqube.com
36.	Dr. Dipti Gupta	IIT Bombay	dipti.kanpur@gmail.com
37.	Dr. Ashok K. Das	SunMoksha Power Pvt Ltd	das@sunmoksha.com
38.	Ms. Akanchha Sehgal	Cognizant	alpi2012@gmail.com
39.	Ronak Chitlangya	Ex-intern TEC	ronakchitlangya1997@gmail.com

40.	K. Ameerbabu	Ex-intern TEC	vtu7357@veltechuniv.edu.in
41.	Shekhar Singh	TEC	ad.iot-tec@gov.in

E. Joint Editorial Team:

S. No.	Name	Organization	E-mail Address
1	Sushil Kumar	TEC	ddgsd.tec@gov.in
2	Prof. Ekram Khan	Aligarh Muslim University	ekhan.el@amu.ac.in
3	Balamurugan MS	VIT Chennai	balamurugan.ms@vit.ac.in
4	Raunaque M. Quaiser	STMicroelectronics	raunaque.quaiser@st.com
5	Sriganesh Rao	Calligo Technologies Pvt. Ltd	sriganesh_rao@hotmail.com
6	Ronak Chitlangya	Ex-intern TEC	ronakchitlangya1997@gmail.com
7	Ms. Ashima	TEC	dirsd1.tec@gov.in
8	Saurabh Gupta	TEC	ddgnr.tec@gov.in
9	Ms. Sunita Chandra	TEC	chandra.sunita@gmail.com
10	Shekhar Singh	TEC	ad.iot-tec@gov.in
11	Ms. Namrata Singh	TEC	namrata.singh51@gov.in

Executive Summary

As per the Census of India 2011, population of the country was around 1.21 billion. Out of this rural population was 0.833 billion and urban 0.377 billion with Rural – Urban distribution as 68.84% & 31.16% respectively. At present India's total population is around 1.3 billion, out of which approx. 68% are living in rural areas (in about 0.65 million villages or 0.25 million Gram Panchayats (GPs)/ Village Panchayats) and the rest in urban areas (towns and cities). From administrative point of view, India is having twenty-eight states and eight union territories and total 720 districts. Districts are further divided into tehsils & blocks and blocks are also further divided into village panchayats for the purpose of administration and development. Each village panchayat generally has 2-3 villages. Tele-density (number of telephone connections (fixed lines and mobile phone subscribers) per 100 inhabitants) as per Telecom Regulatory Authority of India (TRAI) report released in December 2020[1] is 140.57 % for urban areas and 58.94 % for rural areas.

There is a lot of migration from rural to urban areas in view of search of jobs, better education and health care. Cities are being developed as Smart cities to improve the quality of life of citizens, therefore on the similar lines it is very much required to develop Smart villages. IoT/ ICT can play a big role in extending the facilities available in urban to the rural areas.

Scarcity of electricity in villages is one of the major concern for electricity dependent activities. The health, educational and civil infrastructures are also in need of considerable improvement. For launching smart village applications, such as telemedicine, smart agriculture, e-Governance, animal & human health monitoring, and precise irrigation etc., there is a need for increased tele-density and high speed internet facility in rural India. With the development of sensor-based devices and emerging communication technologies, smart infrastructure may be created in various verticals, which will help in improving the quality of life and also in creating employments among the rural populations.

Mahatma Gandhi's idea of Village Swaraj was that a village should be a complete republic, independent of its neighbours for its own vital needs, and yet interdependent for many others in which dependence is a necessity. This has to be enabled at ground level to facilitate self-reliance of villages. Innovation and interventions led by science and technology are key to accelerating the dream of 'Village Swaraj'.

'Smart Village and Agriculture' Working Group (WG) was created in TEC on the requirement from the industry and it was then formally approved by Sr. DDG TEC. It is having members from industries, academia, Government, Start-ups etc. The scope of WG is to study problems and provide smart solutions addressing the major issues related to human being, agriculture and animals, using emerging technologies (IoT /ICT). This WG through detailed deliberations and discussions has included relevant use cases related with smart rural community, e.g. Remote patient monitoring, Soil nutrients monitoring, Smart irrigation, Animal activity monitoring tag, Arresting food adulteration using IoT & Blockchain, Smart anganwadi, IoT & ML based Smart aquaculture, 5G and Intelligent farming, Drone application in Agriculture and A smart village model etc. The WG has also studied the national / international smart villages, and some of them have been briefly described in this report. This report also reflects the Indian scenario and initiatives taken by Government of India, and also the suggestions for expanding the telecom /internet / Smart services in

[1] https://www.trai.gov.in/sites/default/files/PR_No.101of2020_0.pdf

rural areas. Challenges, recommendations and the related international standards for the development of eco system in rural communities have also been incorporated in this document.

In the present scenario of COVID 19, facilities like remote health care, tele-education, e-Governance have become a necessity in rural areas. Provisioning high speed communication network will help in extending these services and also in creating smart applications in agriculture, animal husbandry, fisheries, e-Governance and so many other verticals in rural areas.

1. Introduction

1.1. National Digital Communication Policy (NDCP)- 2018

Following provisions have been made as a directive by Department of Telecommunications (DoT) in National Digital Communication Policy[2] (NDCP)-2018 for the fast expansion of telecom services in the country: -

1. Promoting innovative, effective and scalable alternate technologies for remote areas.
2. Strengthening institutional capacity of USOF to ensure effective rollout of services in uncovered, remote and rural areas.
3. Enhancing the backhaul capacity to support the development of next-generation networks like 5G.
4. Provide universal broadband connectivity at 50 Mbps to every citizen and enable 100 Mbps broadband on demand to all key development institution; including all educational institutions.
5. Implementing a 'Fibre First Initiative' to take fibre to the home, to enterprises and to key development institutions in Tier I, II and III towns and to rural clusters.
6. Facilitate the establishment of Mobile Tower Infrastructure by promoting and incentivizing deployment of solar and green energy for telecom towers.
7. Promoting research and development of green telecom through active participation of stakeholders across government, industry and academia.
8. Creating a roadmap for emerging technologies and its use in the communications sector, such as 5G, Artificial Intelligence, Robotics, Internet of Things, Cloud Computing and M2M.
9. Developing market for IoT/ M2M connectivity services in sectors including Agriculture, Smart Cities, Intelligent Transport Networks, crowd management, Multimodal Logistics, Smart Electricity Meter, Consumer Durables etc. incorporating international best practices.
10. Provide 1 Gbps connectivity to all Gram Panchayats of India by 2020 and 10 Gbps by 2022 under BharatNet.
11. Enable deployment of public Wi-Fi Hotspots; to reach 5 million by 2020 and 10 million by 2022 and achieve 'unique mobile subscriber density' of 55 by 2020 and 65 by 2022.
12. Ensure connectivity to all uncovered areas.
13. Implementation of following broadband initiatives to be funded through USOF and Public Private Partnerships-
    a. **GramNet**- Connecting all key rural development institutions with 10 Mbps upgradable to 100 Mbps.
    b. **JanWiFi**- Establishing 2 Million Wi-Fi Hotspots in rural areas.

[2]http://dot.gov.in/sites/default/files/EnglishPolicy-NDCP.pdf

1.2. Work carried out by TEC in IoT domain

TEC formed 12 multi-stake holders Working Groups in the last 3-4 years, to study and prepare Technical Reports in M2M/ IoT domain with outcome to be used in policies and standards. As a result, 13 Technical Reports have been released so far as detailed below-

1. M2M Enablement in Power Sector
2. M2M Enablement in Intelligent Transport System
3. M2M Enablement in Remote Health Management
4. M2M Enablement in Safety & Surveillance Systems
5. M2M Gateway & Architecture.
6. M2M Number resource requirement and options
7. V2V / V2I Radio Communication and Embedded SIM
8. Spectrum requirements for PLC and Low Power RF Communications.
9. ICT Deployments and strategies for India's smart cities: A curtain raiser
10. M2M/ IoT Enablement in Smart Homes
11. Communication Technologies in M2M / IoT domain
12. Design and Planning Smart Cities with IoT/ ICT
13. Recommendations for IoT / M2M Security

All these reports are available on TEC website[3]. A number of actionable points emerged from these reports. Some of the important points which became the part of policy/ standard are:

1. Based on TEC Technical Report, 13 digit M2M Numbering plan for SIM based devices/ Gateways which will co-exist with existing 10-digit numbering scheme being used for mobile phones was prepared in TEC and recommended for approval
    - DoT approved this scheme in Dec 2016 and issued orders to all the TSPs for implementation.
        Five codes of 3 digits each (559, 575, 576, 579 and 597) have been allotted as a M2M identifier.

2. M2M SIM/ Embedded SIM & remote subscription management: - In view of technical report released on this subject, Interface Requirement (IR) was prepared in TEC.
    - DoT has approved the use of Embedded SIM with OTA provisioning.
    - Ministry of Road Transport and Highways in India has issued a Standard [AIS-140] which mandates the use of Embedded SIM for Commercial Passenger Vehicle Tracking.
    - The Bureau of Indian Standards (BIS) has released a new Standard for Automotive Tracking Device and Integrated Systems (IS16833: 2018) which mandates the use of the embedded SIM as per the Standards/Specifications of TEC, DoT.

3. Any device / Gateway having direct connectivity with PSTN / PLMN should have static IP (IPv6 or IPv4). As IPv4 addresses are going to exhaust, early adoption of IPv6 at device, network and application level will be necessary.
    Bureau of Indian Standards (BIS) in its standard IS16444 has mandated IPv6 for Smart meters to be connected on Cellular technologies.

4. Multi-protocol gateways: Important for Smart homes/ building solutions. Essential requirement has already been prepared under MTCTE.

5. Common Service layer at the platform for sharing of data across verticals and across platforms.

[3] https://www.tec.gov.in/M2M-IoT-technical-reports

6. Spectrum for low power wireless communication technologies
   - Based on Technical Report, additional Spectrum of 12MHz for Low power RF communication technologies in Sub GHz band, adjacent to existing delicensed spectrum (865-867 MHz) was recommended to reserve and release as per requirement.
   - DoT referred the case to TRAI.
   - TRAI had recommended 7 MHz spectrum [1 MHz of spectrum in 867- 868 MHz and 6 MHz in 915-935 MHz band] to be delicensed on priority, in its recommendation on "Spectrum, Roaming and QoS related requirements in Machine-to-Machine (M2M) Communications" released in Sept. 2017.
   - DoT approved the TRAI recommendations. This delicensed spectrum is expected to be released by WPC in the NFAP.

7. **Spectrum requirement in 5.9 GHz for DSRC technology: -** As per recommendation of TEC TR on "V2V/ V2I Radio Communication and Embedded SIM", related to the study of DSRC technology for V2V applications in Intelligent Transport System, 5.9 GHz spectrum was recommended. Dedicated Short Range Communication (DSRC) technology, working in 5.9 GHz band, has been deployed in USA, Canada, Europe, Singapore and Australia for Vehicle to Vehicle (V2V) applications.
   3GPP in its Release 14 (and beyond) has provided specifications for C-V2X technology [here X refers to Vehicle (V), Infrastructure (I), People (P) and Network (N)]. It is having basic safety features (V2V) from DSRC/ 3GPP. It will also work on 5.9 GHz band; therefore, this frequency band may also be used in implementation of C-V2X technology for Intelligent Transport System.

8. **Licensing/ Registration for non-cellular LPWAN technologies (such as LoRa, Sigfox etc.) service providers: -** It is important from the policy as well as security perspective to have the details of agencies providing public services. This may be the part of M2M Service provider registration policy, expected in near future.

1.3. What is a Smart Village?

A comprehensive definition of an ideal village was proposed by Late Dr. A. P. J. Abdul Kalam as "**PURA**" village for Provisioning Urban amenities for Rural Areas. A smart village can be built around the vision of PURA. It addresses the elements of PURA through various hard interventions, such as, sustainable agriculture, water sufficiency, rural industry, locally relevant livelihood, energy sufficiency, waste management, health services, education & skill development, e-Governance, and improved connectivity. Additionally, soft interventions, such as good governance, sanitation, civic services, along with climate change adaptation are also considered. A Smart Village must move the villagers up the value chain to improve socio-economic status of its citizens leading to **'Gram Swaraj'.** This requires, by necessity, to substantially increase the income of the farmers (to be doubled in the next five years, as a short term goal). Some of these facilities may be extended by use of ICT infrastructure. In an ambitious bid to transform rural areas to economically, socially and physically sustainable spaces, the need of the hour is the "Development of a cluster of villages that preserve and nurture the essence of rural community life with focus on equity and inclusiveness without compromising with the facilities perceived to be essentially urban in nature, thus creating a cluster

of Rurban villages". National Rurban Mission[4] provides several glimpses in the requirements of Smart Villages, whose main motivation is to prevent migration of rural workers and youth to major urban cities by improving the living conditions in villages, and provide necessary amenities and access to technology.

A 'Rurban cluster', would be a cluster of geographically contiguous villages with a population of about 25000 to 50000 in plain and coastal areas and a population of 5000 to 15000 in desert, hilly or tribal areas. As far as practicable, clusters of villages would follow administrative convergence units of Gram Panchayats and shall be within a single block/ tehsil for administrative convenience.

To realize the Rurban mission goals, deployment of ICT initiatives is necessary. The increasing reach of technology and related areas in providing innovative solutions can be used to address the requirements of smart villages as listed in the next subsection.

1.4. Smart Village Requirements

In the Rurban Mission document, 14 components are listed as imperatives in reurbanizing villages:

a) Skill development training linked to economic activities
b) Agro Processing, Agri Services, Storage and Warehousing
c) Fully equipped mobile health unit
d) Upgrading school/higher education facilities
e) Sanitation
f) Provision of piped water supply
g) Solid and liquid waste management
h) Village streets and drains
i) Streetlights
j) Sustainable green energy provisions
k) Inter-village road connectivity
l) Public transport
m) LPG for cooking
n) Digital Literacy
o) Citizen Service Centres- for electronic delivery of citizen centric services/e-gram connectivity. Components pertaining to agriculture and allied activities would be required to be given special emphasis while developing these clusters.

Services / applications which may be provided in various verticals using IoT/ ICT creating smart infrastructure are given in table below:

[4]www.rurban.gov.in

Table 1: Applications of IoT/ ICT in rural areas

S. No.	Vertical	IoT/ ICT applications
1	Health	Remote consultation (tele-medicine), Remote monitoring of a patient after surgery (e-health), remote diagnostics, medication reminders, Tele-medicine, wearable health devices, e-ICU
2	Education	Tele-education, e-attendance (biometric)
3	Power	Renewal energy sources like Solar, Biomass and connecting to smart micro grid, Smart distribution network, Smart metering, smart grid, Electric line monitoring, gas / oil / water pipeline monitoring
4	Agriculture	Smart irrigation, Livestock monitoring, weather monitoring and forec asting, sensor based precision agriculture, remote crop monitoring, R emote monitoring of soil quality, Smart warehousing, logistics and di stribution, Smart asset monitoring.
5	Animal Husbandry	Animal tracking, remotely monitoring the health of an animal using wearable health devices
6	e-Governance	Citizen centric services like birth / death certificate, electronic attend ance in Government offices, connecting police station, banks, post offices etc.
7	Food processing	Production & Storage, Better Food safety, Wastage Reduction
8	Aquaculture	Water quality (dissolved oxygen, ammonia, pH etc.) management, Int elligent feeding, aquatic animal health management

Using IoT/ ICT infrastructure in various verticals as detailed above, facilities may be extended in the rural areas for improving the quality of life as well increasing the income of the villagers. It will also help in reducing migration and creating employment.

2. Telecom / ICT in rural and remote areas of the country – Challenges and Requirement

India is one of the fastest growing telecom markets in the world. The unprecedented increase in Tele-density and sharp decline in tariffs in the Indian telecom sector have contributed significantly to the country's economic growth. Telecommunications, along with Information Technology, has greatly accelerated the growth of the economic and social sectors. However rural tele-density is quite low as compared to urban due to a number of challenges in rural areas as detailed below: -

2.1. Challenges

Expansion of telecommunications in the rural areas has been much slower than urban areas due to poor ROI (return on investment) for the service providers. One of the reasons of low tele-density in rural areas is due to poor economic condition of most of the villagers and also due to poor coverage of telecom services. Many other reasons such as lesser number of BTS, abrupt electricity supply, poor transport system, poor conditions of roads and availability of petrol pumps at distant places in major portion of the rural areas, are also responsible for poor telecommunication/ ICT infrastructures in villages.

2.1.1. Urban – Rural digital divide

As per TRAI (Telecom Regulatory Authority of India) report[5] of December 2020, the number of telephone subscribers in India increased from 1,168.66 million at the end of September-20 to 1,171.80 million at the end of October-20, thereby showing a monthly increase rate of 0.27%. Urban telephone subscription increased from 644.26 million at the end of September-20 to 647.36 million at the end of October-20 and the rural subscription also increased from 524.39 million to 524.44 million during the same period. The monthly growth rates of urban and rural telephone subscription were 0.48% and 0.01% respectively during the month of October-20.

The overall Tele-density in India has increased from 86.22 at the end of September-20 to 86.38 at the end of October-20. The Urban Tele-density has increased from 138.25 at the end of September-20 to 140.57 at the end of October-20 and the Rural Tele-density has declined from 58.96 at the end of September-20 to 58.94 at the end of October-20. The share of urban and rural subscribers in total number of telephone subscribers at the end of October-20 was 55.24% and 44.76% respectively.

From these details, it is clear that though there has been telephone subscription growth in rural area, at the same time there is a big urban – rural digital divide. The full potential of mobile and internet in enabling higher growth will not be realised until the use of these services spreads much wider in the rural area. Growth of mobile and internet in the rural area will help in Tele- education, Tele-health, smart agriculture, skill development, expansion of various services such as banking, insurance etc., creation of new jobs and also in running various e- governance programmes. It will in turn help in curbing poverty, reducing migration, population control and also in improving the quality of life of villagers.

[5] https://www.trai.gov.in/sites/default/files/PR_No.101of2020_0.pdf

Over the past few years there has been large expansion of internet services in India, mostly driven by cheaper and affordable smartphones as well as mobile internet plans.

India's smartphone using population is estimated to reach 820 million by 2022. According to a report jointly released by Indian Cellular and Electronics Association and consulting firm KPMG, rural India witnessed a year-on-year growth of 35% in 2018 as opposed to 7% growth in urban India in the same period in terms of internet users. Smartphone penetration in rural India has risen from 9% in 2015 to 25% in 2018.[6]

In India, internet users across the country are projected to grow to over 974 million users by 2025 from around 700 million in 2020, indicating a big market potential in internet services for the south Asian country. In fact, India was ranked as the second largest online market worldwide in 2019, coming second only to China. The number of internet users was estimated to increase in both urban as well as rural regions, indicating a dynamic growth in access to internet.[7]

2.2. Requirements for deploying high speed communication network in rural areas[8]

- High speed optical fiber network to provide at least 100 Mbps bandwidth in a Gram panchayat/ village panchayat, for a cluster of villages, generally 2 – 3 villages. It has been described in detail in Section 2.4 as an example.
- Connectivity in the hilly and remotely accessible areas through Microwave link or Satellite connectivity.
- This connectivity/ bandwidth may be further extended through Wi-Fi hotspots to other nearby villages.
- 100 Mbps bandwidth created in a Gram panchayat may be further extended to other location by telecom service providers by laying OFC for commissioning mobile BTS to provide mobile coverage in the rural area.
- Infrastructure such as tower of 20/40/60 meter height, DG set, Battery set, and Container etc. may be created by infrastructure provider, and may be used by telecom service providers / LPWAN providers. Tower height depends upon the terrain and the geographical region to be covered. Cost effective solar panels capable of replacing electric generators may be a solution for fast expansion of mobile network in rural area.
- Sharing of passive/ active infrastructure and also the unused spectrum in the rural areas will help in reducing the overall cost of the project.
- Towers and the bandwidth may also be used by FM broadcasters for transmitting regional programmes as well as for spreading important news such as cyclone/ heavy rains weather forecast etc. to alert the people and civil agencies for moving to safer areas. It may save thousands of lives during such natural calamities.
- All efforts should be made to utilise the OFC as soon as it is commissioned and it should be monitored from Central Monitoring Server (CMS). OFC if lying idle for a long time and

[6]https://economictimes.indiatimes.com/industry/telecom/telecom-news/indian-to-have-820-million-smartphone-users-by-2022/articleshow/76876369.cms
[7]https://www.statista.com/statistics/255146/number-of-internet-users-in-india/
[8]https://tec.gov.in/pdf/Studypaper/study%20paper%20on%20Telecom%20&%20ICT%20for%20rural%20and%20remote%20areas%20of%20India.pdf

damaged in some development activities such as road widening, drainage work etc. may be difficult to repair later on at the time of rolling out the services.

- Role of equipment manufacturer is also very important. Due to poor electricity condition, poor roads and distant location of petrol pumps in rural areas, it is quite difficult and expensive to run the rural BTS with even 90% availability. Low power BTS & Transmission equipment will also help in reducing the overall power consumption.
- Smart phones/ Laptops/ tablets may be out of the budget of lower medium families in rural areas of most of the developing countries. There may be a big market of cheaper & affordable Smart phones / Tablets / Laptops with long battery life which may accelerate the growth of mobile network in rural areas. Cost of these devices may vary from country to country but if the rural population is able to afford these devices, it will help in increasing the Tele-density, digital literacy, and internet usage in rural areas.
- A complete ecosystem is required to be developed for the rural area. Government as a policy maker, telecom service providers, equipment manufacturer and various local bodies have to work together for a win-win situation for the expansion of telecom services in rural areas.

2.3. Government of India initiative for expansion of Internet services in rural areas

Mobile and Internet services improve the lives of the people by providing affordable access to information and knowledge. Many Information and Communication Technology (ICT) applications such as e-commerce, e-banking, e-governance, tele-education and tele-medicine etc. require high speed Internet connectivity. Therefore, OFC is required in backbone network to create a super highway and may also be used for providing 100 Mbps to 1 Gbps bandwidth for these services.

Department of Telecommunications (DoT), Ministry of Communications, Government of India had created a special purpose vehicle, named Bharat Broadband Network Limited (BBNL) in 2011 for accelerating the National Optical Fiber Network project (NOFN) for providing 100 Mbps connectivity to 0.25 million village panchayats. Approx. 1.5 Km – 2 Km OFC will be laid from the existing OFC coming from the telephone exchange having OLT installed / planned. As most of the existing optical fiber cables are having only few good quality fibers, therefore splitter have been planned to connect these fibers (OFC coming from the OLT) with the OFCs laid for the nearby Gram panchayats.

But if the OFC coming from OLT towards village areas is new and having sufficient number of spare good quality fibers then each Gram panchayat may be connected on separate pair of fibers and splitter is not required. Planner may decide depending upon the availability of fibers and the requirement.

Fiber to the home (FTTH) and Giga bit Passive Optical Network (GPON) technology may be used to create 100 Mbps bandwidth for each gram panchayat. OLT (Optical Line Terminal) installed in the telephone exchange (preferably at Block Head Quarter) is connected with the ONT (Optical Network Terminal) in the Gram panchayat on OFC to create 100 Mbps bandwidth. OLT may be

further connected at the backend with different network terminals / servers on Giga bit connectivity for providing the services[9].

Telecom service providers/ LPWAN providers may hire part of this bandwidth to expand their networks. Internet services may be further extended in nearby village area by using Wi-Fi hotspots for providing internet facility to the villagers.

In the year 2015 the Government of India renamed this project as BharatNet with the target of turning it into the world's largest rural broadband connectivity project using optical fibre.

The overall project status is available on BBNL website.[10] Around 0.15 million gram panchayats have been connected on optical fiber cable by January 2021 and the work for is in progress to connect the remaining gram panchayats.

Recently, Department of Telecom (DoT) released a Framework and Guidelines for Wi-Fi Access Network Interface (PM-WANI)[11] to proliferate Broadband access through Public Wi-Fi networks. This framework takes forward the goal of National Digital Communications Policy, 2018 (NDCP) of creating a robust digital communications infrastructure. It will give a major boost for providing broadband internet connectivity through Wi-Fi network and will also help in enabling smart solutions in rural areas.

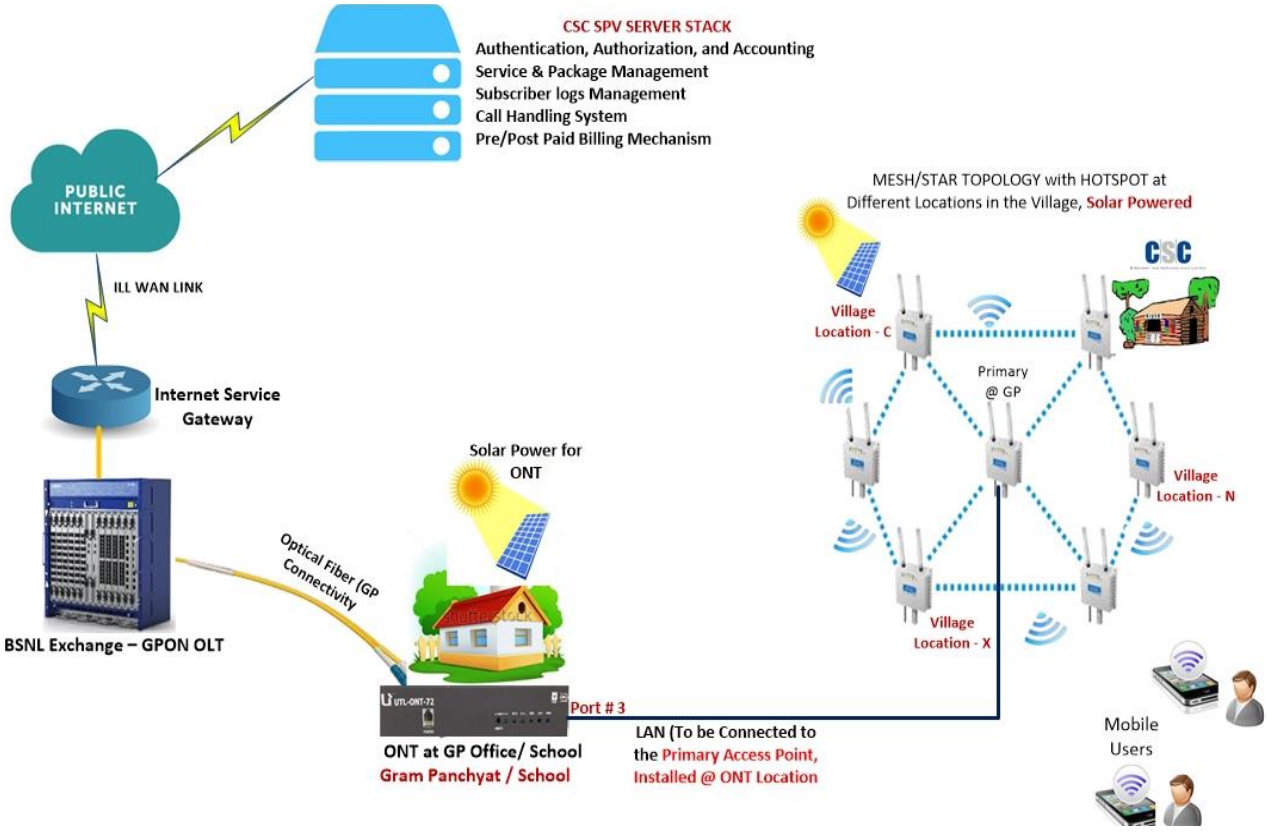

Figure 1: Deployment of telecom infrastructure through BharatNet

[9]https://tec.gov.in/pdf/Studypaper/study%20paper%20on%20Telecom%20&%20ICT%20for%20rural%20and%20remote%20areas%20of%20India.pdf
[10]http://bbnl.nic.in/
[11] https://dot.gov.in/sites/default/files/2020_12_11%20WANI%20Framework%20Guidelines.pdf?download=1

This project will improve the back-bone network for telecom & ICT services in the rural area. BharatNet has the potential to transform many aspects of rural scenario by providing services such as voice, video and data. This project will facilitate Information and communication Technologies (ICT) applications such as e-Commerce, e-Banking, e-Governance, e-Education and Tele-medicine etc. which require high speed Internet connectivity.

2.4. Required IoT / ICT Infrastructure

2.4.1. What is M2M/ IoT?

M2M (Machine to Machine) Communication refers to the technologies that allow wired / wireless system to communicate with devices of same ability. M2M uses a device (sensor, meter etc.) to capture an 'event' (motion, meter reading, temperature etc.), which is relayed through a network (wireless, wired or hybrid) to an application (software program), that translates the captured event into meaningful information.

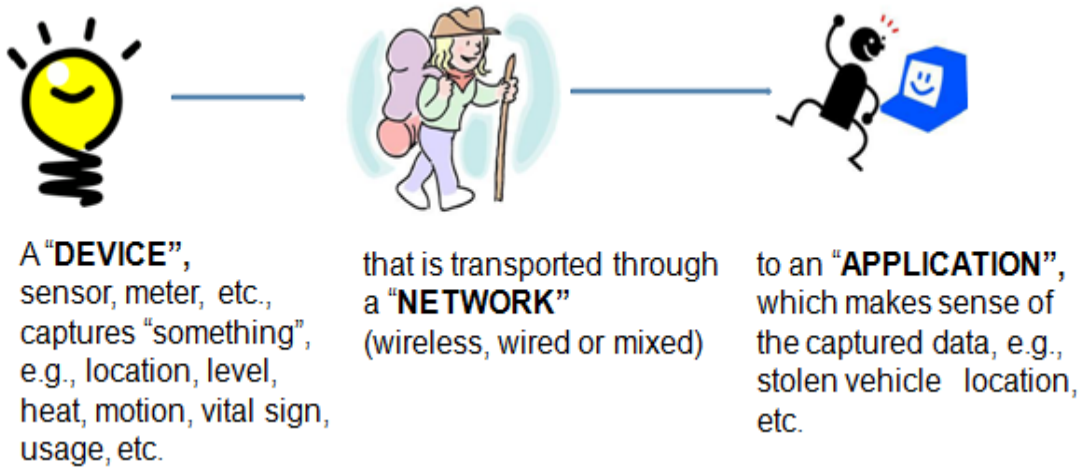

Figure 2: Machine to Machine Communication- a conceptual picture

ITU-T in its Recommendation ITU-T Y.2060 (06/2012) has defined Internet of Things (IoT), as a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.

The IoT ecosystem may have M2M devices, Gateways, M2M Communication technologies, big data and process management, IoT platform, User interface (web, Mobile, HMI) and end to end security. IoT will be having a heterogeneous network, having IP and non-IP devices connected through IP Gateways. Gateways will be connected to IoT Platform. A huge amount of data will be generated by the sensors.

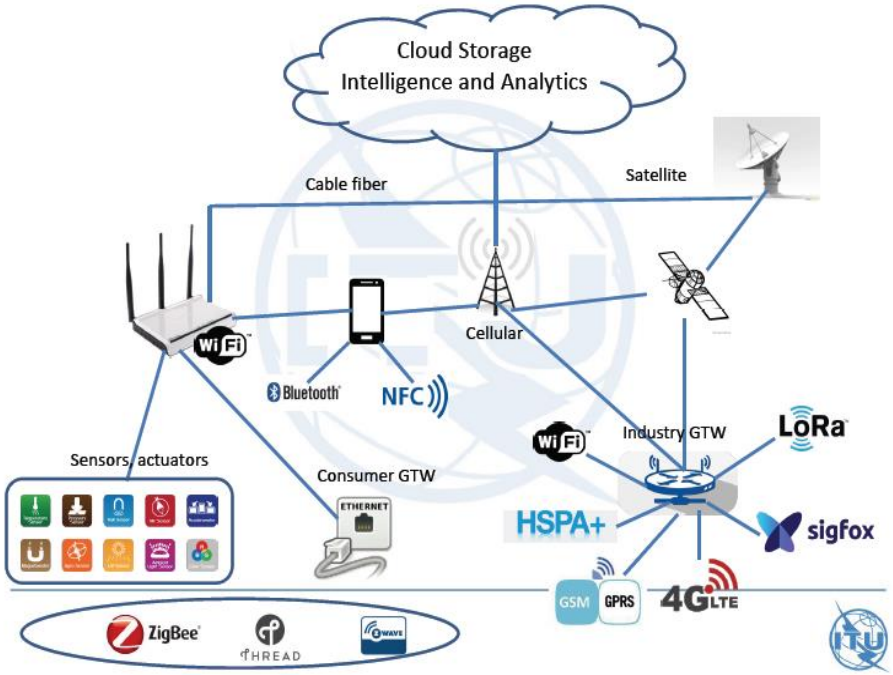

Figure 3: IoT Architecture (Source: ITU)

The Internet of Things (IoT) will revolutionize and change the way all businesses, governments, and consumers interact with the physical world. This level of disruption will have a significant impact on the world in improving the quality of life.

The sensor network and communication technologies required to develop smart villages are briefly described below-

2.4.2. Sensor Network

A Sensor Network[12] consists of small, typically battery powered devices and wireless infrastructure that monitor and record environmental conditions such as humidity, temperature, vibration, pressure etc. The data is collected at a sensor and then relayed from sensor to sensor towards a base station. Wireless sensor networks often deploy mesh networking for effective operation. Such a mesh network can be energy intensive as each node has to pass on another's data as well as its own. Using a wireless sensor network reduces the need for physical cables for power and data transmission. The network itself connects to the internet to transmit data to head end systems/ cloud. As raw data has got no value, therefore data analytics is used to create intelligence. This intelligence may be used for various operational and planning activities.

2.4.2.1. Wireless sensors[13]

Among all the equipment for smart farming currently available in the market, wireless sensors are the most crucial and play a key role when it comes to collecting the crop conditions and other information. Wireless sensors are being used standalone wherever

[12]https://www.elprocus.com/architecture-of-wireless-sensor-network-and-applications/
[13]https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8784034

required, further integrated with almost every portion of advanced agricultural tools and heavy machinery, depending on application requirements. Few majorly used sensors are listed below-

1) Acoustic Sensors

Acoustic sensor functioning is based on measurement of the change in the noise level as it interacts with other materials, e.g. soil particles. These kinds of sensors mostly find applications in pest monitoring and detection and classification of seed varieties according to their sound absorption spectra. These sensors offer low-cost solutions with fast response.

2) Optical Sensors

Optical sensors help in measuring the soil organic substances, soil moisture and colour, presence of minerals and their composition, clay content, etc. by using light reflectance phenomena. Fluorescence-based optical sensors are used for basic plant assessment, especially to supervise the fruit maturation.

3) Ultrasonic Sensors

These sensors are majorly used for monitoring of water tanks, crop canopy etc. Along with camera, these sensors can also be used for the weed detection, where the height of plants is identified using the ultrasonic sensors and the camera determines the weed and crop coverage. The main advantages of these kinds of sensors include their low cost and potential to be operated in a variety of applications.

4) Optoelectronic Sensors

As optoelectronic sensors are able to differentiate plant type, hence, they can be used to detect weeds, herbicides, and other unwanted plants, especially in wide range crops.

5) Airflow Sensors

These sensors can measure soil air permeability, percentage of moisture and identify soil type by analysing soil structure.

6) Electrochemical Sensors

These sensors are mostly used to assess the soil characteristics such as pH value, soil nutrient levels etc. These sensors give precise value of the macronutrients and micronutrients in the soil, salinity and pH value.

7) Electromagnetic Sensors

Sensors based on this technology use electric circuits to measure the capability of soil particles to conduct or accumulate electrical charge, which is mostly done by using methods namely Contact or Non-contact. It finds application in measuring the residual nitrates and organic matter in the soil.

8) Mass Flow Sensors

These sensors are useful for yield monitoring as they provide the yield information by measuring the amount of grain flow, e.g., when passing through the combine harvester.

9) Soft Water Level-Based (SWLB) Sensors

These sensors are used for measuring the water level and water flow in agricultural applications.

10) Light Detection and Ranging (LIDAR)

These sensors are widely used in various agriculture applications, such as land mapping and segmentation, determining soil type, farm 3D modelling (when combined with GPS), monitoring erosion and soil loss, and yield forecasting. Besides, this technology is often used in estimating the biomass of various crops and trees.

11) Telematics Sensors

Telemetry sensors are used to collect data from remote locations (especially inaccessible points), operations of machines and working of its components, and recording location etc. These sensors enable farm managers to record and store all information related to farm operations automatically, thus maximizing the utilization of environmental benefits and further can minimize threats like farm equipment theft.

12) Remote Sensing

Remote sensors are used to capture and store the geographic information, further analyse, manipulate, manage and present all types of spatial or geographical data. These sensors are used in various agriculture applications such as crop assessment, forecasting yield dates, yield modelling and forecasting, identification of plants and pests, land cover and degradation mapping etc.

Table 2: Smartphone based sensors being used in various agriculture applications

Smartphone Sensor(s)	**Purpose**	**Common Agriculture Usage**
Image Sensors (Camera)	Takes pictures of any object	Disease detection, chlorophyll status, Fruit ripeness, Leaf area index (LAI), Harvest readiness, Soil erosion and other analysis
Global Positioning System (GPS)	Measuring the latitude and longitude of device, location	Local information is attached to generate alerts. Mostly used for machine driving & control, and tracking, land management and crop mapping
Inertial Sensor	Uses accelerometer and gyro sensor to determine the object altitude in relation to the inertial system	Precise distance of plant, leave or any other object is measured from camera
Barometer	Measure air pressure as an altimeter. Mostly used in correcting altitude measurements by the GPS	Measures the elevation height in hilly agriculture
Gyroscope	Senses the angular velocity to track the object rotation or twist	Equipment movement , Canopy structure measurement

Accelerometer	Measures acceleration forces that used to observe the tilting motion and orientation of the object	Precise movement or rotation of the camera during use. Detect workers or machine activities
Microphone	Detect usual / unusual sound and convert to electrical signals	Machine maintenance , Bug detection to make audio queries

2.4.3. Communication Technologies

Communication technology plays a key role in the successful implementation of smart village concept to facilitate its benefits to the villagers. As detailed in Section 2.3, work is already in progress to connect gram-panchayats through optical fibre cables for providing 100 Mbps connectivity. However, in order to disseminate information at the doorstep of villagers, get access to available information anytime anywhere and also to provide smart services, emerging and existing wireless communication technologies need to be explored.

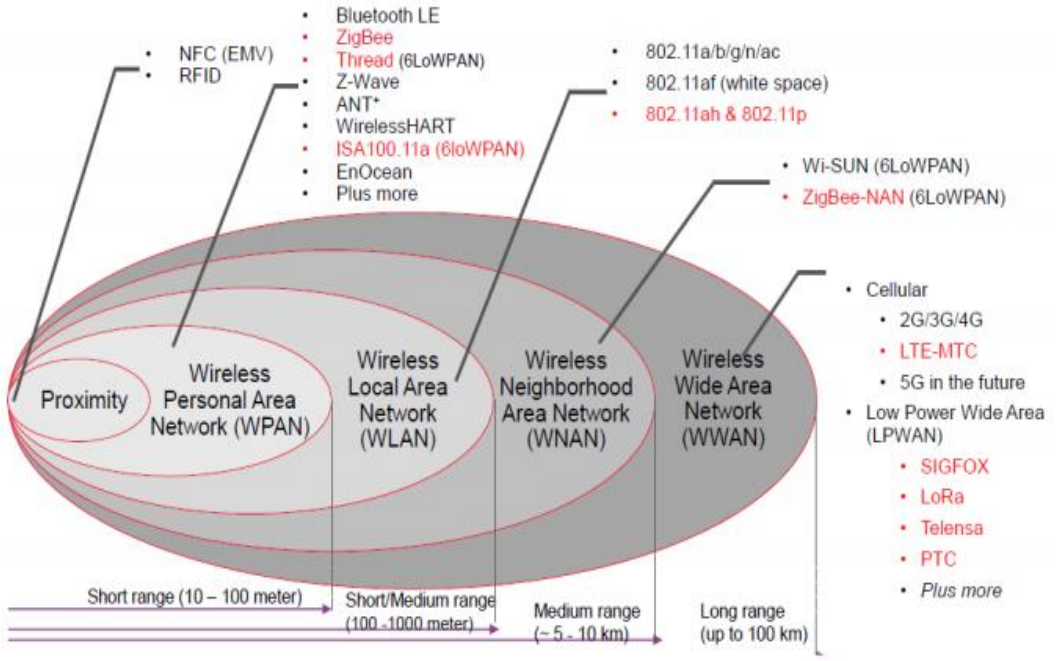

Figure 4: Key enabling wireless communication technologies for IoT

IoT use cases are significantly enabled by the disruption in several technology areas such as sensor networks, Location Based Services (LBS), wired and wireless communication technologies (cellular and non-cellular), Artificial Intelligence, Machine Learning, Big Data Analytics, Cloud Computing, Robotics and 5G.

2.4.3.1. 5G Technology

5G is an emerging communication technology for IoT domain, as it will provide faster speed, lower latency, and wider coverage. 5G technology will provide high speed internet services (eMBB), ultra-reliable Low Latency Communication uRLLC (latency <1ms) and Massive MTC (large number of devices may be connected per square km). Once the 5G

technology is deployed in the country and the rural areas are covered then high speed connectivity may be used for various applications. Some of the cases related to various features of 5G technology have been shown in figure given below-

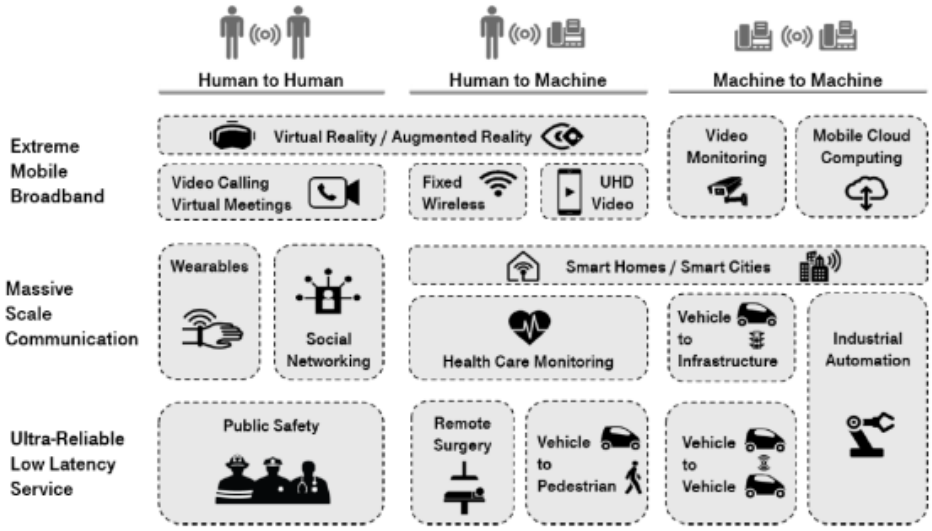

Figure 5: Some 5G use cases (Source: 5G Americas)

5G technology in precision agriculture will ensure greater profitability and efficient utilization of resources by use of automated tractors / harvesters, precision seeders, and automated weed & pest controllers. Drones with 5G technology may be used efficient & precise spraying of fertilizers in fields, and also to scan and identify unwanted weeds through the use of AI. It will help farmers to better organize and allocate their time and attention towards areas that really need it.

uRLLC feature may be used for remote surgery applications, drones and V2V applications in C-V2X etc. Massive M2M and uRLLC features of 5G may also be used for remote monitoring and maintenance of machines centrally and that data could be transmitted in real-time. 5G is key in this area because if such systems function on other networks such as 3G and 4G, then there may be delay in transmission and uploading of collected data on the server.

2.4.3.2. Low Power Wide Area Network (LPWAN) technologies

LPWAN technologies have been developed to carry a very small data to a large distance and consume very low power. It covers 2-3 Km in city (dense) areas and 12-15 Km in rural (open) areas. Expected battery life is around 10 years. LPWAN technologies are available on 3GPP as well as non 3GPP standards, as shown in Figure - 6.

Use cases: Smart metering (water / gas), Smart farming (transmitting Soil testing data), Smart bin, transmitting pollution sensor data, transmitting fire alerts etc.

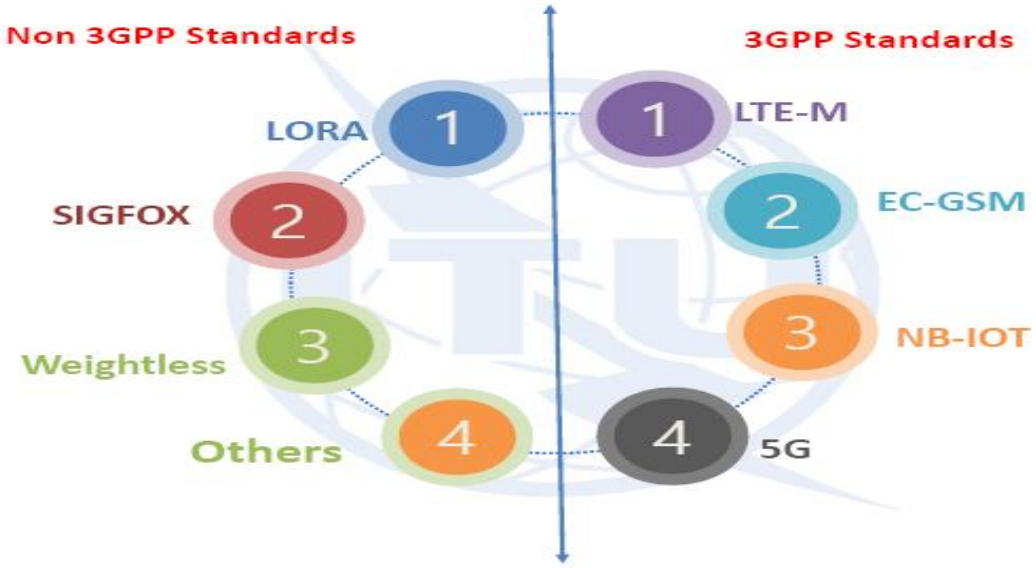

Figure 6: Low Power Wide Area Network (cellular and non-cellular) technologies

Non-3GPP LPWAN technologies such as LoRa and Sigfox are being deployed across the globe. LoRa and Sigfox networks are deployed in delicensed sub GHz frequency band and in India it is 865-867 MHz. M/s TATA Communications Ltd. (TCL) and M/s SenRa are deploying LoRa based network in India.

3GPP has already released specifications in its Release 13 and onwards for LPWAN services, which may co-exist in the existing cellular networks. Three variants in LPWAN technologies in cellular domain are EC-GSM, NB-IoT and LTE MTC. Cellular operators may enable LPWAN services in the existing GSM / LTE networks by upgrading the software. Trials are already in progress and the commercial offerings are also available in a number of countries across the globe. Cellular operators in India are also doing trails for providing NB-IoT services.
TEC has released a Technical Report on "Communication technologies in M2M/ IoT domain", which is available on TEC website[14]

A brief description of various communication technologies along with their suitability in different applications is given in Annexure-1.

2.4.4. Use of AI/ ML and blockchain in data analytics

A huge amount of data will be generated from the sensors/ devices. Raw data has got no meaning. Big data analytics may be used to create intelligence. Intelligence may be used in various planning and operational activities. AI and ML based algorithm may be used to have better results. Data is generally stored in the cloud. As the high bandwidth and low latency communication media will be required to send the data to the cloud, therefore technologies like Edge Computing / Mobile Edge Computing have emerged. Analytics may be done at the router edge or at the edge of mobile network. Such type of solutions are required in the critical applications, where the action is required to be taken immediately. Use cases available in Annexure- 3, 12 and 14 are using AI/ ML algorithms.

[14]http://tec.gov.in/pdf/M2M/Communication%20Technologies%20in%20IoT%20domain.pdf

Blockchain technology plays an important role in ensuring data processing, circulation, sharing and management for all trust operations in supply chain management. Blockchain provides a trust free, tamper-proof, auditable and self- regulating system for data exchange and sharing in support of IoT and smart cities & communities. One such use case employing blockchain technology in milk supply chain has been described in Annexure-11.

2.5. Extending various M2M/ IoT Applications in rural community

Various M2M / IoT applications, which may be provided in rural areas, have been summarised in Table 1.

Out of 100 Mbps data connectivity provided to village panchayat, around 20 Mbps may be used for Tele- education and 15- 20 Mbps for Tele-medicine/ e-health. Internet facility may be further extended at the door step of the rural communities by using Wi-Fi hotspots (as detailed in Section 2.3) for providing high speed internet services, e-Governance applications, banking services, insurance services and e-Post (postal services) etc as described in Figure-7.

Tele medicine/ e-health/ m-health and wearable personal health devices along with Aadhar application for identification may help in improving the health services in the rural areas. Detailed use case is available in Annexure-2.

Figure 7: Role of smart devices and ICT in various applications (Source: ITU)

M2M / IoT applications such as vehicle tracking, safety and surveillance, Food Supply Chain Management System (FSCM) may be implemented in rural areas. Agriculture related M2M services such as remote-controlled water pump solution, water level monitoring, data gathering for milk & Agricultural cooperatives, fisheries, poultry & soil

analysis may also be extended in near future. All these applications will help in improving the social & economic condition of the people living in rural communities to a larger extent and will help in improving the quality of life.

3. Target Areas

This Technical Report presents an overview of the difficulties being faced in rural areas in India and the various efforts being made by the Government of India in coordination with the State Government, Non-Governmental organisations for the benefit of residents in rural areas.

3.1. Agriculture

While the agriculture sector's contribution to GDP has decreased over the past few decades, the contribution of sectors such as manufacturing (employing 10.5% of the population) and services (employing 24.4% of the population) has increased[15]. The agriculture sector employs nearly half of the workforce in the country. The migration is mainly due to the low income in this sector compared to the non-agricultural sectors.

The average holdings have declined from 1.32 ha to about 0.68 ha in 2020 and it is expected to reach mere 0.32 ha in 2030[16]. Declining the size of land holdings without any alternative income results in a fall in agriculture income, causing distress among the farming community.

The total grain demand will increase from 201 million tonnes in 2000 to about 291 and 377 million tonnes by 2025 and 2050, respectively[17]. The demand for high-value commodities such as horticulture, dairy, livestock and fish is expected to increase by more than 100% and these commodities are perishable ones and require infrastructure for handling, value-addition, processing, storage and marketing.

Agriculture is the main backbone of India's economic growth. The most significant barrier that arises in traditional farming is climatic change. The number of effects of climatic change includes heavy rainfall, most intense storm and heat waves, less rainfall etc. Due to these, the productivity in agriculture decreases to a major extent. To boost productivity and minimize the barriers in agriculture field, there is a need to use emerging technologies like Internet of Things (IoT). IoT/ ICT may transform the agriculture sector, enabling farmers to compete with the enormous challenges they face. Farmers may get information and knowledge about recent trends and technology in agricultural sector using IoT[18]. Role of ICT in Agriculture sector is described in Figure-8.

IoT devices can be of great help in enhancing the production and yield in the agriculture sector, since these devices can be used to monitor soil parameters, temperature levels, and other variables. IoT sensors capable of providing farmers with information about crop yields, rainfall, pest infestation, and soil nutrition are invaluable to production and offer precise data that may be used to improve farming techniques over time[19].

[15] https://www.prsindia.org/policy/discussion-papers/state-agriculture-india
[16] https://www.assocham.org/newsdetail.php?id=5599
[17] https://www.researchgate.net/publication/301262798_Production_and_Consumption_of_Grains_in_India
[18]https://www.iosrjournals.org/iosr-jce/papers/Conf.16051/Volume-1/13.%2056-57.pdf?id=7557
[19]http://prsindia.org/policy/discussion-papers/state-agriculture-india

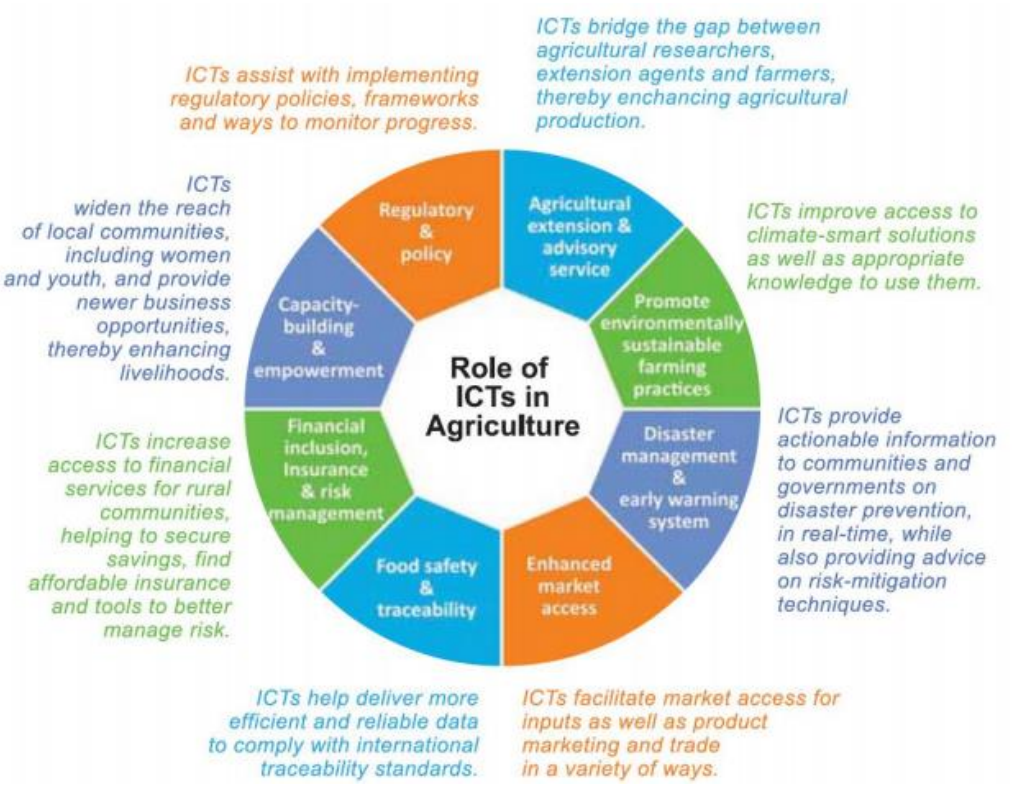

Figure 8: Role of ICT in Agriculture (Source: ITU)

3.1.1. Precision Agriculture

Precision Agriculture (PA) is an approach to the farm management that uses ICT/ IoT to ensure that the crops and soil receive exactly what they need for optimum health and productivity. The goal is to ensure profitability, sustainability and protection of the environment. Precision Agriculture is also known as satellite agriculture, as-needed farming and site-specific crop management (SSCM).

Precision agriculture relies upon specialized equipment, software and IT services. The approach includes accessing real-time data about the conditions of the crops, soil and ambient air, along with other relevant information such as local weather predictions, labour costs and equipment availability. Predictive analytics software uses the data to provide farmers with guidance about crop rotation, optimal planting times, harvesting times and soil management.

Sensors in fields measure the moisture content and temperature of the soil and surrounding air. Satellites and robotic drones provide farmers with real-time images of individual plants. Information from those images can be processed and integrated with sensors and other data to yield guidance for immediate and future decisions, such as precisely what fields to water and when or where to plant a particular crop.

Agricultural control centres integrate sensor data and imaging input with other data, providing farmers with the ability to identify fields requiring treatment and determine the optimum amount of water, fertilizers and pesticides to apply. This helps the farmer avoid wasting resources and prevent run-off, ensuring that the soil has just the right number of additives for optimum health,

while also reducing costs and controlling the farm's environmental impact, as described in Figure-9 below.

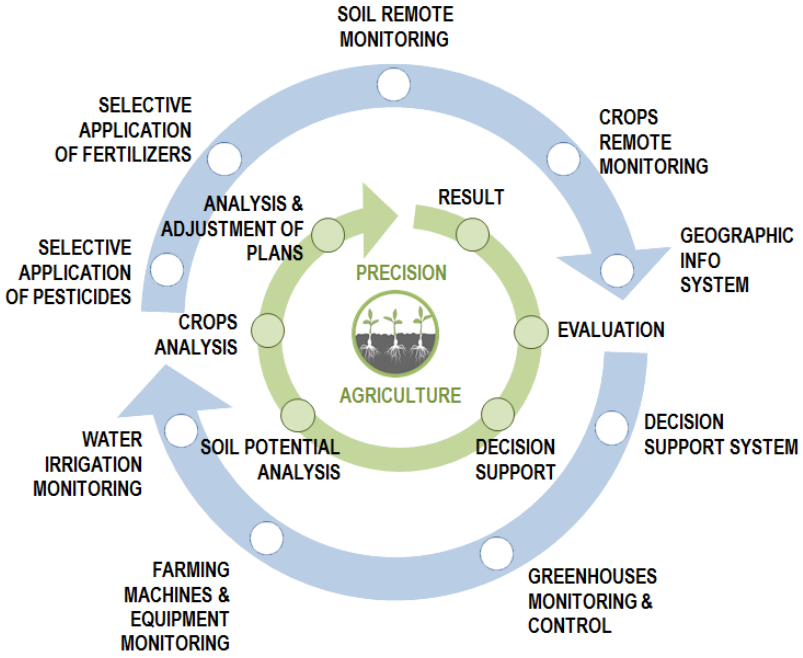

Figure 9: Precision Agriculture cycle[20]

In the past, precision agriculture was limited to larger operations which could support the ICT infrastructure and other technology resources required to fully implement and benefit from the benefits of precision agriculture. Today, however, mobile applications, smart devices, drones and cloud computing makes precision agriculture possible for farming cooperatives and even small family farms[21].

A vital component of this farm management approach is the use of IoT/ ICT and a wide array of items such as GPS guidance, control systems, sensors, robotics, drones, autonomous vehicles, variable rate technology, GPS-based soil sampling, automated hardware, telematics, and software[22].

3.1.2. Soil Parameters

The following are the Soil parameters required to quantify the soil used for cultivation.

Table 3: Soil parameter required to quantify the soil used for cultivation

	Soil Testing (In Lab)	Categories and UOM's
	Analytical methods for the estimation of physical properties and available nutrients	
1.	Soil Texture	Coarse sand: 2.0 – 0.2 mm diameter
		Fine sand: 0.2 – 0.02 mm diameter
		Silt: 0.02 – 0.002 mm diameter

[20]https://www.hexastep.pt/index.php/en/business-solutions-2/m-agriculture
[21]https://whatis.techtarget.com/definition/precision-agriculture-precision-farming
[22]https://agfundernews.com/what-is-precision-agriculture.html/

		Clay: < 0.002 mm diameter
2.	Soil Structure	Very coarse: >10 mm
		Coarse: 5-10 mm
		Medium: 2-5 mm
		Fine: 1-2 mm
		Very fine: <1 mm
2.1.	Soil structure (form)	Granular
		Crumb
		Platy
		Blocky
		Angular blocky
		Sub angular blocky
		Prismatic
		Columnar
		Single grain
		Massive
3.	Cation Exchange Capacity (CEC)	Mill equivalents /100 g of soil (me/100 g)
4.	Soil Moisture	Percentage (%)
5.	Water Holding Capacity (WHC)	Percentage (%)
6.	pH value	Unit less
7.	Lime Requirement	Kg / ha or tonnes / ha
8.	Soil Electrical Conductivity and gypsum requirement	
8.1.	Electrical Conductivity	Millimhos per cm (mmhos/cm)
8.2.	Gypsum requirement	Kg / ha or tonnes / ha
9.	Organic Carbon	Percentage (%)
10.	Total Nitrogen (Kjeldahl Method)	Kg / ha
11.	Mineralizable N	Percentage (%)
12.	Inorganic N – NO3 & NH4	µg/ml
13.	Available Phosphorus	Kg / ha
14.	Available Potassium	Kg / ha

15.	Available Sulphur	mg / kg
16.	Exchangeable Calcium and Magnesium	
16.1.	Calcium by Versenate (EDTA) Method	me /100 g soil
16.2.	Calcium plus Magnesium by Versenate (EDTA) Method	Ca++ + Mg++ me/100 g soil
17.	Micronutrients	
17.1.	Available Zinc, Copper, Iron, Manganese	µg/g soil
17.2.	Available Boron	µg/g or mg/kg
17.3.	Available Molybdenum	mg/kg

3.1.3. Best practices for Smart Agriculture

3.1.3.1. Digital Soil Test and Fertilizer Recommendation (STFR) Kit

The STFR kit has been developed by W S Telematics, under license from ICAR (Indian Council for Agricultural Research) –Indian Agricultural Research Institute (IARI). STFR kit seeks to address the lack of awareness among farmers about their soil quality. It tests the soil samples and recommends the quantity of fertilizer required for different kinds of crops. The farmer does not have to depend on the Krishi Vigyan Kendra (KVK) for its soil testing, where it usually takes more time and lacks modern facilities for soil testing. By using STFR kit, five samples of soil can be tested in one and a half hours and testing can be done at a village panchayat. Some important soil parameters can be tested are given below-

1. Primary Nutrients –
   a) Nitrogen (N)
   b) Phosphorous (P)
   c) Potassium (K)

2. Secondary Nutrients –
   a) Sulphur (S)
   b) Calcium (Ca)
   c) Magnesium(Mg)

3. Tertiary Nutrients-
   a) Zinc (Zn)
   b) Boron(B)
   c) Copper (Cu)
   d) Iron (Fe)
   e) Chlorine (Cl)
   f) Manganese (Mn)

4. Electrical Conductivity

5. pH
6. Lime Requirement Test for Acid Soil
7. Gypsum Requirement Test for Alkaline Soil

This kit is already used in different parts of the country, but making its use widespread by awareness will benefit farmers.[23]

3.1.3.2. NANO Ganesh Technology for Smart Irrigation

Nano Ganesh technology for smart irrigation is a remote-control system for the agriculture water pumps located in rural areas. Using Nano Ganesh and a low-cost mobile phone, a farmer can remotely switch a pump 'on' or 'off', check pump status, and check power availability pump status.

The brief description of this use case is mentioned in Annexure –5.

3.1.3.3. IoT based Crop Pest Surveillance System

To protect the crop from pests and their diseases is a challenging task for the farmer. Plant health condition plays a vital role to earn a good profit for the farmer. The pest can harm crop, reduces yield and also affects crop quality. Farmers use many techniques to kill the pests. The identification of pest disease is necessary before treatment. Without identification, the use of pesticides may harm the crop. Using inappropriate pesticides without identifying the problem, kills many beneficial pests. This problem may be overcome by using IoT based crop pest surveillance system, which may be beneficial to the farmers.

The brief description of this use case is mentioned in Annexure – 6.

3.1.3.4. Unmanned Armed Vehicles (UAVs) in agriculture

In the absence of reliable communication infrastructure in rural and remote areas, the data acquired through the wireless sensor network cannot be transmitted properly. In such a scenario, UAVs offer an alternative, as they can communicate with the wireless sensors spread over large areas in order to harvest data for further processing and analysis. Furthermore, UAVs, better known as drones fitted with high-resolution cameras and precise sensors, may be used over thousands of hectares of farms. The role of surveillance in all agriculture applications is highly critical, especially in forestry and crop monitoring, due to the need to cover large areas. Therefore, a fast, low-cost, real-time, and large-scale surveillance supported with accurate data acquisition and transmission facilities are crucial for agricultural production.

[23]http://www.wstelematics.com/pusa-stfr-meter.html

Figure 10: Agriculture Drones[24]

The quality of images taken through UAVs depends on the resolution of the attached camera, which is usually better than satellite images. Most significantly, it can be adjusted according to the application requirements. With the help of this collected data, a farmer can spot problems early and rapidly and act appropriately. Similarly, UAVs are better in terms of frequency (can take pictures multiple times in a single day) and are also least affected by weather conditions, unless it is raining. Due to the above-mentioned advantages, UAVs are considered as the future of precision agriculture. 5G technology will be quite useful for the drone application as high quality images may be transmitted in real time.

Figure 11: Two types of majorly used agricultural drones[25]

[24]https://dronelife.com/2017/01/16/report-agriculture-drone-sector-yield-2-billion-crop-2021/
[25]https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8784034

The UAVs, used for agricultural applications, usually fall into two categories: fixed-wing and multi-rotor drones. Although both are available in various ranges in terms of cost, payload capacity and mostly distinguished based on hardware differences. For example, when it is required to cover a large area, fixed-wing drones are suggested due to their long-range flight capacity. Most importantly they are crash tolerant. On the other hand, multi-rotor drones are more common due to their easy and faster set up as they can take off and land vertically. Multi-rotors have many advantages over the fixed wings as they are easier to operate, require no advanced wind planning and have the ability to fly more precisely. Moreover, in scenarios where low-altitude flight is necessary to capture extremely detailed images, which is more common in agriculture applications, then the multi-rotor is considered the better choice.

After being equipped with automation and GPS capabilities, UAVs are ready to take the agriculture sector to a further modernized level. As the demand for drones is increasing, they are becoming more inexpensive and reliable, hence, making themselves an ideal choice for new farming applications. Some of the key areas in which drones are already playing significant roles to assist farmers throughout the crop cycle are listed below-

A. Soil and field analysis
B. Planting
C. Crop monitoring
D. Irrigation
E. Plant counting and gap detection
F. Spraying the pesticides/herbicides
G. Crop health monitoring and assessment
H. Detection/recognition of plant species

3.1.3.5. Smart Green House

A Smart Green House, as depicted in Figure-12, helps the farmer to carry out the work in a greenhouse farm automatically without the need of much manual inspection. Greenhouse being closed structure protects plants from extreme weather conditions like wind, hailstorm, ultraviolet radiations, and insect/ pest attacks.

Equipped with modern sensor and communications technologies, smart greenhouses automatically capture and deliver information 24/7 on the surroundings and crop. Collected data is fed into an IoT platform where analytical algorithms turn it into actionable intelligence to uncover bottlenecks and abnormalities. Accordingly, HVAC (Heating, Ventilation, and Air Conditioning) and lighting operations, alongside irrigation and spraying activities, may be regulated on-demand. Continuous data monitoring facilitates the development of predictive models to assess crop disease and infection risks.

By unlocking tremendous crop insights, a smart greenhouse allows cultivators to minimize labour work and improve resource and chemical use while optimizing yield rates.

In a typical Smart Green house:

1. The irrigation of the agriculture field is carried out using automatic drip irrigation, which operates according to the soil moisture threshold set accordingly. This ensures that the optimal amount of water is applied to the plants.
2. Based on data from the soil health card, the proper amount of nitrogen, phosphorus, potassium and other minerals can be applied by using drip fertigation techniques. Fertigation, as the name implies, is the process in which fertilizers are being applied with the irrigation water: Fertilization + Irrigation. The system gathers information to inform growers on how best to fertilize and irrigate their plants. Sensors precisely measure the moisture level of your soil or substrates to determine when irrigation is necessary.
3. Proper water management tanks are constructed and they are filled with water after measuring the current water level using an ultrasonic sensor.
4. Plants are also provided the requisite wavelength light during the night using growing lights. Temperature and air humidity are controlled by humidity and temperature sensors and a fogger is used to control the same.
5. Bee-hive boxes are deployed for pollination and boxes may be monitored using ultrasonic sensors to measure the honey level and send emails to the buyers when they are filled.

Figure 12: Smart Green House[26]

Various wavelengths of light play specific roles for plant growth since different photosynthetic pigments within plants utilize different wavelengths. In the sunny days, leaves receive light directly from the sun, but in order to boost the rate of growth, the greenhouse may be provided with plant regrowing lights that will turn on whenever the reading from LDR (Light Dependent Resistors) sensor falls below cut-off value.

[26](Image courtesy :https://www.whatech.com/)

Advancement in LED (Light Emitting Diode) technology has made it possible to build LEDs that emit the light in very specific spectra to achieve very specific outcomes in plant growth[27].

3.1.3.6. Smart Plant Factories and Artificial Lighting (PFAL)

To address the issues like shortage and unstable supply of food, shortage of resources, and degradation of the environment, transdisciplinary methodologies based on new concepts need to be developed. Plant Factories with Artificial Lighting (PFALs) is one such technique. The benefits of the PFAL include high resource use efficiency, high annual productivity per unit land area, and production of high-quality plants without using pesticides. Major problems to be solved are the increased initial investment and the electricity and labour costs. Using PFAL, the yield and quality of food are substantially improved with less resource consumption and less environmental degradation than current plant production system.

Figure 13: Plant Factories with Artificial Lighting (Image Courtesy : Aerofarms[28])

The "Smart PFAL" is an intelligent or cognitive computing PFAL with the ability to make the decisions and solve almost all the major problems without human intervention. The smart PFAL must adapt its behaviour based on experience (learning), not be dependent on instructions from people (learn on its own), and be able to respond to unanticipated events.

The figure below depicts the image of a smart PFAL management system with the use of Artificial Intelligence (AI), IoT, LEDs, and phenotyping unit.

[27]https://www.researchgate.net/publication/316448621_IoT_based_smart_greenhouse
[28]https://aerofarms.com/2019/11/21/aerofarms-named-one-of-times-best-inventions-of-2019/

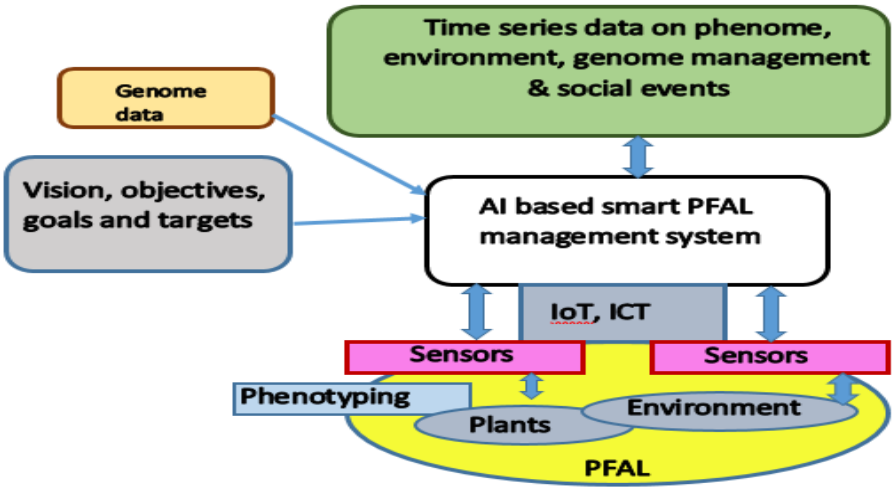

Figure 14: Smart PFAL management system[29]

The next-generation "smart" plant factories with artificial lighting (smart PFALs) are expected to help solve food, resource, and environmental issues concurrently, by significantly reducing the initial and operating costs.

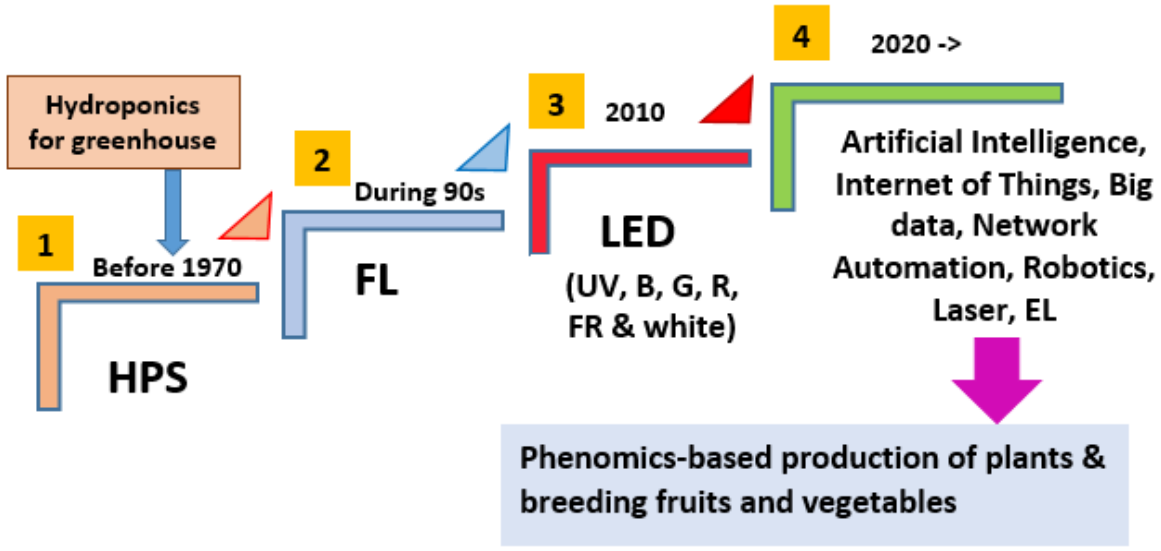

Figure 15: Stages of PFAL[30]

The Figure-15 above describes stages or waves of PFAL wherein the use of different lamps in different stages has been given. In this figure, HPS is High-Pressure Sodium lamp, FL is Fluorescent Lamp, LED is Light-Emitting Diode lamp (where UV, B, G, R, and FR means Ultraviolet, Blue, Green, Red, and Far-Red respectively). The fourth wave of PFAL uses AI, IoT/ ICT, Big Data Analytics, Network Automation and Robotics etc. Here Phenomics (**Plant Phenomics)** is the study of plant growth, performance and composition.

[29] Adopted from the book on "Smart Plant Factory: The next Generation Indoor Vertical Farms" by Toyoki Kozai, Springer publishers

[30] Adopted from the book on "Smart Plant Factory: The next Generation Indoor Vertical Farms" by Toyoki Kozai, Springer publishers

3.1.3.7. Hydroponics Farming

Hydroponics is a method of growing plants without soil, by using mineral nutrient solutions in a water solvent. Terrestrial plants may be grown with only their roots exposed to the nutritious liquid. The roots may be physically supported by an inert medium such as perlite, gravel, or other substrates.

The nutrients used in hydroponic systems can come from various sources, including (but not limited to) fish excrement, duck manure, purchased chemical fertilisers, or artificial nutrient solutions.

Hydroponics farming offers many advantages, one of them being a decrease in water usage for agriculture. It is shown in Figure-16 below.

Figure 16: Hydroponics Farming[31]

3.1.4. Agriculture Market

3.1.4.1. e- NAM (NATIONAL AGRICULTURE MARKET)

e- NAM is envisaged as a Pan-India electronic trading portal that seeks to network the existing Agricultural Produce Market Committee (APMC) and other market yards to create a unified national market for agricultural commodities. e- NAM is a "virtual" market but it has a physical market (mandi) at the back end. e- NAM is not a parallel marketing structure but rather a device to create a national network of physical mandis which can be accessed online. It seeks to leverage the physical infrastructure of the mandis through an online trading portal, enabling buyers situated even outside the state to participate in trading at the local level.

e- NAM and its benefits

[31]https://en.wikipedia.org/wiki/File:CDC_South_Aquaponics_Raft_Tank_1_2010-07-17.jpg

The e- NAM electronic trading platform has been created by the Ministry of Agriculture & Farmers' Welfare, Government of India. It offers a "plug-in" to any market yard existing in a state.

e- NAM is envisaged as a win-win solution for all stakeholders. For the farmers, e- NAM promises more options for sale at the nearest mandi. For the local trader in the mandi, e- NAM offers the opportunity to access a larger national market for secondary trading. Bulk buyers, processors, exporters etc. benefit from being able to participate directly in trading at the local mandi level through the e- NAM platform, thereby reducing their intermediation costs. The gradual integration of all the major mandis in the States into e- NAM will ensure common procedures for the issue of licenses, levy of fee and movement of produce. In the near future we can expect significant benefits through higher returns to farmers, lower transaction costs to buyers and stable prices and availability to consumers. The e- NAM will also facilitate the emergence of integrated value chains in major agricultural commodities across the country and help to promote scientific storage and movement of Agri commodities.

e-NAM Architecture

The government is in process of linking mandis across the country with the National Agriculture Market (e-NAM), an online trading platform for agricultural commodities[32] as detailed in figure below-

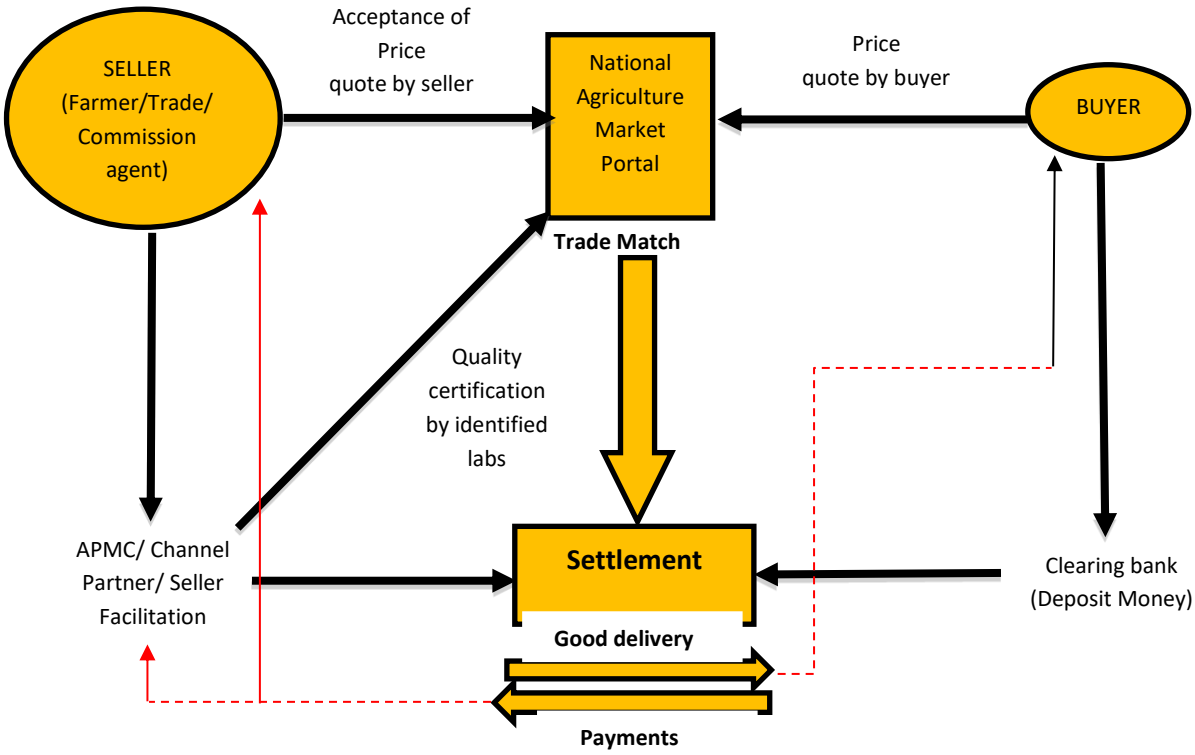

Figure 17: E- NAM Process Flow

3.1.5. Advantages of using IoT in agriculture

The key advantages of using IoT/ ICT in farming are as follows:

[32] https://www.enam.gov.in/web/

1. Water management can be efficiently done using IoT to reduce the water waste.
2. Soil management such as measuring pH level, moisture content, nutrients etc. can be done by using IoT sensors so that farmers can plant seeds according to soil quality.
3. The increase of productivity, reduces manual work, time and makes farming more efficient.
4. Crop monitoring can be done to observe the growth of crops and also to recognize the diseases occurred in plants and crops.
5. Crop sales will be increased in the global market. The farmer can be connected to the global market without the restriction of any geographical area.
6. Drones with sprayer may be used to handle locust attack e.g. such locust attack incident has already been managed in Rajasthan in 2020. Edge Computing may help in creating intelligence at the drone level which may improve the efficiency of the system in decision making.

3.2. Animal Husbandry

Around 70 percent of rural households in India depend primarily on agriculture and animal husbandry for their livelihood. Animals provide an additional advantage to the farmers and land-less labourers being maintained on crop residues and/ or herbs/ weeds which has no food competition with human being. Livestock plays an important role in the Indian economy; briefly, the contribution of this sector is more than 4% in national GDP.

3.2.1. Veterinary Applications of Biosensors for enhancing farmer's income[33]

Animal husbandry practices are followed by the animal keepers while their health is looked after by veterinarians but due to the paucity of an appropriate number of veterinarians, the health of animals is not maintained properly and timely. An animal cannot speak about its illness, it is the veterinarian who uses his/her wisdom to make a diagnosis and exact cause of disease; however, it takes time to identify the sick animal at an early stage. If by using emerging technologies like IoT having biosensors based devices, we can identify the sick animal, appropriate therapeutic, preventive and control measures can be taken to reduce the losses on account of production, morbidity and mortality.

Currently, diseases are controlled mainly with vaccines and drugs but the emergence of antibiotic- and drug- resistant pathogens mean that diseases will continue to be a problem. Moreover, the use of antibiotics will become even more severely restricted in the future. In recent years, there has been a growing demand for biosensors in the fields of veterinary science, animal husbandry, the food industry and environmental monitoring.

There are numerous ways of detection of these microbial pathogens such as isolation and identification of culture, Enzyme linked immunosorbent assay (ELISA), Polymerase chain reaction (PCR). Of late, biosensors' approach for detection of the pathogen has got greater attention from researchers and agencies controlling the spread of disease at hospital, field and point of attack. Hence, the development of portable, sensitive, rapid, real-time biosensor technology with immediate 'on-the-spot' interpretation of results is well suited for the intended purpose. The areas where biosensors have special

[33] Paper on "Veterinary Applications of Biosensors for enhancing farmer's income" by Prof. R S Chauhan, College of Veterinary and Animal Sciences, GB Pant University of Agri & Tech Pantnagar, Uttarakhand

promise include clinical diagnostics, food analysis, bioprocess and environmental monitoring etc. Labelling methods that use an enzyme, fluorescence and radioactivity remain the cornerstone of most of biological research protocol. However, label-free detection methods, which rely on optical, acoustic, and other types of biosensors, may improve on the standard methods, although achieving high-throughput and sensitivity are still important challenges. Disadvantages include lack of sensitivity, interference and cross-reactivity. The efficiency of labelling varies from protein to protein, making the comparison a challenge. Besides, attaching fluorophores may influence the way in which proteins bind to other molecules and cause background signals.

Global biosecurity threats such as the spread of emerging infectious diseases and bioterrorism have generated significant interest in recent years. There is considerable effort directed towards understanding and negating the proliferation of infectious diseases. Biosensors are an attractive tool which has the potential to detect the outbreak of a virus and/or disease at the point of attack and consequently alert us for counter prophylactic measures to contain the disease. There is no doubt that the glucose biosensor, the gene chip, the protein chip, etc. have played and are still playing a significant role in monitoring various biomolecules.

Biosensors based IoT devices having can offer the livestock industry new types of monitoring and measuring devices of which the specificity, sensitivity, reproducibility, speed and ease of use exceed the current technology. These devices can be applied to the detection and identification of infectious diseases in livestock, contaminants and toxins in feed, therapeutic drug residues in animal husbandry and oestrus detection. Biosensor based devices are also applied to the livestock industry by developing a fully automated ovulation prediction system for dairy cows. The results from field-tests show that the progesterone biosensor can characterize the ovulation cycles of cows and detect pregnancy. In the cattle breeding industry, where artificial insemination techniques are employed, the successful prediction of oestrus onset leads to considerable cost savings in herd management.

Based on available knowledge and requirements in near future, following areas are suggested for development of biosensors for different animal species.

1. Generic Biosensor for enhanced production and monitoring which can measure and indicate the followings:
    a. Movement of animal
    b. Body temperature
    c. Pulse rate
    d. Respiration rate
    e. Oestrus / heat detection – ovulation prediction system
    f. Pregnancy diagnosis
    g. Drug residue levels
    h. Environmental pollutants/ Toxin levels
    i. Haemoglobin
    j. WBC / Total leukocyte count
    k. Differential leukocyte count
    l. Mastication

2. Specific biosensors for important diseases affecting the production and life-threatening to the cattle and buffaloes.
    a. Pasteurellosis
    b. Foot and mouth disease/FMD

c. Tuberculosis
d. Johne's disease
e. Brucellosis
f. Rotaviral diarrhoea in calves
g. Pneumonia
h. Rumen acidosis

3. Specific biosensors for important diseases affecting the production and life-threatening to the Sheep and goats
    a. Brucellosis
    b. Peste des Petits Ruminants (PPR) also known as sheep and goat plague
    c. Johne's disease
    d. Sheep pox

4. Specific biosensors for important diseases affecting the production and life threatening to the Dogs
    a. Rabies
    b. Canine distemper
    c. Infectious canine hepatitis
    d. Parvo virus infection

5. Specific biosensors for important diseases affecting the production and life threatening to the Poultry
    a. Colibacillosis
    b. Salmonellosis
    c. Infectious bursal disease
    d. Ranikhet disease
    e. Coccidiosis
    f. Marek's disease
    g. Quail disease

Goal of developing smart villages and doubling the income of farmers may only be achieved through the development of animal husbandry practices as there is limited agriculture land and that too reducing day by day due to urbanization, industrialization and other developmental activities; while one can keep two animals instead of one without much difficulty and thus double the income provided they are supported with proper technological upgradation to enhance the productivity and reducing the losses. Biosensor technology for the development of smart villages will certainly play a great role in enhancing the income of farmers and animal keepers.

Bovine Intervention

India produces about 187.7 million tonnes of milk annually (as per data available on National Dairy Development Board website[34] for year 2018-19) and is on track to grow that output by 49% by 2026, becoming the world's largest milk producer[35].

1. Fitting a sensor and tracking device to a cow's collar, ear, leg, tail, or via an ingestible microchip gives farmers the ability to track a cattle's activity levels, health, and other key behaviours like

[34] https://www.nddb.coop/information/stats/milkprodindia
[35] https://www.livemint.com/Politics/bp0AZY8Vhc8jZWrMlv5vMN/India-to-become-largest-milk-producer-in-2026-Report.html

reproduction activity to increase output and overall herd wellness. This solution may be quite useful for tracking and monitoring health of the animals.

2. A microchip is a permanent method of electronic identification. The chip itself is very small – about the size of a grain of rice – and is implanted subcutaneously (just beneath the skin) between the shoulder blades at the back of the pet's neck. Each chip has a unique number that is detected using a microchip scanner. The risk that the animal will develop cancer due to its microchip is very, very low, and is far outweighed by the improved livelihood that animal keeper will get by finding animal back, if it is lost.

   When a microchip scanner is passed over side the cow, the microchip gets enough power from the scanner to transmit the microchip's ID number. Since there's no battery and no moving parts, there's nothing to keep charged, wear out, or replace. The microchip will last cow's lifetime. In India this solution may be suitable for cow shelters/ dairies. Dairy officials can access the records through their smartphones and act accordingly.

Key Benefits

- Easy animal Identification
- Heat detection for improved conception rates including tracking silent heats and to target best time for insemination
- Lameness detection and general health monitoring to separate and treat sick cows
- Calving detection so the new calf can be entered into the system and so live births can be monitored
- GPS location tracking to monitor herd
- Early mastitis detection to lower risk of milk loss
- Integrate with farm database tracking of any medications or treatments and output
- Rumination tracking to see how long they have been eating to monitor health and manage overall herd feed rations
- Identify animals under heat/cold stress

Sensor based devices (IoT device) may be placed as a collar in the ear/ neck of the animal to monitor vital signs/ parameters in real time to improve the efficiency of dairy farms. For example, in case of cow, the data from the IoT device is transmitted to a IoT platform using various communication technologies such as cellular / LPWAN. Data analytics may be done on the collected data, producing a full health report that includes diagnosing illness and estrus cycle data. Advice may be sent to the farmers for suitable necessary action e.g. farmers can then use this data to feed the animals more scientifically and carry out treatment and breeding at the right times. Smart collar solutions produce higher estrus detection and fertilization rates than manual inspection methods. This can lower breeding costs and avoid the use of health-damaging hormones.

By applying IoT/ ICT technologies, the livestock industry may be able to transform and approach breeding in a scientific way. IoT may increase industry profits, reduce drug use, increase the well-being of animals, and also may increase the quality of livestock products.

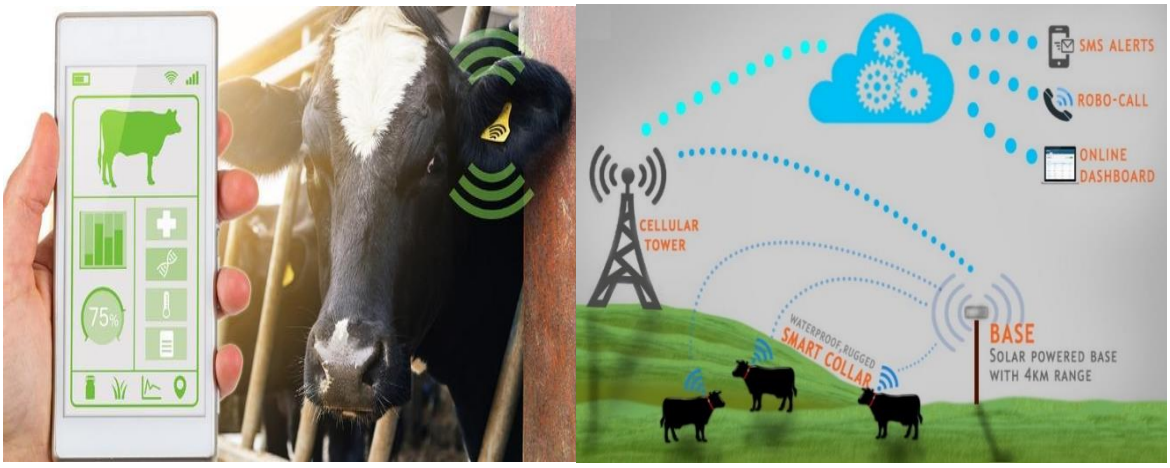

Figure 18: Animal Husbandry by using Internet of Things(IoT)[36and37]

3.2.2. Advantages of using IoT in Animal Husbandry

1. Early detection of disease will further help in their prevention and control, in order to save heavy economic losses due to sickness and death of animals besides saving the veterinary costs and mental tension to the owner's family.
2. Timely detection of heat (oestrus) will certainly enhance the fertility and production leading to economically self-sufficient livestock owner's/ animal keepers in villages.
3. Help in easy animal identification and their activity monitoring.
4. IoT devices will help in tracking of the movement of the animals, that will check the illegal and unethical transport of the animals.

   The related use case is described in detail in Annexure-7.

3.2.3. Arresting adulteration in dairy products through IoT & Blockchain traceability framework

A national-level survey carried out by the Food Safety and Standards Authority of India (FSSAI) has found that adulteration of higher than the permissible level of antibiotic residues in milk remains a problem in the country, though the instances could be much fewer than what is generally perceived. The 'National Milk Safety and Quality Survey 2018' results showed that 12 out of 6,432 samples of milk were found unsafe for human consumption due to adulteration. Detailed report[38] and Press Release[39] are available on links mentioned.

Samples had residues of antibiotics above the permissible limits, contaminated with aflatoxin M1 residues, a chemical compound that gets into the milk through feed and fodder. There is no visibility on the source of production and transparency on the entire supply chain process, thereby providing ample adulteration

[36]https://jeettechnosolutions.com/blogs/digitalizing-dairy-industry-using-iot-based-handheld-system/
[37]https://smartfarmerkenya.com/4749-2/
[38]https://www.fssai.gov.in/upload/uploadfiles/files/Report_Milk_Survey_NMQS_Final_18_10_2019.pdf
[39]https://www.fssai.gov.in/upload/press_release/2019/10/5da973ffaefcfPress_Release_Milk_Survey_Report_18_10_2019.pdf

opportunities in the entire process, in the absence of any wing to wing traceability solutions that are economical in nature.

Food adulteration poses severe dangers. When adulterants in question are consumed in excessive amounts, the risk of reversible damage to various organs inverses multi-fold, as does the risk of cancer.

Additionally, India has also received an advisory from the World Health Organisation (WHO) which states that failure to check the adulteration of milk and milk products would see 87% of Indian Citizens sufferings serious diseases like cancer by 2025[40].

M/s Go4Life has created a unique synthesis of Blockchain framework, IoT sensors, rural community outreach programs, scientific animal husbandry practices, supply chain optimization techniques to deliver fresh, Antibiotics-Free, Aflatoxins-Free, Pesticide-Residual-Free Milk and other products directly from farm to the table of customers and in process augment livelihood promotion and financial inclusion along with Bos-Indicus breed conservation. The brief description of this use case is mentioned in Annexure – 11.

3.2.4. Smart aquaculture: IoT for intelligent Fish farming

Introduction

Fisheries and aquaculture are one of the wildest-growing sub-sectors of agriculture. It plays an essential role in meeting out the food and nutritional security of the rising population. The sector also makes vital contributions to global food production. In the past five decades, the global supply of fish for human consumption has outpaced population growth[41]. Amongst all the countries, India ranks second in aquaculture production. In the 2020 budget of Government of India, it has been announced that fish production is to be raised to 200 lakh tonnes by the year 2022-23[42].

The future of aquaculture depends on the implementation of new and innovative production technologies, management and utilisation of unutilised water resources and suitable market tie-ups. There is a high potential for IoT in fisheries and aquaculture, and fishermen/farmers may have an edge in a competitive market.

Emerging technologies like IoT, AI/ ML and big-data approaches have the potential to improve sustainability and working conditions for fish farmers and help society to understand better the interdependences that aquaculture has with the environment. In line with the vision of the United Nations' (UN) Sustainable Development Goals (SDGs), which anticipates benefits from innovation in Information and Communication Technologies (ICT), the aquaculture sector is rapidly introducing these technologies to improve economic, social and environmental sustainability along value chains. This alliance will result in fully monitored and precision aquaculture, with farms connected to multiple-sensor networks generating big datasets that can be used for all management purposes.

Role of IoT in aquaculture

IoT technology may be used to monitor the water quality as well as vital parameters related to health and development of fishes in aquaculture. Sensor networks used are a set of small, low-cost sensors that

[40] https://www.theweek.in/news/sci-tech/2018/09/06/Indians-drink-milk-adulterated-with-detergent-impure-water.html
[41] http://www.fao.org/news/story/en/item/421871/icode/
[42] http://www.businessworld.in/article/Fish-Production-To-Be-Increased-To-200-Lakh-Tonnes-By-2022-23-Nirmala-Sitharaman-/01-02-2020-183184/

collect and distribute environmental data. Sensors monitor and control the corresponding physical environments efficiently and follow-up more accurately. IoT may be used to monitor and manage the following items in aquaculture-

- **Water Quality Management:** Fishes are cold blooded animals which require optimum environment for their survival, therefore, water quality is a critical factor for culturing aquatic organisms. It mainly depends on several parameters like **dissolved oxygen, ammonia, pH, temperature, salt, nitrates, carbonates** etc. The quality of water is monitored continuously with the help of IoT devices to ensure growth and survival of aquatic life. Vital parameters captured by IoT devices are transferred to the aqua farmer's mobile through cloud. As a result, preventive and corrective measures can be taken in time to minimize the losses ensuring good animal health and increase the productivity.
  E.g.: The wireless system known as **"Smart Aquaculture Monitoring with Internet of Things System (SAM-IoT)"** in Japan is designed to collect data of pH level, dissolved oxygen (DO) and water temperature in shrimp ponds[43].

- **Fish Health Management:** Fish health is a common challenge faced by the farmers during culture period. Various sensors can help in predicting any abnormality occurring in fish. Installed sensors and cameras can collect the daily data of behaviour, locomotion as well as activeness of the animal. External abnormality on the body of the animal can be monitored via cameras and any alteration in the quality of water can be detected by sensors. The farmers are alerted through mobile messages or app notification with preventive measures
  Example- Norway's Seafood Innovation Cluster launched the AquaCloud platform[44], a cloud-based program which aims to help fish-health managers and researchers deal with sea lice, predicting or even preventing lice development in sea cages with the goal of reducing dependency on expensive medical treatments, thus minimising stock mortality. Indian aquaculture technology start-up Aquaconnect offers FarmMOJO[45], a mobile application which helps shrimp farmers to predict diseases and enhance water quality.

- **Weather Monitoring:** Farmers can be alerted of the daily forecast so as they can plan their schedule and alternate any fishing practice with the pre-knowledge of weather. This weather monitoring can also save their produce from any natural calamities and prevent any future loss.

- **Feed Management:** Intelligent automatic feeders ensure the feeding of the cultured fish by monitoring accurate feeding patterns, analysing the behaviour of the fish such as the hunger level and controlling dispensers which release the right amount of feed. This application aids in avoiding wastage of feed and deterioration of water quality.
  Example- Japanese and Singaporean aquaculture technology firm Umitron Cell[46] offers a smart fish feeder which can be controlled remotely. Farmers are given data-driven decision-making advice to optimise feeding schedules. This reduces waste, improves both profitability and sustainability while offering users a better work-life balance by eliminating the need to be out in the water in dangerous conditions.

[43] https://www.nict.go.jp/en/asean_ivo/ASEAN_IVO_2018_Projects04.html
[44] https://aquacloud.ai/
[45] https://aquaconnect.blue/
[46] https://umitron.com/en/index.html

- **Remote monitoring:** An advance technology such as satellite imaging and drones can aid farmers to monitor their remote located farms. Satellite imaging is a great tool for analysing any blooming condition and water discoloration of the pond. Internet of things has a property to store data on cloud which can be accessed from anywhere around the world. This can assist farmers with accurate information regarding size, feeding patterns, health and water quality.

The framework of IoT in aquaculture

IoT devices with sensors to measure the water quality, dissolved oxygen, and other parameters may be installed to monitor in real-time. This data may be sent to data centre/ cloud which may be further analysed using AI algorithms or by specialised personnel and the results may be transmitted to fishermen's smartphone/ mobile for taking further necessary action. Actuators may also take necessary action based on the intelligence created, without the human intervention. Devices may be connected on different communication technologies depending upon the availability and suitability. Cellular/ non-cellular LPWAN technologies may be used to connect the devices as these technologies will consume less power and may transmit small amount of data to a large distance (2-3 Km urban areas, 10-12 Km in rural areas). More details are available in Section 2.4.3 and Annexure- 1.

This is a helpful technique of efficient farming for farmers, investors in aquaculture and fish farm owners. IoT has the potential to revolutionise the approach one desires to manage their pond, removing cumbersome manual processes.

The smart device for aquaculture may have sensors like feeding sensors, water level sensors and water quality parameter sensors (temperature, pH, turbidity, carbonates and bi-carbonates, ammonia etc.) to monitor alterations. Local network system consists of the router, modem and battery which works for sending and receiving data packets either from sensors to cloud server or intelligence from the cloud server to actuators/ smartphones of the fisherman. It processes all the information according to the designed protocol for analysation (commonly used protocols are Constrained Access Protocol (CoAP), Telemetry Transport Message Queue (MQTT) and MQTT-SN for sensor networks).

A use-case related with fisheries is available in Annexure- 12.

Conclusion

In aquaculture, sensor based IoT devices collect various parameters (temperature, pH, turbidity, carbonates and bi-carbonates, ammonia etc.) to monitor fish health. While the past innovations focused on hardware and data collection, the problem faced now is the pressure on farmers to interpret a large amount of data consistently. Here, AI and data processing algorithm can help by identifying patterns in feeding activities and presenting strategies to farmers, ranging from cost-efficient use of feed to maintaining fish welfare. The Government of India has given this sector enormous importance, and now there is an established Ministry of Fisheries, Animal Husbandry and Dairying. It is the time that this sector should take advantage of the Government's focus on Digital India, by embracing new technologies like IoT, AI and mobile apps for its growth.

3.3. Water

Improving access to water and sanitation remains priority for the states where water scarcity, water quality, and sustainability of sanitation coverage are still critical challenges.

Water Management System is one of the sector that may be improved by the use of Internet of Things. It is challenging to ensure the proper utilization of water, but implementation of IoT technology in Water Management Systems will surely make our lives convenient and conserve our valuable resources.

According to the United Nations Development Programme (UNDP), water scarcity is caused mainly because of the poor management of the resources. It is believed that almost half of the world population will face water scarcity by 2025, which indicates that water will be a valuable resource in the near future.

3.3.1. Water management by using IoT

Smart Water Management (SWM) is the use of IoT/ ICT, such as sensor networks, Geographic Information System (GIS) mapping, satellite mapping and other data sharing tools in water management. Over the past decade government, industries and utilities have moved towards the real-time data collection to optimize their operations and knowledge. SWM can provide integrated water management solutions, at all scales and across various contexts to resolve current water challenges in both developed and developing countries.

The important application of smart systems in water management is wide and includes solutions for water quality and quantity, efficient irrigation, pressure and flow management, ecosystem protection, flood and drought management, sewage management, future planning and much more.

1. **Water Conservation:**

   Reservoirs and overhead water tanks need to have sensors and equipment which are specially designed to display the level of water present in it. With the help of these sensors, the water level in the reservoir or the overhead tank can be sent to the server at regular intervals and calculate the amount of water used on a daily basis. This entire process of determining the water level in the reservoir, overhead water tanks and then sending this information to the main server will surely help in conserving water.

2. **Smart Drip Irrigation System:**

   Presently, a huge amount of water gets wasted during irrigation process. This is because the process of irrigation is scheduled automatically at a particular time, irrespective of the weather conditions and moisture present in the soil. This problem of water wastage can be solved by implementing IoT based Smart Drip Irrigation system. This saves water and fertilizer by allowing water to drip slowly to the roots of many different plants, either onto the soil surface or directly onto the root zone, through a network of valves, pipes, tubing, and emitters, based on soil and environmental conditions.

   The soil and environmental parameters are measured by the IoT sensor network, consisting of the following -

   a) Soil moisture sensor to measure water content in the soil.
   b) Temperature sensor to detect the temperature of soil as well as the temperature of atmosphere.
   c) Humidity sensor to measure the humidity in atmosphere.
   d) Rain drop sensor to detect the occurrence of rain and measure rainfall intensity.

   The IoT controller switches on the Drip Irrigation system, based on certain favourable soil moisture and environment conditions only, when irrigation is required. Water is provided directly to the roots of the crop, only when necessary. Hence, wastage of water is minimized, and water resources

are optimized. This system provides benefits to the farmers by increasing the yield of the crop with less water consumption. This Smart Drip Irrigation system automates and manages the watering process without any human intervention.

A use-case on Smart Irrigation System is available in Annexure-5.

3. Waste Water Management:

One of the challenges in water management is to monitor water leakages and the flow of water through different channels. IoT can come to rescue in all these areas. Sensors installed at various places in the water system can detect the water leakage and pressure level in it. These sensors will collect the information and send it to the main server. By using this information, the water leakage may be detected. Another advantage of using IoT sensors in waste water management is that it can detect and calculate the amount of chemical residue present in the water.[47]

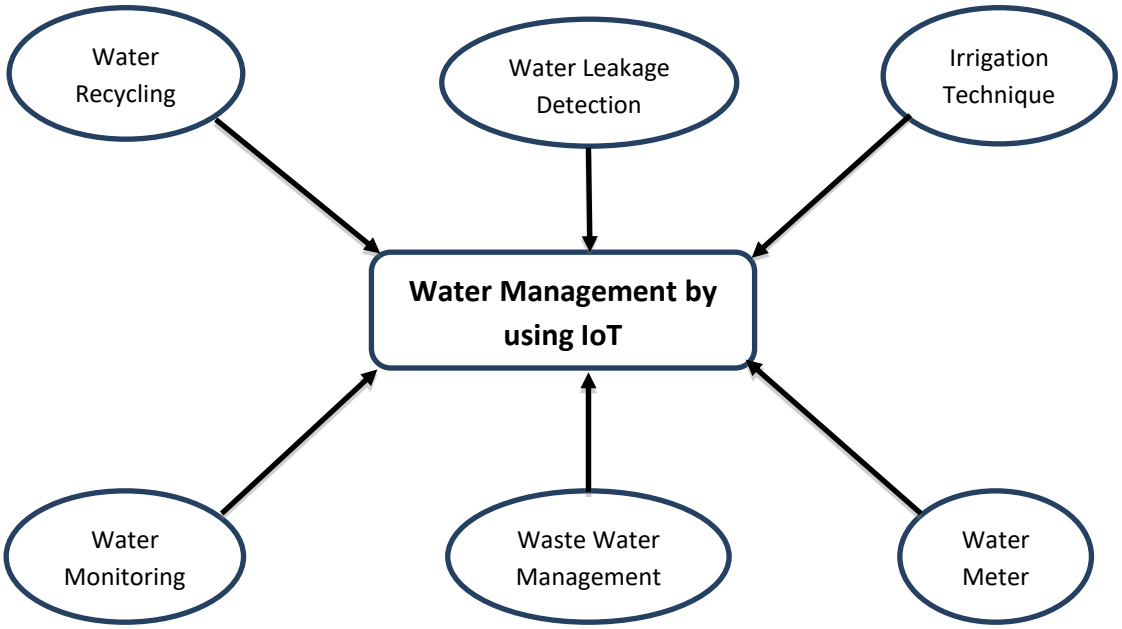

Figure 19: Water management by using IoT

3.3.2. Advantages of using IoT in Smart Drip Irrigation System

1. 50 to 65% water saving as compared to the conventional methods.
2. Crop quality improves and yield increases.
3. Requires least land levelling.
4. Poor quality water can be used in suitable applications; fresh water can be conserved.
5. Saving in labour and field preparation cost.
6. Easy method of fertigation.

3.4. Energy

Increasing economic growth and consumption pattern are leading to ever-growing demand for energy. Since most of the energy supply is in the form of fossil fuels, so the resources are depleting thus increasing

[47]https://smartwatermagazine.com/blogs/parija-rangnekar/how-can-iot-help-water-management-system

the cost of energy. Burning fossil fuels is also increasing the concentration of carbon-dioxide in the environment.

There is a scarcity of electricity in the country mainly in rural areas. Until rural communities have sufficient electricity as per their requirement, little progress can be made to develop their economies and improve their living.

Without reliable energy supply, rural communities face negative impact on agriculture and associated activities that are extremely important within the rural economy. Energy shortages also create problems for lighting homes, charging mobile phones etc. Access to reliable energy sources will be a key catalyst to transform agriculture from subsistence to commercial enterprise, especially for youth. Energy enables irrigation, charging of mobile phones to access production recommendations, online market access and supports processing of produce into value added products, all of which may enable farmers to increase their earnings.

Once struggling to get basic electricity like most villages in India, Dharnai which is located in Jehanabad district, Bihar has now changed its fate and has become the first village in India to completely run on solar power. Residents of Dharnai had been using diesel-based generators and hazardous fuel like cow dung to meet the electricity requirement for decades, which were both costly and unhealthy. Since the launch of Greenpeace's solar-powered 100-kilowatt micro-grid in 2014, quality electricity is being provided to more than 2,400 people living in this village in Jehanabad district.[48]

Figure 20: First fully Solar powered village in India[49]

[48]https://www.forbes.com/sites/jeffmcmahon/2017/08/03/what-if-we-gave-the-world-solar-mini-grids-and-the-world-didnt-want-them/#727a748b5db4
[49]https://www.greenpeace.org/india/en/story/390/dharnai-story-of-one-solar-village/

3.4.1. Advantages of using IoT in Energy Monitoring and Conservation

Energy is an extremely important aspect for any household, industry, agriculture. Managing the energy efficiently and conserving it intelligently for appliances is very important. Smart lighting systems have been developed by various R&D organisations which help in conservation of energy. Some companies have developed Arduino based smart home system for monitoring the usage of power to avoid any kind of irregularity. Researchers have also worked towards automating the appliances control with the focus on energy conservation.

With the help of M2M communication/ IoT, devices can be connected wirelessly over different communication technologies. In an IoT based Smart Energy Management system appliances like fan and bulb can be controlled wirelessly based on humidity and light intensity (colour/ hue also) information respectively. These inputs are used for controlling the appliances intelligently rather than just switching 'on' or 'off'. In addition, the system also keeps computing the throughput, which gives the information of power being consumed by appliances over a period of time. These details are updated in Cloud/ server. This prototype system may help in energy conservation in every household.

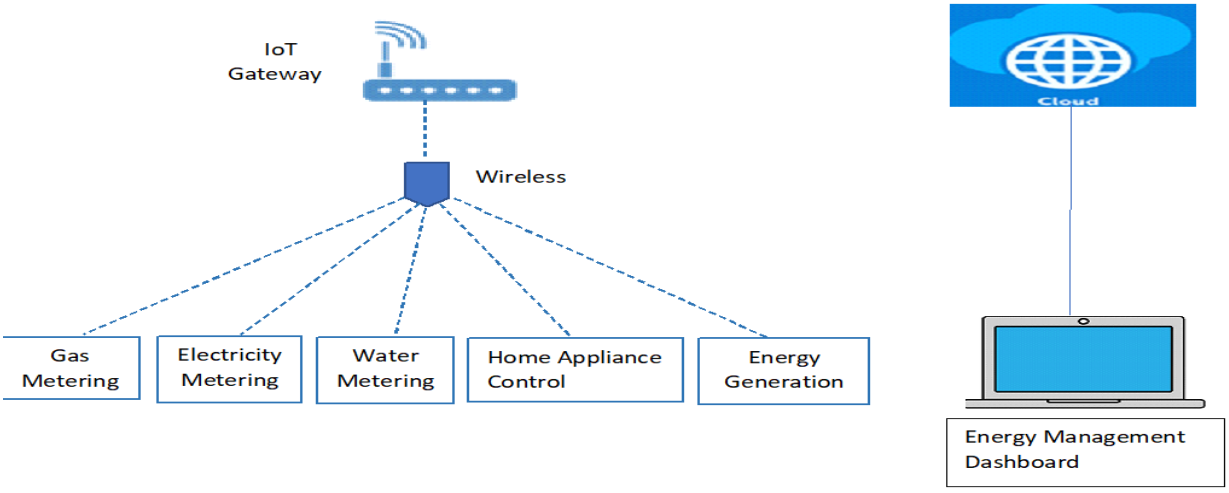

Figure 21: Energy monitoring by the use of IoT[50]

3.5. Tele-education

Newer means of education such as smart classrooms connect students in villages to educational institutions around the world. By incorporating insights from sociological and behavioural studies, ICT and IoT technologies can be used to convert a regular tutorial room into a smart classroom that dynamically connects students and analyses their conversations, actions, behaviours, etc. This will help in ensuring effective learning and have a positive impact on students as well as their tutors.

The ratio of dropouts at school or college level is quite high amongst the rural youth which negatively impacts the education policy and targets of the Indian government. There is lack of availability of vocational avenues in rural areas which further adversely affects the aspirations of the rural youth. Such youth with little education and lack of vocational skills pass through utter poverty and they think to migrate to the nearest towns or cities for employment.

[50] https://software.intel.com/en-us/articles/save-on-energy-and-streamline-operations-with-incenergy-and-intel

One of the objectives of smart village concept is to promote tele-education and to reduce the dropout rate. The prevalent factors that negatively affect the ability of rural students to acquire the knowledge and skills necessary to achieve economic goals need to be addressed through the use of ICT. The ICT-equipped schools, having high-speed internet connectivity, can provide good deal of handholding in accessing information and the world's knowledge base, which may lead to ending the information isolation experienced by many rural communities. Distance and adaptive learning become a new possibility, reducing the need to move to towns or cities to achieve better quality of education, which otherwise rural students are deprived off due to non-availability of quality teachers in remote areas. Also, ICT and internet access is a 'pull-factor' providing incentives for school attendance and for attracting and retaining good teachers. Tele-education brings together different technologies like Internet, Mobile and smart devices hence, assist in the learning process. The use of LCD screens and interactive videos can foster the learning in students specially children. Schools in rural areas can be equipped with Internet and other devices so that learning can be made a fun activity, turning schools into Smart schools. Taken together, these various factors can enhance the ability of students to acquire the knowledge and skills necessary to achieve economic goals and improve productivity.

Figure 22: E- Class in villages to make a smart school[51or52]

During COVID-19 pandemic, various types of applications and remote participation platforms like Zoom, Google meet etc. are being used for organising virtual classes in the education sector for the students living in cities as well as in rural areas. WhatsApp is also being used to send video lectures and study material online. For this purpose, low-cost smartphone/ tablet/ laptop with basic minimum features like Wi-Fi and long battery life etc., may be used to provide school education in rural areas. During this time, many online learning platforms like BYJUs offered free access to their services. It is believed that even after the pandemic is over, traditional offline learning and e-learning may co-exist.

3.5.1. Advantages of using IoT in Tele-education

1. Smart classrooms may be created in villages having connectivity with other educational institutions around the world
2. Student's drop-out rate may be reduced

[51]https://digitallearning.eletsonline.com/2018/12/need-for-smart-schools-in-rural-areas/
[52]https://www.indiamart.com/proddetail/interactive-smart-board-finger-touch-or-pen-4246735291.html

3. Distance and adaptive learning is possible, thus reducing the need to move to towns or cities to achieve better quality of education
4. Various applications and remote participation platforms assist in organizing virtual classes

3.6. Healthcare

Medical facilities are of prime importance for a common man. The number of hospitals and doctors in rural areas are not adequate at present. Many rural residents are not able to take treatment for basic ailments due to unavailability of health care services in the vicinity. The infrastructure as well as the staff required to provide the health care services in rural areas is insufficient. For providing the health services in these areas, smart health care solutions such as e-health, m-health and telemedicine solutions are required to be implemented. Healthcare IoT devices that can be easily used by the patient without the intervention of medical practitioners will be enablers for successful implementation of telemedicine solutions.

To address the challenges faced in extending medical facilities in rural areas, Remote Patient Monitoring system may be used. Remote Patient Monitoring (RPM) is a Tele-health solution that enables monitoring of patients outside of conventional clinical settings (e.g. in the home). The patient has medical device on or close to his / her body which has sensors that capture the patient's healthcare/ physiological data such as Electrocardiogram (ECG), Electroencephalogram (EEG), temperature, pulse-rate, respiration rate, Blood pressure meter, Glucometer, Heart rate monitoring, Weight scale, Physical activity etc. These vital parameters may be recorded in a Tablet / PC having communication facility for connecting with the medical devices and transmitted to the cloud or head end server using internet through cellular / broadband network. This data may then be analysed using AI algorithms or by a doctor sitting in an urban area, who may further send the outcome as an advice to the doctor / patient in the rural area on his/ her phone or patient ID.

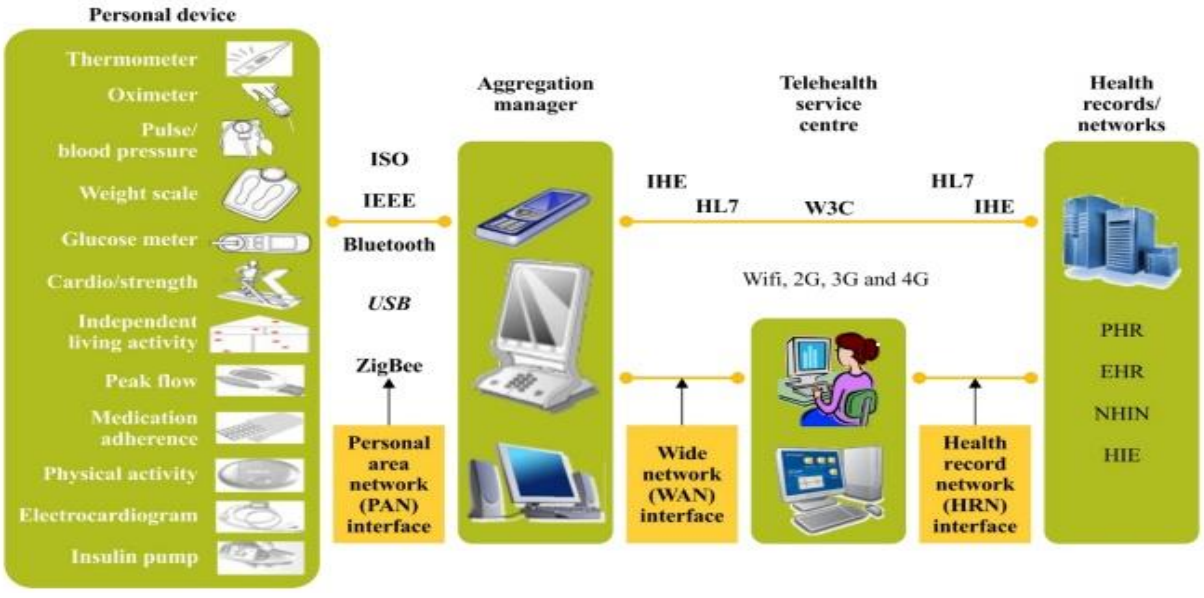

Figure 23: Remote health monitoring architecture by Continua Health Alliance[Source : ITU-T H.810]

Technical paper "Introduction to the ITU-T H.810 Continua Design Guidelines[53]" released by ITU-T in 2014 describes the interoperability architecture of Personal Health Devices using IEEE 11073 protocols (Bluetooth, Wi Fi, ZigBee in PAN / LAN and 2G/ 3G/ 4G/Wi Max/ fixed line broad band in WAN). This architecture (as shown in Figure 23) may be used for providing health services in the rural community in India.

Such type of application may also be used for remote monitoring of patients after surgery, who can be shifted to their homes and vacant beds may be used for other patients. It also reduces the cost of treatment in case of surgery.

Once 5G network is deployed, uRLLC feature may be used for remote surgery of patients. Places which are not connected on OFC, 5G will be beneficial in providing high speed connectivity for provisioning of smart services in rural areas.

A detailed use case on "Remote monitoring the health of a patient" is available in ITU-T Recommendation Y Suppl.53. This document may be accessed using link[54]. A brief description of Remote Patient Monitoring (RPM) is also discussed in Annexure-2.

Electronics Corporation of India Limited (ECIL), in association with AIIMS Rishikesh has developed a product named 'Monal 2020[55]' that enables round the clock remote monitoring of COVID -19 patients who are under home isolation. The system consists of an indigenously developed intelligent wearable instrument for measuring vital parameters of a corona virus patient such as body temperature, SpO2 (blood oxygen level), heart rate and respiration rate along with the patient's location and a novel application software that remotely displays these parameters on a mobile phone, laptop/desktop computer for monitoring by doctors from any location.

The system is built on IoT based technology to reduce the exposure of doctors and frontline healthcare personnel to coronavirus patients and can be easily installed on hospital premises and quarantine centres. It digitally transmits the recorded parameters of the patient on a Bluetooth/GSM SIM to an IoT gateway/Internet cloud from where data is securely uploaded over a network to a command control centre from which the data can be downloaded by doctor on his mobile phone or laptop through an application software (App) developed by ECIL for remotely monitoring the health parameters of patients. This device may be highly useful for the COVID-19 like pandemic as it reduces the demand for personal protection equipment and mitigates the problem of increasing exposure of this deadly virus to doctors and other healthcare workers.

3.6.1. ASHA (Accredited Social Health Activists)

An ASHA (Accredited Social Health Activists) or Anganwadi worker visits individual user's home to monitor their health. In rural areas healthcare devices may be given to ASHA workers and their services may be used to collect the data having vital parameters of the residents.

The solution comprises of a mobile device (phone or a tablet) connected to the medical device with wired or wireless interface and enabled with Biometric ID, Camera and GPS with a mobile

[53]https://www.itu.int/itu-t/recommendations/rec.aspx?rec=H.810
[54]https://www.itu.int/ITU-T/recommendations/rec.aspx?rec=13867&lang=en
[55]https://www.thehindu.com/news/cities/Hyderabad/ecil-aiims-unveil-remote-health-monitoring-system/article31512735.ece

network connectivity to the backend server where data can be submitted individually or in a consolidated manner. Patient ID can be validated through Aadhaar.

In addition, current process involves collecting the readings manually on paper and also on the Health card provided to the patients having details of the patient, (name, gender, age etc.) and Health readings along with their address. The same data needs to be transferred by the health worker to a register and consolidated at office.

M2M communication allows complete automation of this workflow with accurate data recordings with GIS mapping, time stamp and automatic transfer to central server where individual and consolidated reports, demography wise is available. This avoids paper work, less error prone and provides live update of data with visibility to the health care professionals at all times.

TEC has released a Technical report on M2M Enablement in Remote health management, which is available on TEC website[56]

3.6.2. Key advantages of using IoT, AI/ ML in Healthcare

1. Wearable IoT health care devices help in remote monitoring the vital parameters of the patients.
2. Specialist sitting in the urban areas may monitor the vital parameters and advise the doctors / patients in the rural areas.
3. Using 5G technology, remote surgery of patients will be possible.
4. Health related data of a patient may be stored on a cloud/ server for future use without human intervention.
5. After surgery, patients may be shifted at home in a e-ICU type environment. Vital parameters of the patient may be transmitted to the hospital for monitoring. It will help in managing the shortage of beds in the hospital.
6. Connected devices in health care domain will be quite useful in the COVID 19 pandemic and thereafter in managing the health care in the urban as well as rural areas.
7. Use of AI in healthcare helps in better prediction, diagnosis and treatment of diseases.
8. AI enabled healthcare tools augment medical professionals' capabilities to deliver better healthcare services.
9. Machine Learning (ML) may be used to analyse increasingly sophisticated medical images to diagnose fractures, cancers, strokes and many other medical conditions.
   A use-case on AI and edge analytics based rapid assessment of avoidable blindness has been described in Annexure-3.

[56] http://tec.gov.in/pdf/M2M/M2M%20Enablement%20in%20Remote%20Health%20Management.pdf

4. Smart village initiatives around the world

Many initiatives are being implemented around the world to make villages self-sustainable by using smart technology like ICT and IoT and hence reducing migration towards urban areas. Some of the examples of global smart village initiatives are[57]: -

4.1. Info Poverty Programme by OCCAM

The Observatory for Cultural and Audio-visual Communication (OCCAM) launched the Info Poverty Programme in 2001, which focuses on creating ICT villages in remote areas and ensuring primary services in food security, e-health and e-learning to the population. The OCCAM programme focuses on the following key ICT initiatives to fight against poverty:

1. Telemedicine—to provide professional medical services through ICT in cases where access to healthcare is limited
2. e-learning—to promote remote teaching, making learning interactive not only for primary and secondary schools but also for continuing higher education
3. e-agriculture—to promote food security
4. e-governance—to enhance services related to public administration

4.2. The Millennium Villages Project

The Millennium Villages Project[58] involves partnership with academia, civil society, local governments, United Nations agencies and the private sectors to achieve the Millennium Development Goals (MDGs) and was initiated in the year 2005. This project focuses on an integrated package of interventions in agriculture, education, health, roads, power, ICT, water and sanitation and business development. During the first five years of its operation, the Millennium Villages Project has achieved success by increasing food security, reducing hunger, improving education, decreasing maternal and child mortality, improving local infrastructure and controlling malaria, AIDS and tuberculosis. This project, in particular, focuses in three crucial areas by using ICT: strengthening primary health systems though expanded mobile-health services; scaling up access to high-quality secondary education for girls through connectivity at schools; and providing access to renewable energy (electricity) and safe water using smart metering and broadband-enabled systems.

4.3. Dynamic Smart Village Project by Government of Niger

Government of Niger, had launched a Dynamic Smart Villages Project for rural growth and digital inclusion in 2019. The Niger is a country where young population lives mostly in rural, remote and hard to reach areas. The project aims to improve the internet access in rural areas of Niger through improved broadband infrastructure. It also involves the prioritized expansion of digital services in areas such as health, education, finance and agriculture. Niger's National Agency for the Information Society is collaborating with ITU and several other organizations such as the World Health Organization (WHO), Food and Agriculture Organization (FAO) to implement the smart villages project.[59]

[57]http://www.shram.org/uploadFiles/20170802030955.pdf
[58]https://www.un.org/esa/coordination/Alliance/Earth%20Institute%20-%20The%20Millennium%20Villages%20Project.htm
[59]https://news.itu.int/smart-villages-empowering-rural-communities-in-niger-2-0/

4.4. Smart villages pilot project: European Commission (EC)

As per European Commission (EC), Smart Villages are “rural areas and communities which build on their existing strengths and assets as well as on developing new opportunities”, where “traditional and new networks and services are enhanced by means of digital, telecommunication technologies, innovations and the better use of knowledge”.

The European Commission (EC) together with the European Parliament published a document titled "EU Actions for Smart Villages" in the year 2018 in order to make opportunities for villages and rural communities more visible. One of the targeted actions is the pilot project on Smart eco-social villages[60].

The overall aim of the pilot project is four-fold:

1. To map the opportunities and challenges in rural areas;
2. To provide a definition of “Smart Villages”;
3. To describe in detail existing best practices: ten best practices will be identified and analysed;
4. To investigate how to become a “Smart Village”: six case studies will receive support in setting up an action plan, including roadmaps to kick-start the process of becoming a “Smart Village”.[61]

This pilot initiative is working alongside the European Network for Rural Development (ENRD) thematic group on the same subject.

Channelling policy support for Smart Villages

The EU’s Rural Development policy supports rural areas to meet the wide range of economic, environmental and social challenges of the 21st century. It aims to achieve the following strategic objectives:

- fostering the competitiveness of agriculture;
- ensuring the sustainable management of natural resources and climate action;
- Achieving a balanced territorial development of rural economies and communities, including the creation and maintenance of employment.

Rural Development policy is referred to as the ‘second pillar’ of the EU’s Common Agricultural Policy[62] (CAP), complementing the system of direct payments to farmers and measures to manage agricultural markets (‘first pillar’).[63]

[60] https://ec.europa.eu/eip/agriculture/en/news/smart-villages-pilot-project#:~:text=The%20European%20Commission%20together%20with,on%20Smart%20eco%2Dsocial%20villages
[61]https://ec.europa.eu/eip/agriculture/en/news/smart-villages-pilot-project
[62] https://ec.europa.eu/agriculture/cap-overview_en
[63]https://enrd.ec.europa.eu/policy-in-action/policy-framework_en

5. Smart village initiatives in India

The Government of India and some state governments have initiated many pilot projects in the recent past in order to improve ICT infrastructures in villages and gram-panchayats and connecting them to district headquarters. This will facilitate the instant availability of information to improve their socio-economic conditions, bridge digital divide gaps between rural and urban areas, to increase crop productivity, provide education to their children and improved healthcare to villagers. Some of these initiatives are listed below:

5.1. National Rurban Mission (NRuM), Ministry of Rural Development

NRuM[64] was launched in 2016. NRuM follows the vision of 'Development of a cluster of villages that preserve and nurture the essence of rural community life with focus on equity and inclusiveness without compromising with the facilities perceived to be essentially urban in nature, thus creating a cluster of "Rurban Villages"'. The objective of NRuM is to stimulate local economic development, enhance basic services and create well-planned Rurban clusters. The larger outcomes envisaged under this mission are: (i) bridging the rural-urban divides— namely economic, technological and those related to facilities and services; (ii) stimulating local economic development with an emphasis on reduction of poverty and unemployment in rural areas; (iii) spreading development in the region; and (iv) attracting investment in rural areas.

5.2. Digital Village Project

The Government of India has announced the Digital Villages initiative, during the Budget 2019. Finance Minister announced the initiative to connect as many as 1 lakh villages with the digital services offered by the Government, within the next five years. Ministry of Information and Technology (MeitY) has been actively monitoring the Digital Village Scheme which is implemented by its arm- Common Service Centre (CSC) Special Purpose Vehicle. The Digital Village scheme is being implemented in 700 villages, one in every district across India. Under the scheme, villages are provided Wi-Fi connectivity for healthcare and education to be provided digitally. Similarly, CSCs in Digital Villages have also become hubs of financial inclusion. CSC's tie up with HDFC Bank is only going to make financial inclusion faster and better in rural India[65].

5.3. Smart Villages Project: 60 Smart Villages in India

In a bid to face the challenge of transforming rural India, the Centre selected 60 villages in three districts in 2016—Rajgarh, Sehore and Satna—to be developed as smart villages under the ambitious Smart Cities (or villages) project. The government will provide funds for the development of specific aspects of these villages. The government will focus on climate change, smart energy, agriculture and water[66].

5.4. Madhya Pradesh: 1,100 'climate-smart' villages

Madhya Pradesh has embarked on an ambitious plan to develop 1,100 'climate-smart' villages with the aim of preparing farmers to manage climate change risks timely and ensuring good productivity. The focus

[64] www.rurban.gov.in

[65] https://www.thehindubusinessline.com/news/national/modi-govt-to-scale-up-digital-village-20/article27277363.ece

[66] https://timesofindia.indiatimes.com/city/bhopal/after-three-smart-cities-mp-to-get-60-smart-villages/articleshow/53363080.cms

will be on integrated agriculture, comprising animal husbandry and fisheries, in addition to traditional farming. Agroforestry will also be adopted in these villages[67].

5.5. Maharashtra: 50 smart villages

Maharashtra Government aims to transform 50 villages into Smart Villages. Harisal village in the Melghat region of Amravati district is the first ideal digital village, which was earlier known as the malnutrition capital. State has laid an optical fibre network and installed Wi-Fi in the villages. The villagers who have been taught how to use the Internet now sell their produce online, and get a much better price for their products. To tackle the dismal literacy rates in Harisal, a state of the art e-Classroom was built, where the medium of teaching was in the local language and lessons were taught in short films and movies on television screens. The interactive mode of teaching has reduced the dropout rate of students. To overcome the lack of basic health-care facilities, the state tied up with Super-specialty Hospitals to provide tele-medicine. Solar power panels have been installed to provide power. To train students further, ICT (Information and Communication Technology) classes are being held for them. To boost crop productivity, soil testing services have been made available to the villagers who are now advised on the crop to be sown[68].

The purpose behind developing smart villages is to bring financial prosperity to the villages along with better educational and healthcare facilities.

5.6. Pradhan Mantri Adarsh Gram Yojana (PMAGY) Model Village

It is a rural development programme launched by Government of India in 2009–10 for the development of villages with the aim to build an "Adarsh Gram" (Model village) having adequate physical and institutional infrastructure to meet the minimum needs of all sections of the society. Initially, 1000 villages from Tamil Nadu, Rajasthan, Bihar, Himachal Pradesh and Assam were selected for the Pilot phase. All the 1000 villages had been declared as Adarsh Gram. During 2014-15, PMAGY was further extended (Phase-I) to cover another 1500 villages across 11 States. Till date States have declared 149 villages as Adarsh Gram and remaining villages are slotted for declaration as Adarsh by 31-03-2021. More details are available on link[69].

5.7. Saansad Adarsh Gram Yojana (SAGY)

Government of India launched “Saansad Adarsh Gram Yojana (SAGY)” in 2014 with the aim to translate the comprehensive vision of Mahatma Gandhi about an ideal Indian village into a reality, keeping in view the present context.

Under SAGY, each Member of Parliament adopts a Gram Panchayat and guides its holistic progress giving importance for social development at par with infrastructure. The '**Adarsh Grams**' are to become schools of local development and governance, inspiring other Gram Panchayats.

It aims to keep the soul of rural India alive while providing its people with quality access to basic amenities and opportunities to enable them to shape their own destiny. It also envisages integrated development

[67] https://www.hindustantimes.com/bhopal/mp-plans-to-develop-1-100-climate-smart-villages/story-wXQjFAstNmbw6watzP2gcJ.html#:~:text=Madhya%20Pradesh%20has%20embarked%20on,timely%20and%20ensure%20good%20productivity.

[68] https://economictimes.indiatimes.com/news/politics-and-nation/harisal-village-adopted-by-microsoft-to-be-developed-as-indias-first-ideal-digital-village/articleshow/58187649.cms?from=mdr

[69] https://pmagy.gov.in/aboutPMAGY

of the selected village across multiple areas such as agriculture, health, education, sanitation, environment, livelihoods, etc. [70]

[70]http://saanjhi.gov.in/Aboutus.aspx

6. Smart Villages in India- a Case Study

6.1. Mori village, Andhra Pradesh

Mori Village[71], which is located in near the Bay of Bengal in the East Godavari district has become the first smart village in the state of Andhra Pradesh to be completely digital, every household in the village now have access to Wi-Fi, Internet connectivity and cable TV while making all transactions cashless. All the 1,189 households are provided with the internet at 15 Mbps speed, cable TV, and telephone connection through fiber grid. All their transactions are through e-banking, AP Purse, Rupay cards and SBI Buddy. Even small kirana shops have been given e-pos (electronic point of sale) machines. Many corporate companies have joined this project, such as C-fog, which installed a sensor technology in tanks. By using this sensor, the villagers can monitor the level of tanks. Whenever level increases or decreases the message is sent to the villagers' mobile.

6.2. Taudhakpur, Uttar Pradesh

Taudhakpur Village[72], a remote village in Raebareli in the state of Uttar Pradesh, which can be termed as the country's first SmartGaon. This village has proper waste management system, streetlights, CCTV cameras, a Wi-Fi zone and 20-hour power supply and connectivity. Two friends created an app 'SmartGaon' which connects the entire population of Taudhakpur. It serves as a knowledge and information centre, market place, helpline and a development tool.

6.3. Punsari village, Gujarat

Located in Gujarat's Sabarkantha district, Punsari village[73] has emerged as a model village with modern urban amenities such as 24X7 power supply, Wi-Fi connectivity, CCTV cameras to ensure security and pucca roads connecting the village with other villages and towns. Punsari was awarded with Best Gram Panchayat Award by the central and state government. Other important features of the village include a use of solar power for agricultural purposes, accidental insurance cover to one member of every household, air-conditioned primary schools with no dropouts, bus facility for all households and focus on behavioural change through campaigns and awareness drives. For the last purpose, 120 loudspeakers have been installed in different parts of the village.

[71]https://wirally.com/first-smart-village-in-andhra-pradesh/
[72]https://www.technologyforyou.org/see-how-mobile-technology-is-transforming-lives-in-taudhakpur-up/
[73]http://www.shram.org/uploadFiles/20170802030955.pdf

7. Standards

ISO 11783 Serial control and communications data network for agricultural tractors

ITU-T Recommendations

ITU-T L.1700	Requirements and framework for low-cost sustainable telecommunications infrastructure for rural communications in developing countries.
ITU-T L Suppl. 29	Low-cost sustainable telecommunication for rural communications in developing countries using cellular radio technologies
ITU-T Y.4450	Overview of Smart Farming based on networks
ITU-T Y. 4408	Capability framework for e-health monitoring services
ITU-T Y. 4110	Service and capability requirements for e-health monitoring services
ITU-T Y. 4101	Common requirements and capabilities of a gateway for Internet of things applications
ITU-T Y. 4418	Gateway functional architecture for Internet of things applications
ITU-T Y. 4553	Requirements of smartphone as sink node for IoT applications and services
ITU-T Y.4103	Common requirements for Internet of things (IoT) applications
ITU-T Y.4117	Requirements and capabilities of the Internet of things for support of wearable devices and related services
ITU-T Y Suppl. 53	IoT Use cases

ITU-T SG-20 standardisation work in progress related to Smart Village & Agriculture:

a. Requirement for deploying smart services in rural community
b. Use cases of IoT based smart agriculture
c. Framework and Capabilities for Smart Livestock Farming Based on Internet of Things

8. Recommendations

1. Under BharatNet project of Government of India, a large number of Gram Panchayats (GPs) have been connected on OFC with 100 Mbps connectivity. Some of the GPs may not be having cellular coverage. For such GPs, USOF may create a mechanism for providing infrastructure such as tower, battery sets, DG set / solar panel etc. through a Telecom Service Provider (TSP)/ infrastructure provider, which may be shared by TSPs / LPWAN providers. It will help in extending smart services in rural areas.
2. Smart phones / Tablets/ Laptops may be out of the budget of the economically poor households. Low cost devices with minimum features such as Wi-Fi, Bluetooth, cellular connectivity and long battery life are required to accelerate the use of technology in various applications in rural areas.
3. Sensors are at the bottom of pyramid for IoT systems, however, at present most of the typically used sensors are imported. Further, there is a dire need to develop new sensors all the time. Looking at these requirements, sensors need to be developed indigenously with focus on low cost, high throughput and scalable manufacturing techniques such as printing based techniques.
4. An eco-system may be created for the research & development of sensor based connected devices (IoT devices) to harness the advantages of using IoT in agriculture, fisheries, animal husbandry, health care etc. Indigenous manufacturing of such devices will make them affordable for deployment in rural areas.
5. To enhance the productivity of farmers, information generated by variety of sensors deployed in the field may be analysed by a cloud based smart agriculture app which may include crop management through smart irrigation, smart pesticide control, proactive information sharing frameworks on crops and weather (using sensors, cameras, drones etc.). Options may be explored to share this data with Kisan Call Centre (1551 or 1800-180-1551) for the benefits of farmers.
6. Smart City platforms should be able to manage the emergency health services to the public of city as well as rural areas by analysing data from the connected health care devices as well as respond to the calls of the public, especially in a pandemic situation.
7. IoT devices should be safe and secured. To ensure this, devices are required to be tested and certified in designated labs under MTCTE (Mandatory Testing and Certification of Telecom Equipment) regime of TEC[74].
8. If any IoT device is hacked or exposed to any vulnerability, it should be reported. For this, a suitable mechanism is required to be created for reporting of vulnerability by manufacturer, user or service provider.
9. All devices/gateways (to be connected directly to Public Switched Telephone Network (PSTN)/ Public Land Mobile Network (PLMN)) should have IPv6 or dual stack (IPv4 and IPv6) capability.
   In view of the Internet Architecture Board (IAB) statement on IPv6, IPv4 compatibility may not be available in future developments i.e. in new or extended protocols. Therefore, transition to IPv6 only in PSTN/ PLMN networks will be required in the future. Gateways and devices to be connected directly to these networks will also be required to switch over to IPv6-only capability. The networks will indeed require to maintain backward compatibility for existing IPv4 devices for some more time.

[74] https://tec.gov.in/mandatory-testing-and-certification-of-telecom-equipments-mtcte

9. Challenges and Way Forward

Figure 24: Major challenges in technology implementation for Smart Agriculture[75]

Apart from the technology related challenges mentioned in the above figure, following challenges are also required to be addressed for the development of smart rural community:

1. Lack of adequate infrastructure
   There is the shortage of required infrastructure like electricity, communication infrastructure for providing internet facility etc. in rural areas.
2. Illiteracy (Technical illiteracy)
   There is need of literacy as well as technical literacy in India; there is a connection between education level and use of electronic means or Internet. This is a major drawback in which the users are not technically literate to use the technology. In India the literacy rate of the rural population is much less than the urban population. The government is working on creating ways to increase the literacy rate amongst rural population.
3. Poverty
   In India the majority of population in rural areas depends on agriculture, animal husbandry like practices to earn their daily living. For those people, accessing Internet is a costly affair.
4. Language Dominance
   The dominance of English language over the internet, limits the access of non-english speaking population. In India, most of the population speak Hindi or their regional language. Due to such

[75]https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8784034

irresistible domination of English over these communication channels, computers and the internet, it becomes difficult for villagers and farmers to access these things.

5. Digital divide-

   The digital divide refers to the separation that exists between individuals, communities, and businesses that have access to information and communication technology and those who do not have such access. An individual living below poverty line cannot afford a computer for himself to harness the benefits of e-governance and other online services. As the digital divide narrows, broader adoption of e-governance in the public domain becomes possible. Economic poverty is not the only cause of digital divide. It can also be caused by the lack of awareness among the people.

Abbreviations

Table 4: Table of Abbreviations

AI	Artificial Intelligence
APMC	Agricultural Produce Market Committee
BBNL	Bharat Broadband Network Limited
B2CS	Business to Consumer Services
BHQ	Block Headquarters
BSNL	Bharat Sanchar Nigam Limited
BTS	Base Transceiver Station
CCTV	Closed Circuit Television
CEC	Cation Exchange Capacity
CGF	Critical Gap Funding
CMS	Central Monitoring Server
CSC	Common Service Center
DL	Deep Learning
DO	Dissolved Oxygen
DoT	Department of Telecommunications
ECG	Electrocardiogram
EDTA	Ethylene Diamine Tetraacetic Acid
EEG	Electroencephalogram
FAO	Food and Agricultural Organisation
FSCM	Food Supply Chain Management System
FSSAI	Food Safety and Standards Authority of India
FTTH	Fiber To The Home
G2CS	Government to Citizen Services
GIS	Geographic Information System
GDP	Gross Domestic Product
GP	Gram Panchayat
GPON	Gigabit Passive Optical Network
GPS	Global Positioning System
HA	Hectare
HRN	Health Record Network
HVAC	Heating, Ventilation, and Air Conditioning
ICT	Information and Communication Technology

IEEE	Institute of Electrical and Electrical Engineering
IoT	Internet of Things
ISO	International Organization for Standardization
ITU	International Telecommunication Union
LAN	Local Area Network
LIDAR	Light Detection and Ranging
LPWAN	Low Power Wide Area Network
LBS	Location Based Service
LoRa	Long Range
MBPS	Megabit Per Second
MDG	Millennium Development Goals
M2M	Machine to Machine
ML	Machine Learning
MTCTE	Mandatory Testing and Certification of Telecom Equipment
NAM	National Agriculture Market
NB-IOT	Narrowband -Internet of Things
NDCP	National Digital Communication Policy
NFC	Near Field Communication
NEON	National Ecological Observatory Network
NOFN	National Optical Fibre Network
NRuM	National Rurban Mission
OFC	Optical Fiber Cable
OLT	Optical Line Terminal
ONT	Optical Network Terminal
PA	Public Address
PAN	Personal Area Network
PCR	Polymerase Chain Reaction
PFAL	Plant Factories and Artificial Lighting
PMAGY	Pradhan Mantri Adarsh Gram Yojana
PURA	Provision of Urban Amenities to Rural Areas
RDM	Remote Device Management
RFID	Radio Frequency Identification
RPM	Remote Patient Monitoring
SAGY	Saansad Adarsh Gram Yojana

SCCM	System Center Configuration Manager
SDGs	Sustainable Development Goals
SNF	Solids-Not-Fat
SPMRM	Shyama Prasad Mukherji Rurban Mission
SWM	Single Wire Multiswitch
TEC	Telecommunication engineering Centre
TRAI	Telecom Regulatory Authority of India
UAVs	Unmanned Armed Vehicles
UN	United Nations
UNDP	United Nations Development Programme
UOM	Unit of Measure
USB	Universal Serial Bus
USOF	Universal Service Obligation Fund
WAN	Wide Area Network
WBS	Work Breakdown Structure
WG	Working Group
WHC	World Health Council
WSN	Wireless Sensor Network

10. Annexures

Annexure: 1

Communication Technologies Table

Table 5: Communication Technologies for deploying smart services in rural community

Note: This table has been taken from the detailed list available in TEC Technical Report on *Communication Technologies in M2M/ IoT domain.*

Technology/ Protocol	Frequency band (s)	Advantages	Limitations	Suitable for
1. Low power short range technologies				
Bluetooth Low Energy	2.4 GHz	• Mature technology • Easy to implement • Low Power • Powered by coin cell • Longer battery life	• Small data packets	• Healthcare devices • Fitness devices • Remote Health Monitoring • Smart Metering
NFC	13.56 MHz	• Consumes less power • Almost instantaneous connectivity between devices • No power is required in-case of passive Tags	• Extremely short range • Expensive • Low information security • Low market penetration	• Healthcare devices • Fitness devices • Smart Metering
Wi-Fi	2.4 GHz	• Mature technology • High home/office penetration • High data rates achievable • Easy to implement	• Limited range • Poor building penetration • High interference from other sources • Power consumption higher than those technologies that operate in the sub-GHz band	• Base station in Health Clinics • Smart Metering • Home Automation
Z-Wave	Sub 1GHz for India (865-867 MHz)	• Standardised by CSR 564 (E) • very successful due to its ease of use and interoperability • Majority share of the Home Automation market	• Proprietary radio systems available • Limited Range drives up costs	• Security systems. • Home automation. • Lighting controls
2. Cellular Technologies				

Cellular (2G-GSM/EDGE, 3G-UMTS, 4G-LTE)	For India, 900 MHz, 1800 MHz, 2100 MHz and 2300 MHz is allocated.	• Mature technology • Developed by global community of 400+ companies from 39 countries • Rapid deployment • Communication modules are low cost and standardised. • Roaming • Wide availability of Network Infrastructure	• Coverage not 100% • Reliability not the best • Short technology life-cycle (2G, EDGE, 3G, LTE etc.)	• Tele-Health • Remote Health Monitoring • Smart Metering • Remotely switching ON/ OFF the water pump in rural areas, using mobile phone
Cellular 5G:		• High speed internet services (eMBB) • Low latency (<1ms) (uRLLC) • Large number of devices may be connected / Sq Km. (massive M2M) • Wider coverage • Technology for vertical applications		• e-Governance, • Remote surgery • Drones, • Remote maintenance of machines, • Precision agriculture • Livestock monitoring and management
3. Cellular Low power wide area network technologies				
Cellular: EC GSM IoT	2G Bands	• Network infrastructure is backwards-compatible to previous releases to allow the technology to be introduced into existing GSM networks	• Eco system is yet to be developed	• Smart cities & homes • Smart utilities • Industrial automation • Wearables • Smart energy • Intelligent transport systems
Cellular: NB-IoT	Conventional LTE cellular bands like 700 MHz, 800 MHz and 900 MHz, and re-farmed 2G bands	• Standards based defined by 3gpp, the global standardization organizations supported by a mature global ecosystem • wide area ubiquitous coverage • deployed through upgrade of existing network (reuses existing network infrastructure) • Ultra-low-power consumption in devices • Enhanced for 20+dB additional coupling gain. (reaches deeper	• Limited Mobility is not yet supported (limited support based on cell reselection) • Voice is not supported • Low Data rate applications with link peak DL = 60~100kbps & UL=~50kbps	• Sensor based applications, with low data rate requirement. • Applications not requiring high speed mobility handovers. • Systems where devices/sensor measurements are expected to be for long ~10years

		in-building & underground) • low cost terminal • plug and play • high reliability and high carrier-class e2e network security (based on LTE)		
Cellular: eMTC	Conventional LTE cellular bands like 700 MHz, 800 MHz and 900 MHz	• Developed by 3GPP a mature global ecosystem • Low power consumption • Works over existing LTE networks • Easily configurable on demand scaling possible • Supports full mobility • Supports voice through VoLTE • high reliability and high carrier-class e2e network security (based on LTE)	• Support of higher bandwidth limits the other optimizations possible, compared to NB-IoT and EC-GSM-IoT	• Wearables, • Asset Tracking, • Pet Trackers • Telematics, • KIOSK, • Parking, • Industry environment monitoring, • Connected Healthcare personal & Enterprise equipment • Industrial IoT with Emergency Voice call support
4. Non Cellular Low Power Wide area network technologies				
LoRa	Sub GHz	• Network can be defined by the individuals / owners. • Support long range and high battery life • High security using AES 128 encryption • Low Cost infrastructure	• Own deployment with no subscription fees • Works in unlicensed band. • Limited data rate and payload size	• Smart Metering, • Smart street Lighting solutions • Asset monitoring • Tracking • Transmission of soil data, transmitting fire alerts etc. • Weather forecasting • Environment (CO_2, CO, humidity, Temperature etc.) Monitoring
5. Wireline Technologies				
DSL	0-2.208 MHz	• Inexpensive (installation and use) • High SLA • Less installation time • Bonded DSL provides inherent redundancy	• Low data security • Lower throughput • Higher latency	• Gateway for Remote Health Monitoring • Concentrator for Tele-Health • Home Automation

Ethernet	16,100,250 ,500, 600 MHz 1 GHz, 1.6-2.0 GHz	• Inexpensive (installation and use) • Excellent throughput • Low installation time • Easily scalable	• Lowest data security • Lowest SLA • Highest latency • Bursts of additional bandwidth not possible	• Gateway for Remote Health Monitoring • Concentrator for Tele-Health • Smart Metering • Home Automation

Annexure: 2

Use Case: Remote Patient Monitoring (RPM)

Source: This use case is described here in short; detailed use case is available in the document on ITU-T website[76]

Remote Patient Monitoring (RPM) is a Tele-health solution that enables monitoring of patients outside of conventional clinical settings (e.g. in the home). The patient has medical device on or close to his/ her body which has sensors that capture the patient's healthcare/ physiological data. This data is then transferred across networks with the help of transmitters and is monitored for any abnormality with the help of software and/or by clinical experts.

By using RPM, patients after surgery can be shifted to their homes and monitored remotely. It will help in reduction of cost (in case of surgery) and availability of the beds for other patients.

Increasing number of people with chronic medical conditions and senior citizens, coupled with shortage of skilled medical personnel is driving the demand for remote Tele-health services all over the world. Remote Patient Monitoring increases access to healthcare services, simultaneously decreasing healthcare services' delivery cost. It addresses the key concern points of the stakeholders in a healthcare system by enabling the exchange and flow of information from the patient's medical device (outside of hospital) to the clinical staff such as doctors, nurses and paramedics.

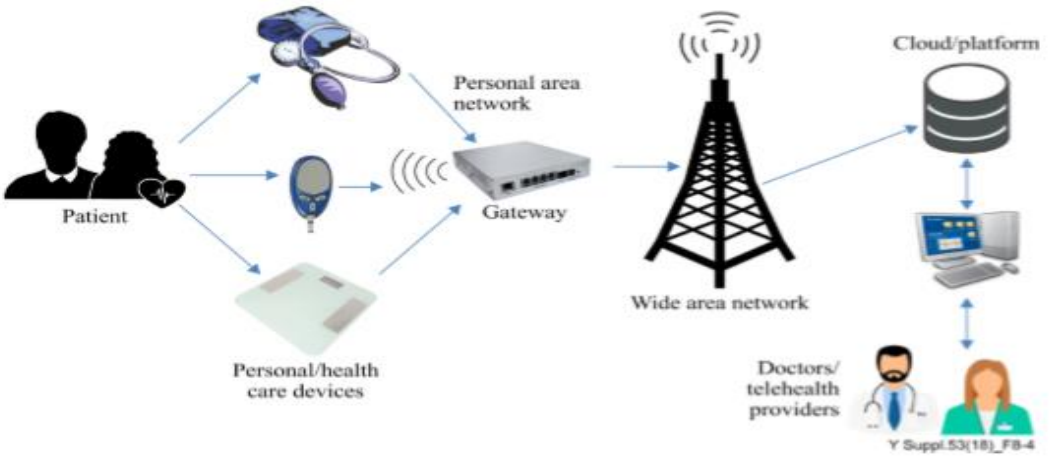

Figure 25 ANNEX2- 1: Remote patient monitoring concept

Components of RPM Solution:

- Sensor based IoT healthcare device enabled by wired or wireless communication to measure physiological parameters.
- Local data storage at patients' site that interfaces between sensor based IoT healthcare device and other centralized data repository and/or healthcare providers.
- Data transmission and connectivity.

[76]https://www.itu.int/ITU-T/recommendations/rec.aspx?rec=13867&lang=en

- Centralized repository to store data.
- Diagnostic application software that generates treatment recommendations and intervention alerts based on the analysis of collected data. This may be augmented by medical experts such as doctors, nurses, etc.
- Depending on the disease and the parameters that are monitored, different combinations of sensors, storage, and applications may be deployed.

Communication channel used

- Wired communication like serial port, USB, audio port etc.
- Wireless Data Transmission Channels such as Bluetooth, Wi-Fi, GPRS or any other form of telecom connectivity.

Data bandwidth requirements

Data bandwidth requirements are dependent on the vital parameters used, nature of patient's data being monitored and the frequency of data transfer. Based on the range of devices available/ put to use, the data bandwidth requirements differ.

At times, the remote device or gateway device may store the data in case network connectivity is unavailable, and all data is forwarded in bulk once network connectivity is available.

Annexure: 3

Use Case: AI based rapid assessment of avoidable blindness

Source: M/s Calligo Technologies Pvt Ltd, Bangalore (https://www.calligotech.com)

The most common eye problems are

- Cataract
- Diabetic retinopathy
- Macular degeneration
- Refractive errors
- Glaucoma

Diabetic Retinopathy (DR), also known as diabetic blindness, is rapidly evolving as a leading cause of blindness globally. Globally, there may be around 511 million diabetic patients, with 98 million in India alone by 2030[77]. One of the consequences of diabetes is diabetic retinopathy, caused by high blood sugar levels damaging the back of the eye. Almost 35% of all diabetic patients have some form of diabetic retinopathy, which if left undiagnosed and untreated, can lead to blindness. Many people might not be aware that they have diabetes and early onset of diabetic retinopathy. In these situations, timely detection and intervention can minimize the loss of vision as there are no solutions to reverse the condition.

In most of the developing countries, there is a lack of trained ophthalmologists. Generally, rural areas and smaller towns in India have inadequate facilities for diagnosis and investigation.

Healthcare is emerging as a prominent area for AI research and applications. And nearly every area across the industry will be impacted by the technological developments. One such example is Image recognition, which is revolutionizing the diagnostics. For this, data is required to be analyzed quickly, especially in healthcare. Edge Computing is a technology by which the time between data capture and analytics are considerably reduced. It works in such a manner that the devices themselves are configured to handle critical analysis on their own.

Solution named as Calligo Health Engine uses AI and Edge Analytics to detect unusable images taken during an examination and prompts the technician in real-time to select a new image. Once usable images are captured, the system grades the images and identifies if the images have DR. If a patient is found to be Diabetic Retinopathy positive, they are instantly advised to consult an ophthalmologist to determine the next course of action.

This simple, cost effective system means that even a minimally skilled technician can take usable, quality images of the eye fundus, and diagnose if a patient has DR. This system results in earlier detection of DR, which can help high-risk patients to retain their sight and enable specialists to focus on treatments.

[77] https://www.indiatoday.in/education-today/latest-studies/story/98-million-indians-diabetes-2030-prevention-1394158-2018-11-22

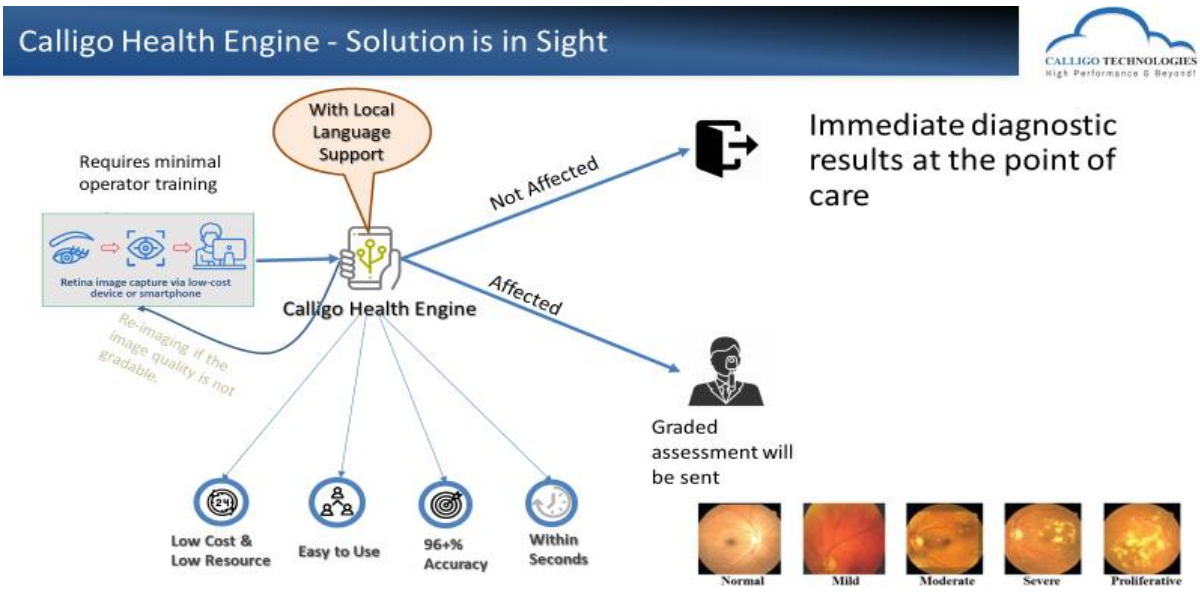

Figure 26 ANNEX3- 1: Calligo Health Engine Solution

Key Benefits:

- Very useful for addressing the problem in villages, which may not have trained Ophthalmologists and medical facilities.
- Early detection of DR can help people to retain sight and enable specialists to focus on treatments
- Automatic feature extraction uses deep and iterative learning to continuously improve the outcomes.
- Relatively lower cost than manual methods.
- Advance image processing capabilities.
- Very high accuracy.
- Highly scalable process with a quick response time.
- Solution is extensible for other eye diseases (Glaucoma, Retinopathy of Premature, Hypertensive Retinopathy, Macular Oedema etc.)
- Solution can also be extensible to other common problems like Oral Cancer, Cervical Cancer etc.

Annexure: 4

Use case: Live soil nutrient monitoring and management (SLiM)

Source: M/s Agenttech, Bangalore

Contact details- ravindra@agenttech.org

Introduction-

The world's population growing at a rapid rate, which leads to an increased demand of food production across the globe. The conventional soil testing methods, based on manual or mechanical soil sampling and colorimetric or atomic emission spectroscopy, are costly and time consuming. To overcome disadvantages associated with the conventional methods, M/s Agenttech, Bangalore developed an AI based IoT product and solution named as SLiM. Parameters associated with the reference soil samples are extracted by appropriate transducers or sensors or chemical reaction or electrical/optical methods or any combination.

Working of Product and Solutions-

This product provides solution for control, measure, monitoring, prognostic and diagnostic of soil parameters. Using this product, one can trans-receive soil nutrients parameters such as Nitrogen, Phosphorus, Potassium; Calcium, Magnesium, Sulphur; Boron, Copper, Iron, Manganese, Carbon, Zinc; Conductivity, pH value etc.

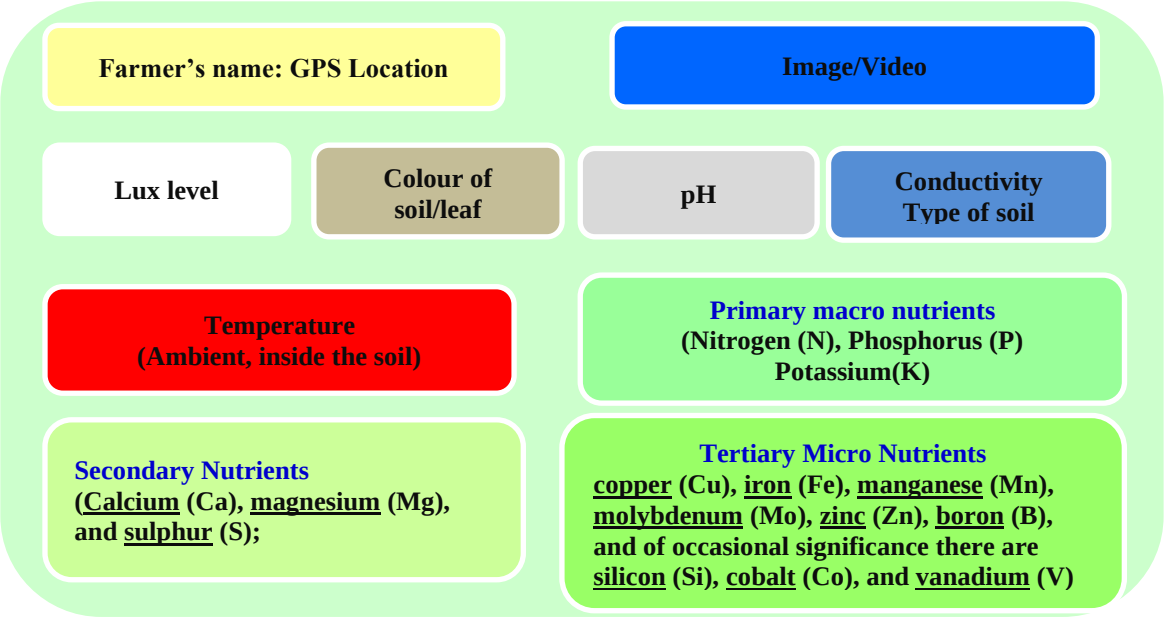

Figure 27ANNEX4- 1: Mobile User Interface

This product and solution also provide live Global Positioning System (GPS) location, and multimedia (text, audio, and video) of the soil testing location/farm. This information is made available to view locally (mobile device/product display) or over cloud, or any other possible communications network (ZigBee, Bluetooth/ BLE, Wi-Fi, others) or any combination thereof. Received parameters from various transducers are fed to novel software tool which would accurately determine the available nutrient status of soil and guide the efficient use of fertilizers. It is also possible that if a person/farmer sends an SMS or presses a

button, then automatically he/she would receive the soil parameters of the mention farm/land. With the increasing awareness of fertilizer's effects on environmental and soil quality, these live soil parameters are needed for efficient agricultural production, including site-specific crop management as per the local requirements. This product and solutions can be used for various other applications to trans-receive parameters. All these parameters are made available live at local or central or multi location by a communication network via wired or wireless or satellite communication.

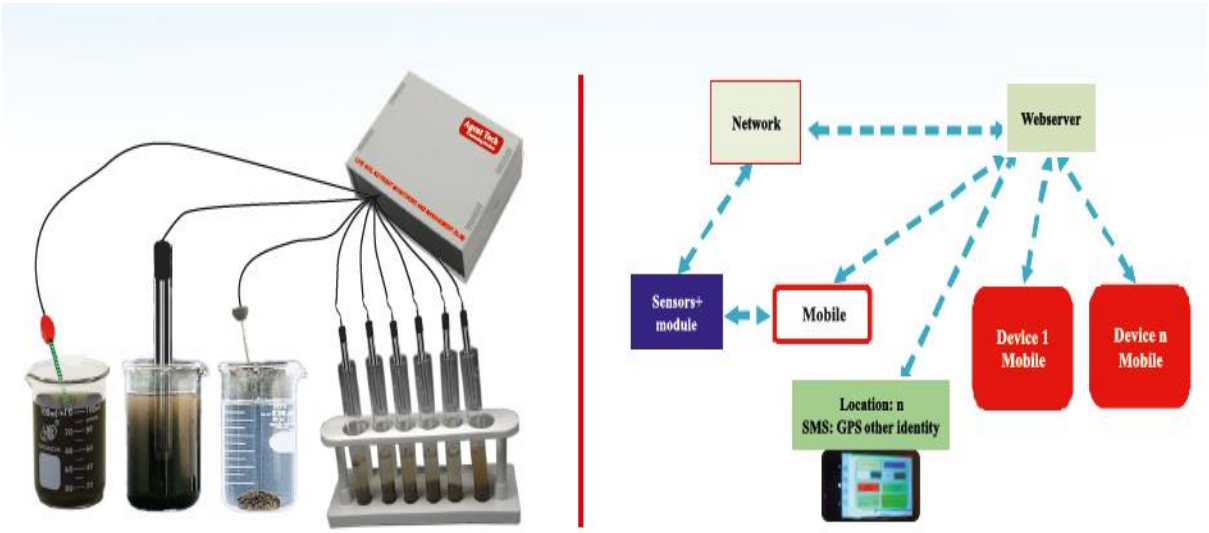

Figure 28ANNEX4- 2: Live soil nutrient parameter measurement and monitoring

Working and usage of the user interface-

In this product user authentically login to the application using password, then user is able to see the user interface display as shown in Figure 27ANNEX4- 1. As and when user presses/touches any of the parameter button say primary nutrient, then application would open a new page and provide detail information about the parameters (Nitrogen: N, Phosphorus: P and Potassium: K) associated with the reference soil. Whenever user presses image/video then live video will be played with audio. In the first version of the product release, user interface was designed for English language and later it could be extended to other Indian languages as well. This application would also provide inferences such as which crop would be the best option for the reference soil/farm, and if the farmer choses for other crop then how much fertilizer is needed, limestone/salt to be put and so on. If the user is uneducated to operate the mobile application, then one special button would automatically trans-receive soil nutrient information.

Advantages-

1. The tiny portable product kit provides live monitoring of around twenty-four soil parameters, primary (NPK), secondary, tertiary nutrients; colour, pH value, moisture, conductivity, temperature, GPS location along with audio and video.
2. Farmers in mobile phone would receive their farm land soil nutrients parameters in less than 30 minutes.

3. The product provides input for right crop for the reference farm to be cultivated with maximum profit in a timely manner for the farmer.
4. The product suggests site-specific crop management as per local supply and demand requirements.
5. The product enhances farmers' standard of living.
6. AI and IoT based solution guides the famers to efficiently use right fertilizer, manure, and pesticides.

Annexure: 5

Use case: Smart Irrigation System

Source: (Taken from web)
M/s Ossian Agro Automation, Pune, Maharashtra.
Contact detail- shostwal@yahoo.co.in

Introduction-

India, being an agriculture-based country, does not have enough support to help farmers to increase the production. One of the most common problem a farmer faces, is regulating their pump in the farms. At the time of rain or any other adverse conditions, it becomes difficult for farmers to shut down the pumps. To overcome this problem, M/s Ossian Agro Automation developed a product "Nano Ganesh Technology" for smart irrigation.

In some parts of India, farmers have to walk several kilometres to turn 'on' and 'off' the irrigation pumps that water their fields. With the electrical supply often being erratic, they sometimes find that there is no electricity when they reach the pump. Nano Ganesh helps them to remotely check the pump status, to check whether there is electricity or not and to automatically turn the pump 'on' and 'off', all through a low-cost mobile phone. It helps the farmer avoid various difficulties in reaching remote water pumps, like long travel over difficult terrain, bad weather and hazardous locations.[78]

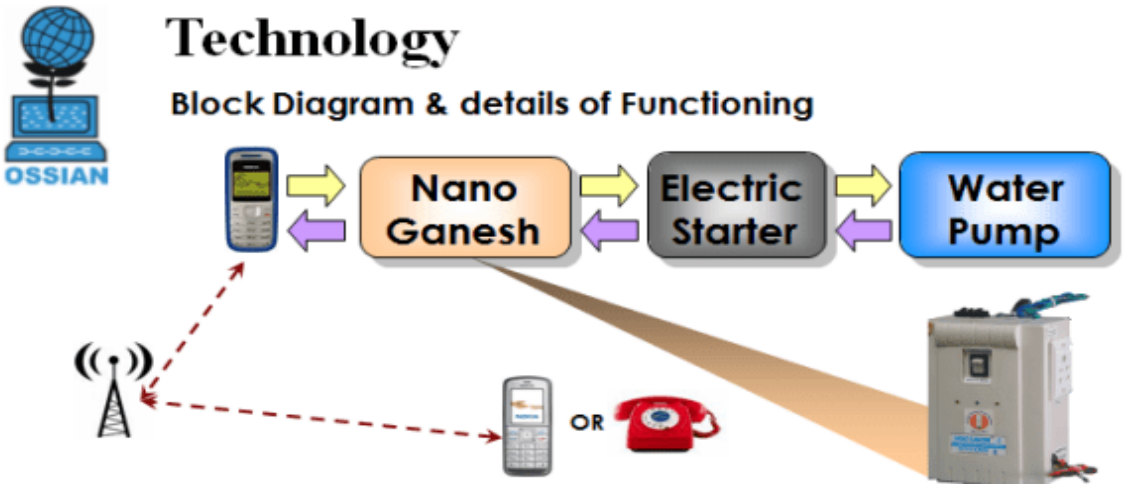

Figure 29ANNEX5- 1: Mobile User Interface

Operation-

Device named as Nano Ganesh is connected to the existing starter of the pump set. A farmer has to simply dial a number dedicated for a Nano Ganesh set and then punches his 'on' or 'off' code to control the pump set. It can be connected to any existing electrical starter and motor pumps. Hence, there is no necessity of replacing the pumping set. For higher hp pumps, it can be connected along with the protection systems.

[78]http://www.nanoganesh.com/

Features-

- Water pump can be controlled from any distance by a mobile or land line phone.
- A mobile network is essential near the water pumps.
- One can check availability of the power supply at the pump end.
- One can check the load ‘on’ / ‘off’ status by a simple audio tone.
- Automatic Mode / Remote Mode available.
- Provision of memory for storing the ‘on’ and ‘off’ commands.

Annexure: 6

Use Case: Crop Pest Surveillance System

Source: (Taken from web)

Introduction-

By the use of Internet of Things (IoT) and sensor network technology, farmers can manage and monitor the pests and also improve the production, quality of crops. Farmer can use various sensors for insect pest detection on crops. Such sensors are: Low power image sensor, Acoustic sensors etc. The acoustic sensor is an insect pest detection sensor which works by monitoring the noise level of the insects. Also, by using drones in the field, the image of crops may be captured and send to the users which will help in detecting the pests in the field[79]. These systems help the farming community to identify various pests, disease and other nutritional deficiencies in their crops through an interactive model and to take suitable control measures on time.

Sensors for Insect Pest Detection-

Farmers can use various sensors for insect pest detection on crops. Some of the most common sensor types are:

1. Low power image sensor-

The low-power image sensor is a wireless autonomous monitoring system that is based on a low-cost image sensor. Placed in a single trap, the wireless sensor periodically captures images of the trap contents and sends them remotely to a control station. Sent images are then used for determination of the number of pests found at each trap. Based on insect population numbers, a farmer can plan when to start with crop protection and in which field areas.

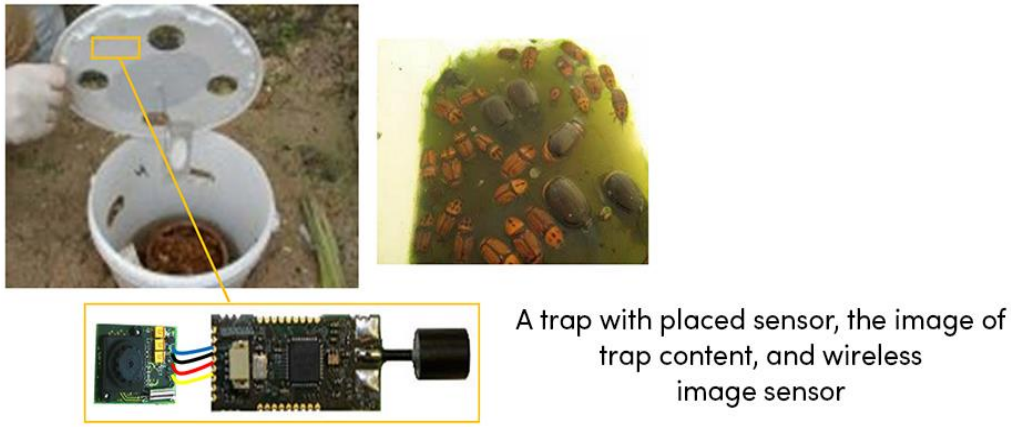

Figure 30ANNEX6- 1: Pest monitoring by low power image sensor

2. Acoustic Sensor-

An acoustic sensor detects pests by monitoring the noise level of the insect/ pests. The wireless sensor nodes are connected to a base station, which is placed in the field. When pest's noise level crosses the

[79]https://blog.agrivi.com/post/farm-revolution-sensors-for-crop-pest-detection

threshold, sensor transmits that information to the control room's computer, which then accurately indicates the infestation area.

These sensors help to detect an infestation at a very early stage, thus significantly reducing crop damage. These are good tools for monitoring large field areas with very minimal energy consumption.

Besides abovementioned sensors, there are numerous other sensors that can be used for detection of insect pests and crop diseases using electrical, chemical, electrochemical, optical, magnetic, or vibrational signals. However, farm technology is modernizing rapidly. New sensors are continually being developed to support early pest identification based on bio-recognition elements such as DNA/RNA, antibody and enzymes.

Intelligent insect pest monitoring system using AIoT: Use of Artificial Intelligence of Things (AIoT), convergence of AI and IoT, in agriculture is intelligent insect pest monitoring. By keeping track of the insects'/ pests' population density in ones' farm, data-driven strategies can be developed for implementing Integrated Pest Management (IPM). An insect pest monitoring system has been designed to fulfil this goal, comprising wireless imaging and environmental sensor nodes. Each node includes an embedded system, RGB camera, a temperature-humidity sensor and a light intensity sensor. A sticky paper trap is held at a fixed distance in front of each node and the camera captures the image of the sticky paper trap. Along with the environmental data, the sticky paper trap images are sent to the remote server via internet for remote processing. The nodes are hung inside the greenhouses depending on the suspected insect pest hotspots, as suggested by the farm owners. The architecture of the system is shown in figure below-

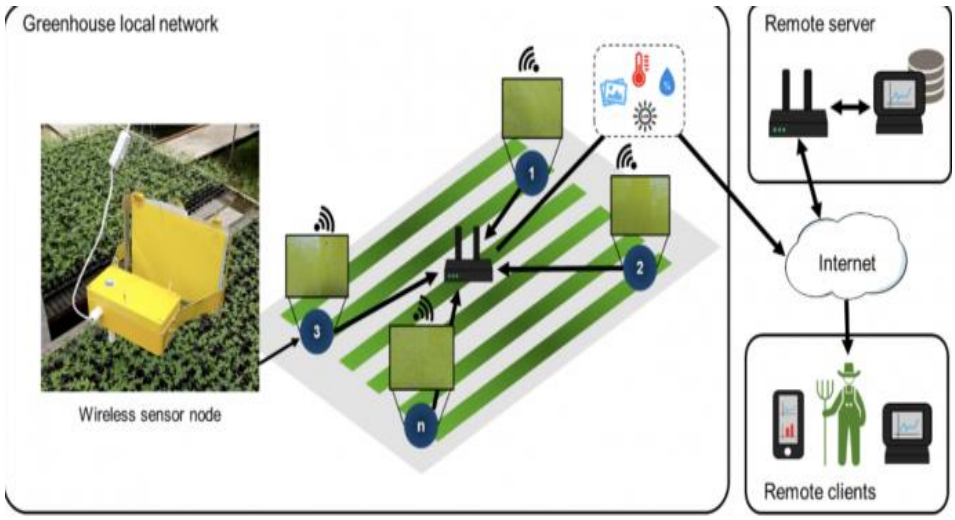

Figure 31ANNEX6 – 2: Intelligent insect pest monitoring system[80]

In analysing the sticky paper trap images, an insect pest detection and recognition algorithm is used. Before the emergence of AI in image processing, most insect pest detection algorithms use traditional image processing techniques for analysing the sticky paper trap images. Ever since most works use a method in image processing called colour segmentation for detecting the insect objects from the photos. Colour segmentation aims to separate the foreground (insect objects) from the background of the sticky

[80]http://ap.fftc.agnet.org/ap_db.php?id=1077

paper trap image and determine insect objects' location. The features of the detected insect objects such as colour, shape and size and gradient are then obtained. These features are then used to classify the insect objects by using feature analysis or statistical approaches such as support vector machines. However, it was then realised that these methods have some limitations, especially for more dynamic applications.

In recent years, several works using AI for detecting and identifying the insect objects became more popular due to its adaptability and accuracy. However, using deep learning based object detection, the algorithm's detection rate got remarkably improved, thus improving the accuracy.

The data obtained using the insect pest detection and recognition algorithm is automatically analysed and designed before transferring to the farmers. The data is converted into more meaningful information through data analysis such as alarms rather than offering only the raw data to the farmers. This enables farmers to understand their data more quickly and easily.

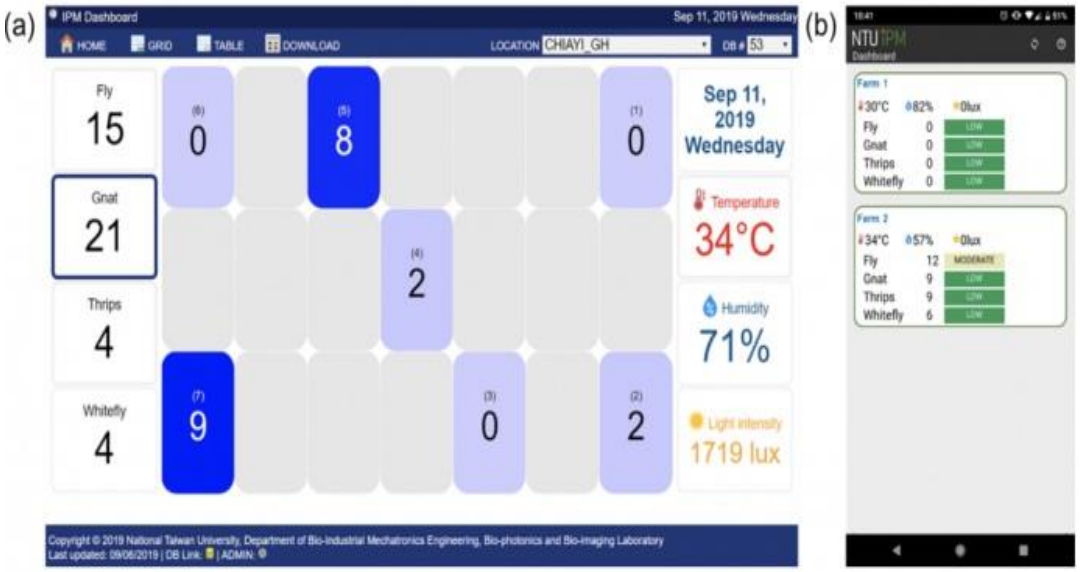

Figure 32ANNEX6 – 3: Screenshot of parameters (a) Website (b) Mobile App

It shows the insects' count, node locations identifying the hotspots and sends alerts to farmers using data-driven methods. This information can be used by the farmers to plan the spraying of pesticides more efficiently.

Annexure: 7

Use case: Animal Activity monitoring tag

Source: M/s Prompt Equipments Pvt. Ltd, Ahmedabad, Gujarat
(www.promptdiarytech.com)
Contact: info@promptdairytech.com; info@promptgroup.co.in

Introduction-

M/s Prompt provides innovative solutions for an efficient dairy procurement supply chain. M/s Prompt have developed BovSmart Animal Wearable tag, which is a comfortable non-invasive IoT solution designed for detecting the onset of the cow's heat cycle with 90% proven accuracy. Developed with a specialised algorithm, it is designed to ensure timely breeding with high-success rates. This cattle management software leads to improved productivity and better animal health. Good cattle health facilitates better quality of milk, which results in an increased yield.

The BovSmart animal heat detection tag plays a crucial role as it enables timely detection for insemination. As precise heat detection is difficult, so farmer may end up losing out on timely breeding. Along with ensuring timely breeding, the farmer is also notified in case of any deviation or emergency. The BovSmart animal heat detection tag consists of following components.

1. Mobile App-
   The Mobile App provides 24*7 real-time monitoring of the cow. It lets farmer easily manage the breeding activity taking place at the farm while keeping a log of all previous breeding activity of the cattle.
2. Individual cow tags –
   The Web Portal also consists of a special section known as the individual cow page which displays the entire activity of the cow during the last month. Documenting of heat or any observation of low activity in the animal can be found on the page. Moreover, in the event of heat or low activity, an alert is sent to farmer via SMS and e-mail.

Figure 33ANNEX7 – 1: BovSmart Animal Wearable Tag

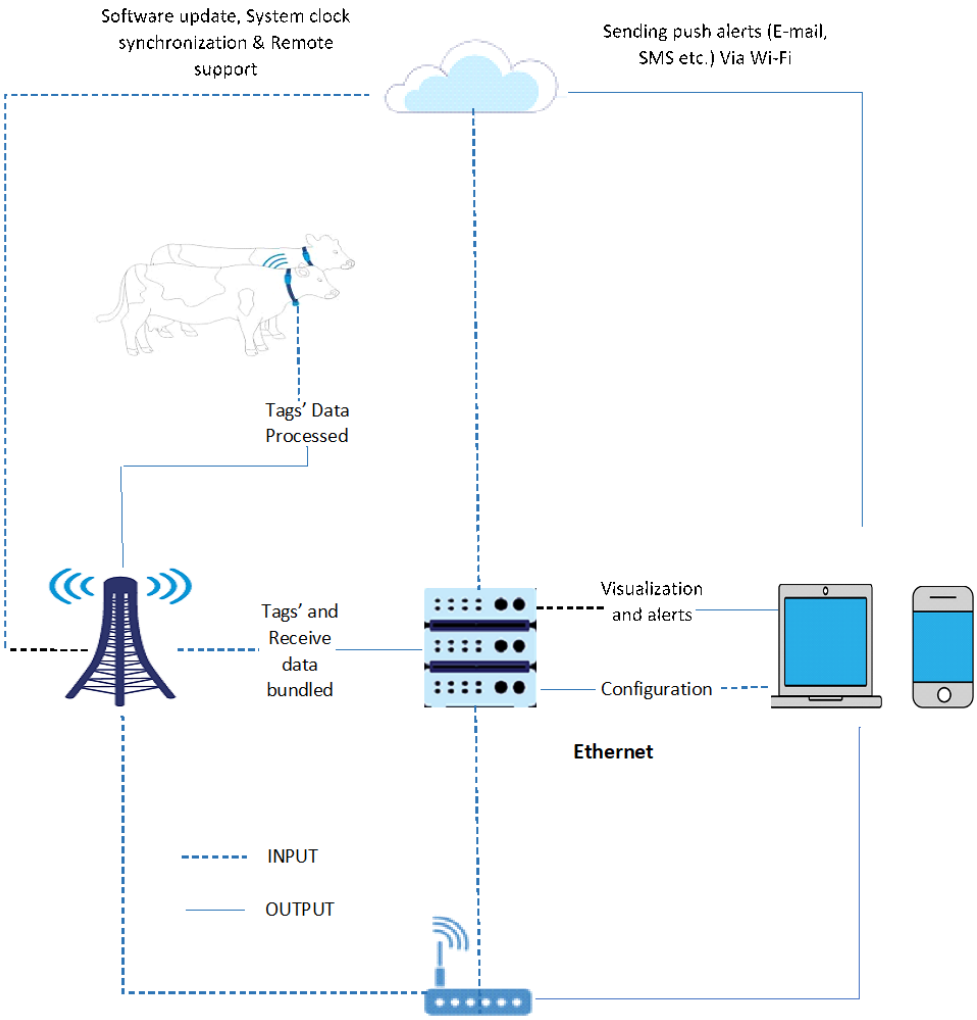

Figure 34ANNEX7 – 2: Animal monitoring information flow diagram[81]

Key advantages-

1. Remote and real time monitoring as well as tracking of cattle through collar-worn wireless activity tags.
2. Records activity profile, rumination profile.
3. Provides actionable insight to improve farmer's earning through real time monitoring of oestrus cycle and animal health.
4. Sends actionable timely alert to farmer through SMS or e-mail regarding heat detection and general growth of the cattle.[82]
5. Sends alert in case of Animal in Heat, Anima Non cyclic, Animal Repeat Breeder & Animal low active.

[81]https://www.promptdairytech.com/animal-heat-detection-system/
[82]https://www.promptdairytech.com/

Annexure: 8

Use case: Milk Testing Device

Source: M/s Prompt Equipments Pvt. Ltd, Ahmedabad, Gujarat.
(www.promptdiarytech.com)
Contact: info@promptdairytech.com; info@promptgroup.co.in

Introduction-

M/s Prompt provides innovative solutions for an efficient dairy procurement supply chain, from farm management and milk collection to quality analysis and preservation to ensure that the purity of milk is retained at every step. Company has developed the devices namely Indiz -Ultrasonic Milk Analyzer, Fat'omatic and BMC SmartBox which measure and record milk fat, Solids-Not-Fat (SNF), added water, milk density, temperature and has inbuilt features like power on self-test and ensure accuracy of readings. This ensures that the quality of milk is not compromised in a high throughput environment.

This milk analyzer kit provides accurate milk parameters reading and link it with the pay-out to farmer in real-time. All the data is stored online on cloud platform and can be accessed through Bluetooth mobile application. This increases transparency and profitability arising out of improvement in the quality of milk collected.

Figure 35ANNEX8-1: Real time measuring the quality of milk

Three steps towards accuracy-

1. Sample bottle is placed under the invert-U shaped suction pipette. 0.5 ml milk will be sucked in.
2. Use empty beaker under the pipette to collect milk and fat solution mixture that comes out.
3. Place the beaker below the suction piece on left side of the machine. Mixture gets sucked and fat% will be displayed in due time.

Figure 36ANNEX8-2: Fat'omatic and Milk analyzer kit

Key Advantages-

1. Milk fat, SNF, added water, milk density, temperature etc. can be measured.
2. Online secured central calibration.
3. Eliminates human errors.
4. An indigenous product, offering services across India.
5. Preventive maintenance through Bluetooth mobile application.
6. Low operation and maintenance cost.
7. Measuring time 30/40 second, depends upon the model.

Benefits-

1. Transparency and fair payment to farmer-
   Due to online calibration, farmer can be assured that the machine displays accurate milk parameter and is free from any adjustments due to manual intervention. No difference in Fat/SNF reading at the dairy and at milk collection center leads to optimal pay-out to the farmer, increases transparency and ensures the desired quality of milk.

2. Real time information on cloud-
   All the historical data logs such as Fat, SNF, self-cleaning data, calibration data etc. are maintained online on the cloud which can be accessed in real-time.[83]

[83]https://www.promptdairytech.com/

Annexure: 9

Use case: Smart Anganwadi

The Smart Anganwadi project was launched by Vadodara Municipal Corporation in the year 2014 for monitoring health and nutrition of children[84]. Smart Anganwadi app was launched to ensure timely delivery of food supply to Anganwadi, real-time health tracking and also to eliminate multiple data updation in various registers. This app provides a platform to connect delivery workers, Anganwadi teachers and data background centres over smartphones.

An application has been developed and installed on the mobile devices provided to Anganwadi teachers. The Android application is linked with Smart Anganwadi software and helps in monitoring the weight of children, their health status, the quantity of milk supplied to them and the timings of milk supply, which would be displayed on the smartphones of Anganwadi workers. The supply workers confirm their food delivery on the app which is endorsed by the teachers; subsequently teachers have to update the profile of students on the app and tag their health progress on the colour range of red, yellow and green. Additionally, all other details need to be submitted on the app to eliminate the use of various registers and its collaboration. The application also generates monthly progress reports and monthly reports of food delivery at Anganwadi centers.

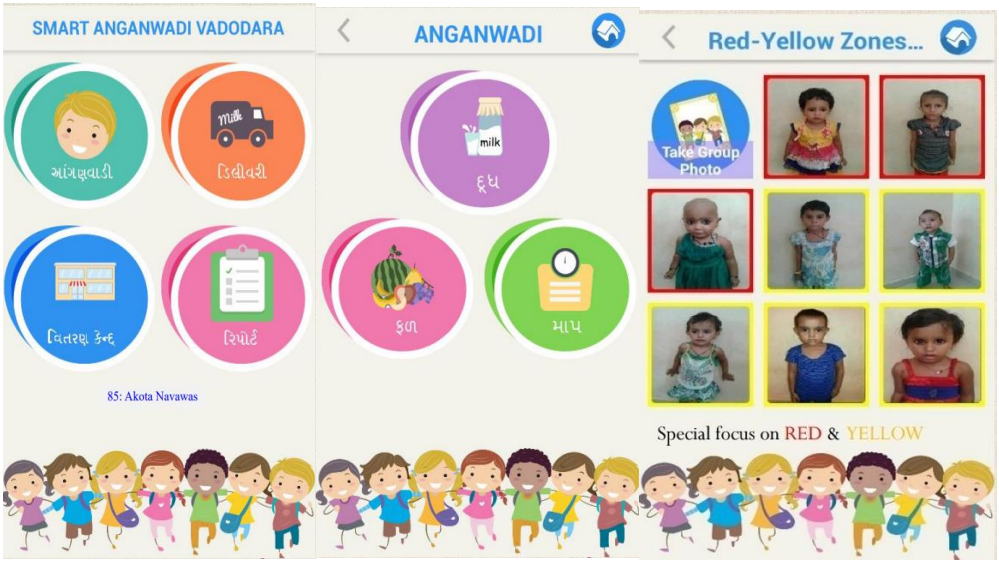

Figure 37 ANNEX9-1: Smart Anganwadi mobile application

Key advantages-

I. Improved service delivery

II. Provides real-time information on service delivery at Anganwadi center and on growth and nutrition status of children.

III. Support Anganwadi workers' jobs through in-built counselling aids, alerts and auto plotting of graphs and due lists.

IV. Aid collection of real-time data, enabling supportive supervision and timely intervention by the department official.

[84] https://vmc.gov.in/pdf/Smart%20Anganwadi%20Presentation.pdf

V. Auto-generation of registers which were compiled manually by Anganwadi workers.

Annexure: 10

Use case: e- gram Vishwagram project

This project was launched in 2009 which aims to address the digital divide between urban and rural citizens. It is implemented in the state of Gujarat. The Panchayat, Rural Housing and Rural Development Department of Government of Gujarat are responsible for implementing this project. Now, e-Gram has been integrated with Common Service Center (CSC).

These centers provide Government to Citizen(G2C) services (e.g. birth, death, caste, income certificates; tax collection receipts, land right records etc.) and Business to Consumer(B2C) services (e.g. e-ticketing, bill payments, financial services etc.) and services through entrepreneurship. They are operated through village computer entrepreneurs on Public Private Partnership (PPP) model. Panchayats are the delivery points for these services. Scalability depends on enabling infrastructure.

This initiative targets to promote and sustain village panchayats, the basic unit of governance in rural India, as the delivery point/conduit of e-services for various government departments. This project empowers rural community through access to global communication and information. The services are available at the doorstep of the villagers. This is also effective in the quick redressal of grievances that used to take a long time before this intervention[85].

Government of India created Special Purpose Vehicle (SPV) named Bharat Broadband Network Limited (BBNL) in 2011 for accelerating the National Optical Fiber Network (NOFN) project to connect 0.25 million Gram Panchayats on OFC. It was later renamed as BharatNet in 2015. Details are available in Section 2.3.

[85] https://egram.gujarat.gov.in/pages/home.aspx#

Annexure: 11

Use Case: Using IoT sensors & Blockchain led Food Traceability Solution to arrest Food Adulteration

1. **Title of the use case**
   - Name: Using IoT sensors & Blockchain led Food Traceability Solution to arrest Food Adulteration
   - Source: Go4Life Organic Milk Private Limited (https://www.go4life.in/)

2. **Objective of use case**

   The use case describes the building blocks for arresting adulteration in food products by increasing wing to wing traceability in the supply chain by juxtaposing IoT Sensors, Blockchain Framework and Rural Community Outreach Programs.

3. **Background**

   A: Country specific scenario

   A national level survey carried out by the Food Safety and Standards Authority of India (FSSAI) has found that adulteration and higher than permissible level of antibiotic residues in milk remain a problem in the country, though the instances could be much fewer than what is generally perceived. The 'National Milk Safety and Quality Survey 2018' results showed that 12 out of 6,432 samples of milk were found unsafe for human consumption due to adulteration. FSSAI published the results of this survey in a report[86] and released in public domain through a Press Release[87].

   Samples had residues of antibiotics above the permissible limits contaminated with aflatoxin M1 residues, a chemical compound that get into the milk through feed and fodder.

   There is no visibility on source of production and transparency on the entire supply chain process, thereby providing ample adulteration opportunities in the entire process, in the absence of any wing to wing traceability solutions that are economical in nature.

   Food adulteration poses severe dangers. When adulterants in question are consumed in excessive amounts, the risk of reversible damage to various organs increases multi-fold, as does the risk of cancer.

   Additionally, India has also received an advisory from World Health Organisation (WHO) which states that failure to check the adulteration of milk and milk products would see 87% of Indian Citizens sufferings serious diseases like cancer by 2025[88].

   B: Current Practice

[86] https://www.fssai.gov.in/upload/uploadfiles/files/Report_Milk_Survey_NMQS_Final_18_10_2019.pdf

[87] https://www.fssai.gov.in/upload/press_release/2019/10/5da973ffaefcfPress_Release_Milk_Survey_Report_18_10_2019.pdf

[88] https://www.theweek.in/news/sci-tech/2018/09/06/Indians-drink-milk-adulterated-with-detergent-impure-water.html

Due to the manual handoff's between multiple stakeholders in the course of supply chain of farm products, the existing infrastructure is ineffective in ensuring that an authentic product is delivered to the customer's table in the most natural state itself without any adulteration. Most of the testing and control mechanisms are far spread over in the supply chain and are most reactive.

C: Need for Use Case

Adulterated food consumption leads to various irreversible health risks and can be fatal in extreme situations. The health challenges further create economic strain on the citizens as well as on the already stretched Healthcare Infrastructure.

4. Description

Go4Life Organic Milk Private Limited uses a synthesis of IoT Sensors, Blockchain principles, farmers outreach programs to deliver fresh, traceable milk directly from farm to consumers' table. In near future, the company is extending the same protocols to map Fruits & Vegetables Supply Chain to provide the same benefits of traceable products to the end consumers.

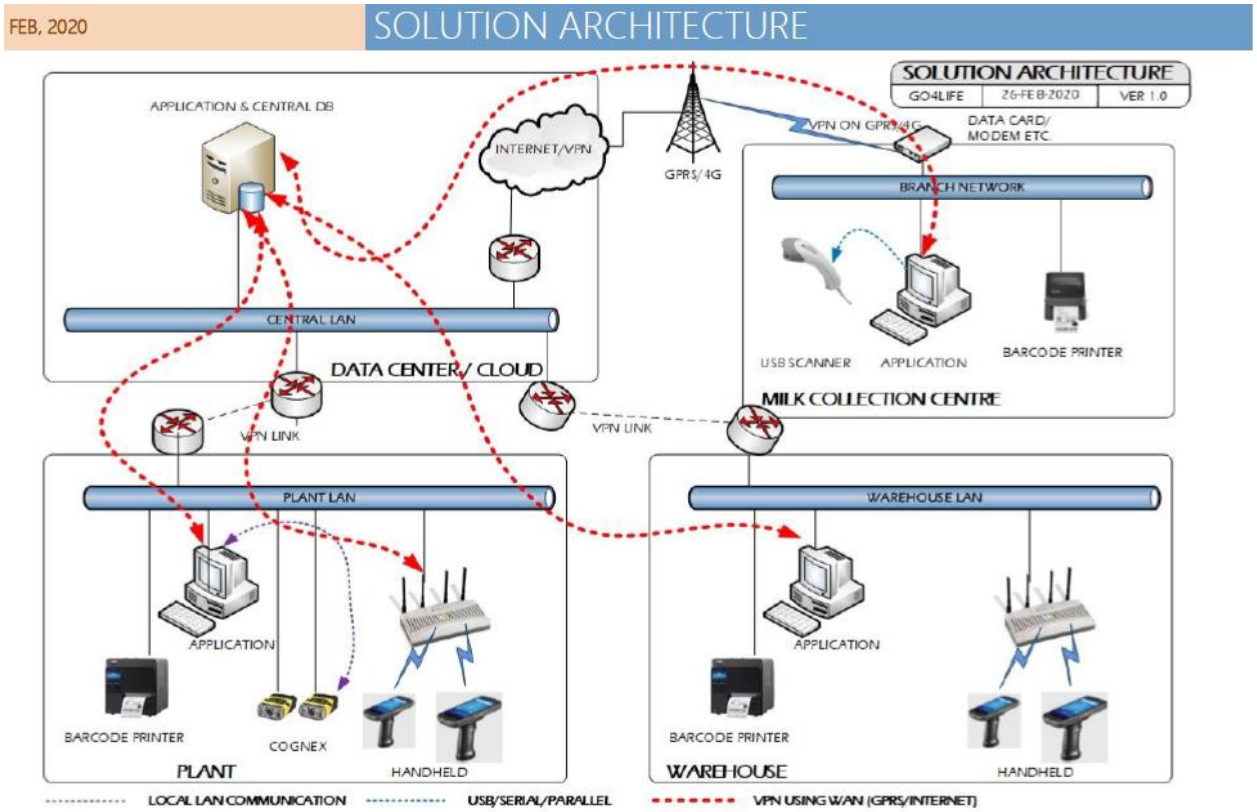

Figure 38 ANNEX11- 1: Go4Life Milk Traceability Solution Architecture

Go4Life works directly with farmers in multiple clusters. LF-RFID (Low Frequency - RFID) Tags attached with the cows are being used to map them with the farmer's Unique ID. A group of farmers is mapped to a Cluster ID, and a Group of Cluster ID are mapped to a processing & packaging centre. While currently the milk is in pouches, we are shifting the packaging to Gable

Top and attaching a GS1 standard compliant unique barcode to each packed carton. The cartons, when packed in group of 12 are assigned BIN numbers, and then ware house space is allocated to them. The required batch is subsequently transported to a nearby cold storage to be shipped directly to consumer's homes before 07:00 hours, through unique mapped delivery persons. At each stage of handshake, data is captured in the system and stored in the cloud. When the last mile delivery person hands over the packets to end customer, he sends a confirmation to the system on close looping of the cycle. The data gets uploaded in the cloud and the customer, while scanning 2D Barcode through Go4Life app, can see the entire journey of the milk from the cluster (with a group of farmers and unique cows) within time frame.

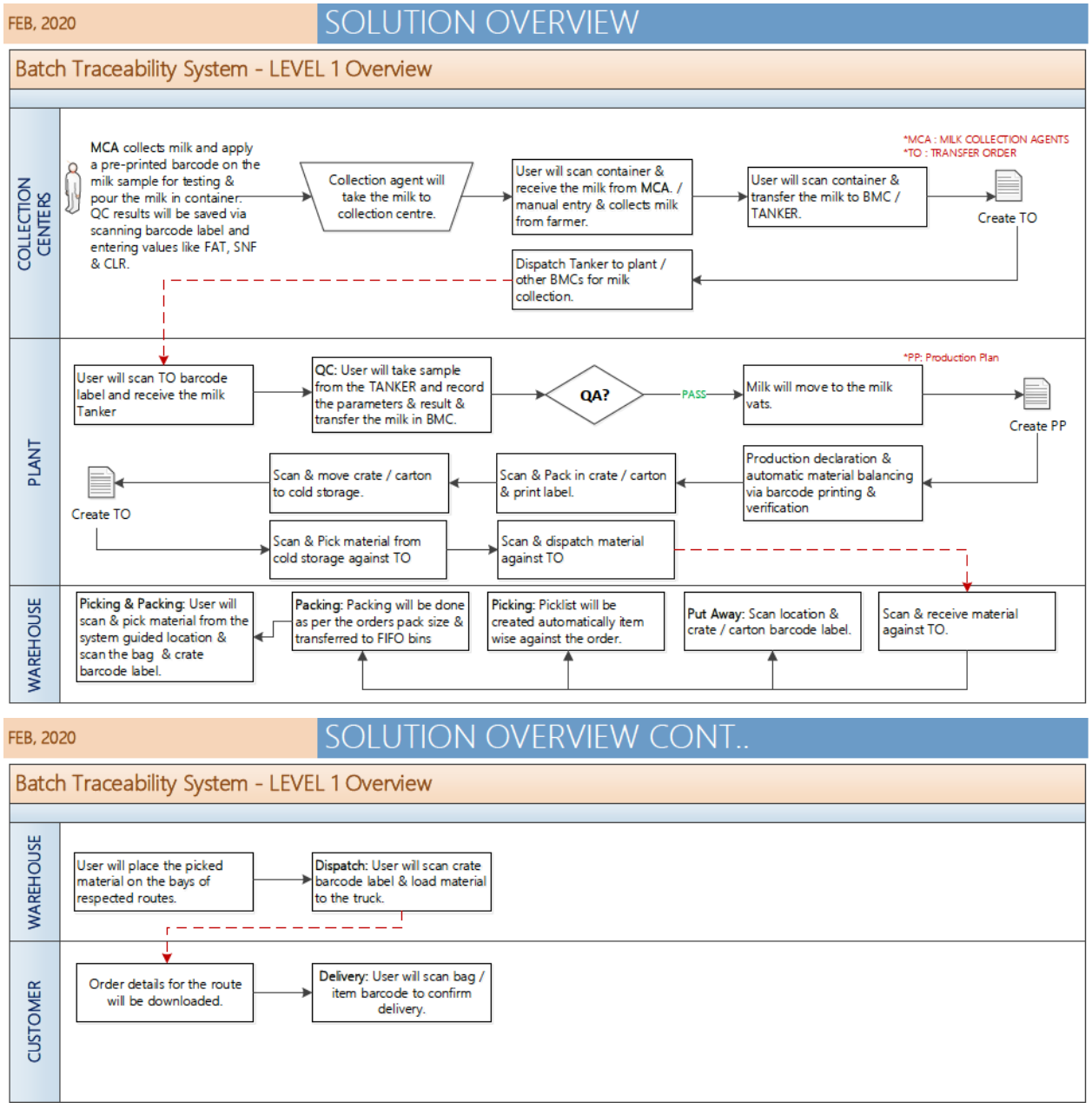

Figure 39: ANNEX11- 2: Go4Life Batch Traceability System Level 1 Overview

In **Phase II**, same principles are being extended to the feed/ fodder of cows – from which source it is coming from, how is it being stored & processed and the handshakes. The above data capturing will also enable us to manage the Fruits & Vegetables Supply Chain traceability mapping for ensuring consumer confidence.

In **Phase III**, a Blockchain layer is expected to be used for public to provide more transparency, which will further enhance the credibility.

Importance: Leveraging our insights and quality data, we are seeking to provide our end-customers a necessary trace of their food to ensure a fairer and more transparent value chain, thereby creating a value which is intrinsic to ethos of Go4Life in creating more sustainable, trustable and efficient food industry.

Annexure: 12

Use Case: IoT and ML based Smart Aqua Culture

Source: M/s MSQUBE Technology Solutions Pvt Ltd. (http://www.msqube.com)
Product Web: https://www.msqube.com/aquaqube/

1. Objective of the use case

The objective is to create an ecosystem capable of automatic and continuous monitoring of possible aqua health hazards by leveraging IoT and ML in Aquaculture in order to –

1. Predict and prevent fish mortality
2. Data-centric actionable insights to reduce operational cost for farmers
3. Monitoring the health condition of AquaCulture thus increase in growth and yield

2. Background

A: **Country specific scenario**:

The World Bank Group (WBG) and FAO summarize and highlight the critical challenges towards global food and agricultural sector due the projected increase in the worldwide population. According to a research published in "Genomics and Biotechnological Advances in Veterinary, Poultry, and Fisheries", the growing demand of food fish in recent years along with scope of economic gain has favoured both horizontal and vertical expansion of aquaculture.

According to National Fisheries Development Board [89], India; there are several challenges mentioned with few highlighted in relevance to the use case –

- The rapid growth of culture fisheries has enhanced the sector's vulnerability to aquatic diseases
- Specific problems negating the growth of culture fisheries include
    - poor physical condition of resources (specially the water quality and quantity)
    - inadequate regulatory mechanism
    - increased incidents of disease
    - low adoption of technologies and shortage of skilled manpower
- Exposure to misuse of drugs/medicines[90] due to inadequate monitoring and regulatory steps
    - How much drug is expected to get into the environment?
    - The drug's potential toxicity to aquatic life, and
    - Potential effects the drug's use will have on the environment.

B: **Current Practice**

Due to lack of infrastructure, awareness and suitable technology; the farmers in fisheries apply traditional knowledge that is ineffective in the current situations of continuous environmental

[89] http://nfdb.gov.in/PDF/National_Fisheries_Policy_2020.pdf
[90] https://www.fda.gov/animal-veterinary/animal-health-literacy/aquaculture-and-aquaculture-drugs-basics

changes, diversifications of various aqua products and unavailability of timely actions. Most of the testing and control mechanisms are so far manual and irregular.

C: **Need for Use Case**

The advent of emerging technologies like IoT, AI/ ML, widely available communication network and adoption of cloud may transform the Aquaculture. Following is needed to promote healthy and sustainable Aquaculture –

- 24x7 continuous monitoring of hazardous health situation prone to disease
- Reduce the use of excess drugs with data insights on fish health
- Predict and prevent fish causalities and disease outbreaks
- Create an ecosystem with the favourable growing condition, stress level

Following diagram depicts the high-level process flow of the solution for Smart Aquaculture.

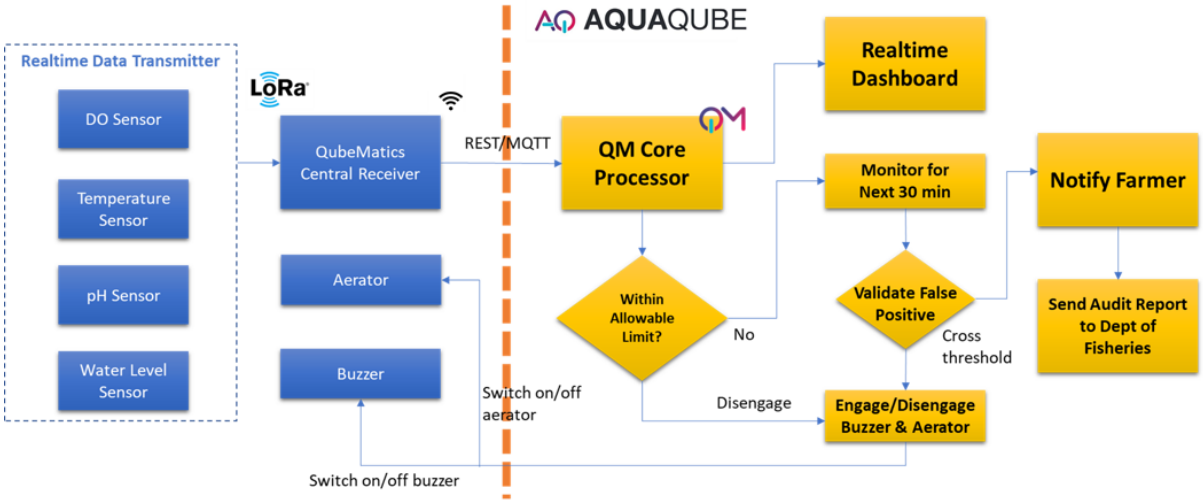

Figure 40ANNEX12- 1: Block diagram of IoT and ML Based Smart Aqua Culture

3. Description:

AQUAQUBE allows fish farmers to monitor water quality, predict the growth of their fish and adjust their feeding regimes appropriately. It leverages machine learning to turn valuable aquaculture data into powerful business insights, address production challenges such as fish illness or insufficient weight gain earlier on in the process and ultimately predict harvest times with greater certainty than ever before.

Based on various research outcomes, the following are vital parameters for ensuring better water quality, lesser fish casualty and improved fish production.

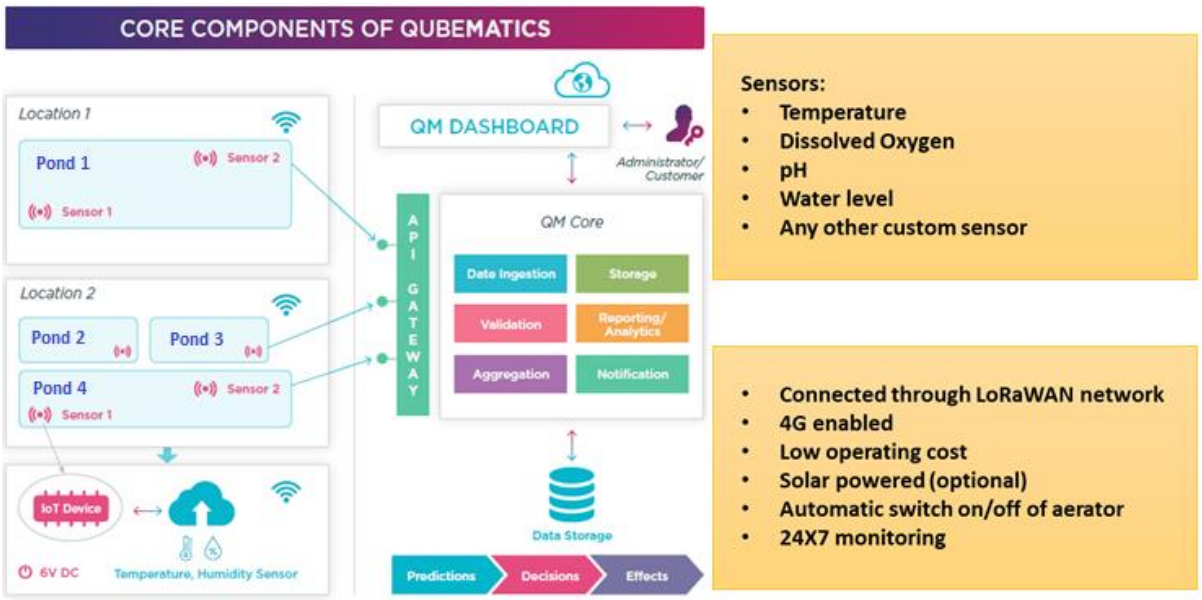

Figure 41ANNEX12- 2: Core Components of Qubematics

- Recommended dissolved oxygen (DO) should be above 5 ppm to ensure that fish has enough oxygen in the water to survive. Otherwise they stay at the surface to catch up more oxygen, thus have slower metabolism, slower growth, and ultimately can die due to lack of oxygen.
- Optimum pH for fish life is between 7 and 8.5, ideal for biological productivity, otherwise fishes can become stressed in water, again slowing down their growth.
- Optimum temperature depends on the fish species, but as fish are coldblooded animals, the temperature must be controlled and maintained in the correct range.

The solution is built with high availability having scalable and end-to-end secured architecture. Working of the end-to-end solution is shown in the figure below-

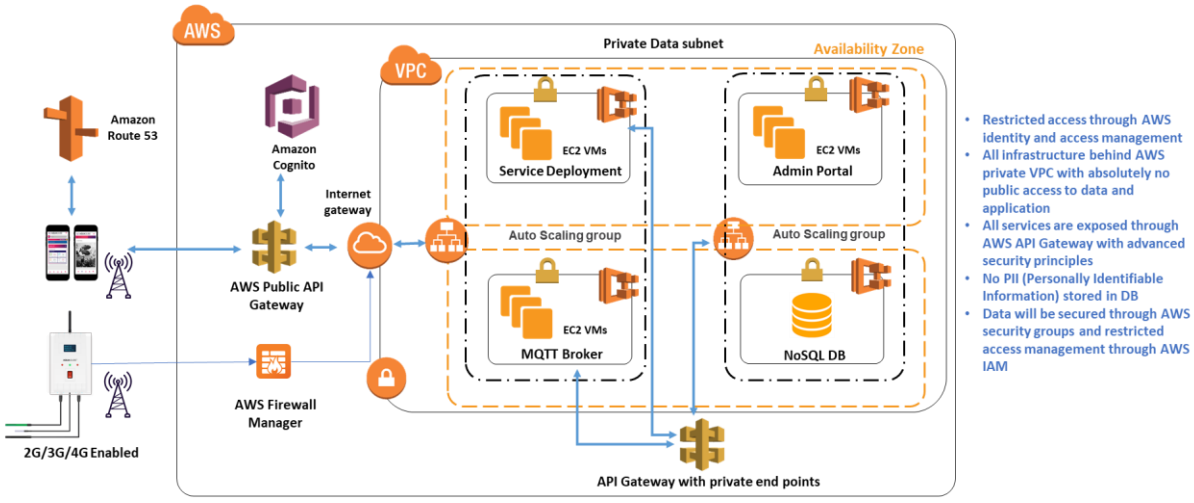

Figure 42 ANNEX12- 3: Working of Smart Aqua Culture system

AWS – Amazon Web Services (our public cloud provider)
VPC – Virtual Private Cloud
VM – Virtual Machine

Importance:

AQUAUBE™ can monitor all the essential parameters through IoT based sensors; and by leveraging the data insights, quality information, the solution can provide necessary eco-system for farmers and consumers to optimize operating cost and increase yield.

- ✓ Real-time monitoring of temperature, humidity, dissolved oxygen (DO), pH, proximity, water level through industry-leading reliable sensors.
- ✓ Alerts and notification for any threshold breach.
- ✓ Intuitive dashboard for end-user monitoring and statutory compliance.
- ✓ Intelligent automation for corrective action.
- ✓ Historical Data analysis to forecast improvement areas.
- ✓ Prescriptive Analytics to regulate control parameters to affect final outcomes.
- ✓ Specialized Object Detection and Computer Vision technology to help automation.
- ✓ State-of-the Art Machine Learning and Deep Learning capabilities for early detection and preventive action.

Annexure:13

Use case: 5G and Intelligent Farming

Source – M/s John Deere

The world population is continuously increasing however the land size remains constant. This demands for high productivity of farms. IoT in agriculture potentially could be a possible solution to cater the need of enhancing the crop productivity.

A report released by United Nations(UN)- Food and Agriculture Organisation(FAO)[91] states that "to food the populations across the globe, the farmers will have to grow 70% more food in 2050 than what they are producing in 2006". With current climatic conditions such as climate change, less water levels, poor soil conditions this target looks difficult to achieve.

5G networks and IoT are great opportunities for the world to tackle challenges that the rising population and climate changes are posing to the future not so far from today.

Intelligent farming may provide farmers and the agricultural industry with the infrastructure to use IoT technologies for tracking, monitoring, automating and analyzing their agricultural and industrial activities.

Various applications of Intelligent Agriculture are:

1. Machines Co-ordination

When the fields are huge there is a possibility that at the same time there would be multiple machines in the same filed performing same or different operations. The Agriculture machines (Tractor + Implement) or (Tractor + wagon) communicate with each other's using IoT devices (GPS receiver, gateways, etc.) and Wireless technologies (4G LTE etc.) to transmit the machine data such as location of each machine, maps of worked area by the one machine.

The Agricultural data shared by machines may be in the form of agronomic data, text, images, maps, trajectories, etc. This data could be stored on the cloud for future consumption.

Scenario-1, Machine to Machine infield:

In-field operational data sharing between two or multiple agricultural machines (Tractor + implement with one or more Tractor + implement or any other equipment) working in same or different fields

Scenario – 2, Machine to on-road vehicle:

- Operation/machine data sharing between agricultural machines and transportation or any other machines on highway or any other agricultural operation supporting machines (Fuel/fertilizer/Harvested product carrying machines)

[91] How to feed world in 2050
http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf

Figure 43ANNEX13- 1: machine to on-road Vehicle

Advantages:

- Machine data can be shared instantly in the real time.
- Machine utilization is optimum and avoid any overlapping areas by the adjacent machines working in the same field.
- Less down time as the machine operators have current machine performance parameters.
- The data stored on cloud can be used by operator for further use and subsequent operations.

Limitations:

- Wireless equipment may face range issues as these are in the fields in the rural areas.
- Sensors used may be susceptible to environmental issues, as they would be facing extreme conditions during working in fields.
- Operator skills to handle Information & Communication Technology equipment efficiently.
- Serviceability in remote area in the field.

2. Equipment to Cloud/Infra communication

During the peak seasons, machine owners would be having multiple machines working in the farms performing various operations. The operations data needs to be stored on the cloud/ head end server to be used for various purposes.

The machine data such as maps, text, images, etc. of the operations performed by fleet of machines can be transmitted to cloud via gateways and stored on cloud. This data can be accessed by machine owner/ operator through computer/ Notebook / Tab / Smartphone.

The data can be transferred on the move using Short Range Low power devices from machine to the Tablet / Smartphones.

Scenario-1: Machine to Cloud (for transmitting Machine Agronomic data)

- One or more agricultural equipment and agricultural operations supporting machines to connect to cloud services for management of agricultural operations and also the fleet management
  - Machine telematics data
  - Agronomic operation data
  - Machine fleet management and tracking

Scenario-2: Fleet management using location data

- Agricultural equipment to internet to provide internet services to operator, ranging from infotainment, getting agricultural produce market information, getting machine operation/diagnostics information etc. Fleet owner/ service operator may access these information using the internet services.

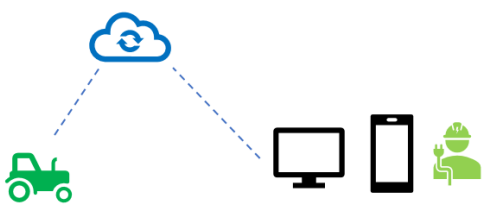

Figure 44ANNEX13- 2: Fleet management using the location data

Agricultural equipment includes – Tractor + Implements, combine harvesters, forage harvesters, self-propelled sprayers, pull behind implements etc.

Advantages:

- Machine owner/ operator can check the health of machine from remote location at any time, without being physically present there.
- Machine owner/ operator can get the location of machine remotely to manage the fleet of machines.
- Farmers can analyze the field agronomic data gathered during the operation for post analysis and take suitable action accordingly.

Limitations:

- Wireless equipment may face range issues as these are in the fields in rural areas
- Sensors used may be susceptible to environmental issues as they would be facing extreme conditions during working in fields.
- Operator skills to handle ICT equipment's efficiently

3. Remote After Sales Support

During the peak season the machines are working in various fields performing operations round the clock. Due to this, machine would experience wear and tear. The machines would generate various messages related to its condition. In present scenario, when the size of messages is relatively small, their transmission wouldn't be heavily impacted by low latency and speed. But in future, 5G technology, uRLLC feature will allow faster transmission of data, that probably may not be sent over 4G. For example, using high resolution imagery and video to help diagnose a problem, the manufacturer representatives can take actions remotely as per their requirement by sitting away from the machine. These messages would enable to manufacturer representatives to clearly understand the issues in the machines before they have seen the machine.

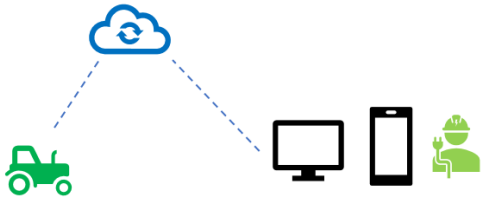

Figure 45ANNEX13- 3: Remote After sales support

Scenario-1, Remote monitoring of machine for preventive maintenance

The messages sent by the machines related to its conditions are received by manufacturer representatives and appropriate remedies can be provided to the Operator / Owner of the machines to avoid any breakdown.

Scenario-2 – Remote maintenance of machine

With the help of 5G technology, data such as high-resolution images and videos may be sent quicker, the manufacturer representatives can remotely address the issues of the machine. This would help them in understanding the modes of failures, without being near to the machine. This would eventually avoid breakdown in the machine. Use of 5G technology will help in reducing the breakdown time.

Advantages:

- Due to connectivity of dealers, field engineer, parts warehouse through the communication network, the messages may be shared very quickly, which will reduce the break down time drastically.
- Remote trouble shooting will help in accurate addressing of the issues, that will reduce the need of physical presence of field engineers.
- The dealers and field engineers will get regular messages about the performance of the machine, which will help them in tracking the condition of machine, and also in avoiding any major breakdown of the machine on field.

Limitations:

- Remote areas on the field may have limited access to the network.
- May require skilling/ re-skilling of the field engineer to enable them to use the emerging technologies to address the issues.

Annexure: 14

Use case: Weather forecasting using IoT and ML/ DL

Source: Prof. Balamurugan MS, VIT Chennai

1. Objective

The objective of this research based pilot project is to create an ecosystem which is capable of forecasting weather by leveraging IoT and ML/DL:

- Forecast weather
- Provide relevant information to agriculturists
- Monitoring the health condition of crops

2. Introduction

Weather is an unpredictable parameter as it keeps changing. The traditional methods being used to predict the weather is by observing a particular weather pattern and then classifying the seasons accordingly, which may not be an efficient way to predict. In the recent past, the meteorological department has been using numerical weather prediction model, which is a mathematical model that uses the model of atmosphere and ocean to predict current values. Later when they produced realistic results, the mathematical models were changed to computer programs that used the atmospheric and ocean-based data to get information about the current weather. As the data acquired was huge, the need for supercomputers arose to perform computation. Later depending upon the current values, future weather is predicted.

3. Background Literature

For this research work, a number of literatures have been studied.

a. "Design and implementation of weather forecasting system based on temperature and light sensors" [1] developed a web-enabled system for weather forecasting and monitoring. It uses an At-mega controller, LDR and temperature sensor module. Based on current and previous statistics of weather, future weather is forecasted.
b. "An effective weather forecasting using neural networks" [2] uses neural networks for weather prediction. Neural networks support different types of learning algorithms. ANN (Artificial Neural Network) can be used for prediction. Through this research it has been tried to figure out the best algorithm for weather prediction using the data obtained from Rice Research Station, Kaul, Haryana.
c. "Temperature forecasting based on neural network" [3] uses ANN approach to predict next day's temperature in prior, of Kermanshah city located in West of Iran. Training and testing is done using ten years past meteorological data. In this approach, only weather is being predicted.
d. "Rainfall Monthly Prediction Based on Artificial Neural Network" [4] uses ANN approach to predict the rainfall condition accurately. In this paper, a BPNN (Back Prorogation Neural

Network) algorithm was used to model and predict rainfall in Tenggarong, East Kalimantan – Indonesia.

e. Automatic weather station LIDAR is hardware developed to monitor the polar stratospheric cloud. The device uses a compact, low power diode based LIDAR. The instrument was deployed at Antarctic geo physical observatories. The system worked during the night continuously and recorded the parameters. The instrument employed a micro pulse LIDAR technique in which high peak power, laser pulses at low repetition frequency are exchanged for low peak power pulses at several kilohertz repetition frequencies thereby conserving average laser power.

4. Working architecture

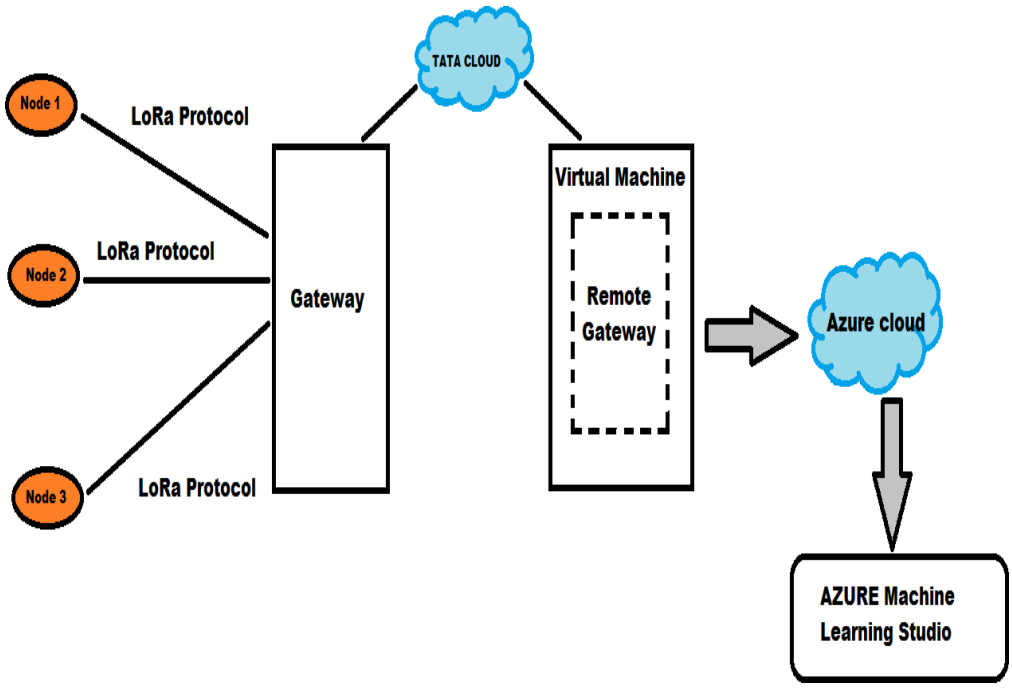

Figure 46 ANNEX14- 1: Architecture for Weather forecasting

The proposed system aims at creating wireless sensor node using LoRaWAN communication, as shown in the above figure, to transmit the sensor data to the cloud using LoRaWAN gateway. Each node consists of sensor interfaced with the STM32F4 microcontroller, the data acquired is thus sent to the gateway using LoRa protocol. Data obtained is encrypted and converted to packets and then transmitted and stored into the Tata Communication cloud. The data from the cloud is pulled by a remote gateway running on a virtual machine. The data is decrypted and uploaded to Azure cloud for storage. The stored data is imported to azure machine learning platform. The data is then split as training data and prediction data. Then suitable prediction algorithm is applied on the training dataset to train the data with the algorithm. Once the data is trained, then another set of data is fed for prediction and the predicted results are obtained.

Table 6. Comparison of various IoT standards and its benefits

Networks	Standards	Data Rate	Benefits
LAN	WiFi, Bluetooth, Zigbee	Both high and low	Legacy and existing infrastructure

LPWAN	Sigfox, LoRa, NB-IoT	Low	New technologies and very low power consumption
Cellular Network	4G, LTE (3GPP)	High	Existing coverage and high data rate

Provisioning LAN and cellular network-based devices for long distance transmission will affect the battery performance and, in this case, cellular network is the mostly preferred for long distance, but however they are used for high data rate applications.

The LoRa physical layer which used FSK modulation enables long distance transmission possible for a very small data. LoRaWAN uses adaptive data rate so that the battery performance is not compromised. Since IoT is intended for multiple end applications, LoRaWAN uses three different device classes to adapt to the application requirement. Class A devices are basically bi-directional devices and mostly preferred by devices operated by battery. Class B devices are devices which are energy efficient with its latency controlled by downlink. Class C devices are the one which keeps listening continuously except when it is transmitting. From the Friis transmission Equation-

$$P_{R=\frac{P_T G_T G_R c^2}{(4\pi R f)^2}}$$

It can be very well inferred that more power is lost in higher frequencies. So, for transmitting LoRaWAN is preferred over other IoT communication protocol.

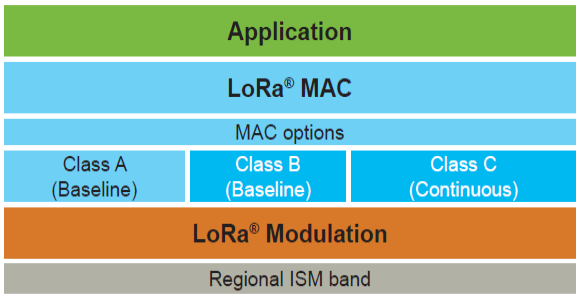

Figure 46 ANNEX14- 2: Block diagram of LoRaWAN

5. Results

This work involves setting up a LoRaWAN based node at Vellore Institute of Technology, Chennai campus to monitor the weather data like Temperature, Humidity, Pressure and Wind speed. Further data is observed through the comparison from weather station. In this implementation LoRaWAN based communication was preferred for the fact that the requirement was to receive the data from a remote station operating on battery and backhaul internet at the node is not the need. Internet facilities are required only at server for further computational and AI studies. So LoRaWAN is the best preferred in these kinds of scenarios. Also, theoretically these nodes can run 2 years on a 3.3 V battery, so they are energy efficient. In addition, the LoRaWAN has strong encryption algorithms AES end to end incorporated in it. The data frames are decrypted further on the server side to identify the relative parameters. Once the respective parameters are recorded further with the datasets observed from

IMD helps us in applying the Artificial Neural Network algorithms to study the data for further analysing. In this case Logistic regression was preferred as the need is to study whether it will rain tomorrow or not based on the various input parameters. The following results has predicted a value of P(Y=1) =0.49. This forewarning yielded good results, as there no epidemic was inferred during the said period of study as plotted. If P(Y=1) <0.5, then the probability of such a catastrophic event can be considered minimal.

Figure 47 ANNEX14- 3: Output of Weather Forecasting System

6. References

[1] Pranjali U Wankhede, Amit Pimpalkar, “Design and implementation of weather forecasting system based on temperature and light sensors”

[2] Pooja Malik, Prof. Saranjeet Singh, Binni Arora, “An Effective Weather Forecasting Using Neural Network”, International Journal of Emerging Engineering Research and Technology Volume 2, Issue 2, May 2014, PP 209-212

[3] Mohsen Hayati, Zahra Mohebi, “Temperature forecasting based on neural network approach”, World Applied Science Journal 2,613-620 (2007)

[4] Mislan,Haviluddin, SigitHardwinarto, Sumaryono, Marlon AipassaRainfall “Monthly Prediction Based on Artificial Neural Network: A Case Study in Tenggarong Station, East Kalimantan – Indonesia”, Procedia Computer Science,Volume 59, 2015, Pages 142- 151

Annexure: 15

Use case: Drones for Farming

Source: Prof. Rajkumar. M, VIT Chennai

1. Objective

To achieve the goal of Government of India for doubling the income of Indian farmers amidst the VUCA (Volatile, Uncertain, Complex and Ambiguous) environment, the quantity and quality of the crop yield needs to be improved. For this the emerging technologies like drones are to be used in agriculture sector.

2. Introduction

- World's population is burgeoning & expected to reach 9.7 billion by 2050 (source: www.un.org). Feeding this population is expected to be a big challenge, as there is a big mismatch between the growth percentage of population and crop yield.
- United Nations has come out with sustainable development agenda 2030, which talks about eradicating rural poverty. (source: https://unstats.un.org/sdgs/metadata)
- Agri exports yield is lower in India i.e. US $ 39.4 billion (source: Directorate General of Foreign Trade, Ministry of Agriculture & Farmers welfare), compared to China, while the irrigated land area is almost the same. This may be due to unpredictable weather, inefficient water management, use of unwanted amount of pesticides etc.
- Agri Drone market value is expected to reach $3.7 billion, by 2022[92]

3. Background of the Literature

Crop yield is affected by many factors like disease [1], use of pesticides, growth of weed, locust attack. Drones are being used -

a) for spraying right quantity of pesticides in Perambalur, Trichy District, Tamil Nadu state (Refer https://www.youtube.com/watch?v=C5ShVFsE8Wo),

b) for weed pressure mapping outside India (www.fao.org),

c) for controlling the locust/ swarm attack (e.g. during May, 2020 - Union Ministry of Civil Aviation has given permission to the Agriculture department of Government of Rajasthan to use drones - for anti-locust operations),

d) for minimizing the wastage and reducing the cost incurred for pesticides.

The existing solutions are not adequate to handle the spread of disease. Innovative solution has to come in. Use of ICT in agriculture (Agriculture 4.0), Use of IoT, AI/ ML and unmanned autonomous vehicles in agriculture (Agriculture 5.0), helps in monitoring the plants. Drone with high pixel camera may be used to capture the image of affected plants. The images are to be verified against the master database to identify the right disease in a minimum time, thus

[92] https://agfundernews.com/ag-drones-market-to-reach-3-7bn-by-2022-as-cropio-first-to-integrate-drones-with-satellite-imagery5648.html

maximizing the yield. Drones can identify the affected plants by taking the images of the top layer of the leaves [2][3][5].

Leaf spot diseases are usually seen first on the lower branches, where the humidity is relatively higher and leaves are shaded. Spots occur randomly on the leaf surface because the pathogens that cause leaf spots are blown there by wind/ splashed by rain/ by irrigation. No solution is available to identify these problems. Leaf spot disease (different size, shape, colour) normally matures in 2 weeks. Identifying the disease by human eyes - when it is present on the lower branches or rear side of the leaf, is very difficult.

4. Benefits

1) Capturing the image of rear side of the leaf is possible, with this solution.

2) Using Drone as a service (DaaS), to enhance the income of farmers.

3) Rural youths can be trained to become drone pilots.

4) Time saving (of about 80%) for the farmers.

5. Solution

Integration of drone sensing, imaging, internet of things and deep learning is the recommended solution [4]. Team of experts from VIT Chennai and industry designed a solution to address the challenges and filed the patent for the same [6].

6. Components

1) MOSFET with a dimension of 2 x 2x 0.5 cm and weight of around 20g
2) BO Motor & light weight high pixel wireless camera
3) Pulley mechanism - for movement of camera, in both ways

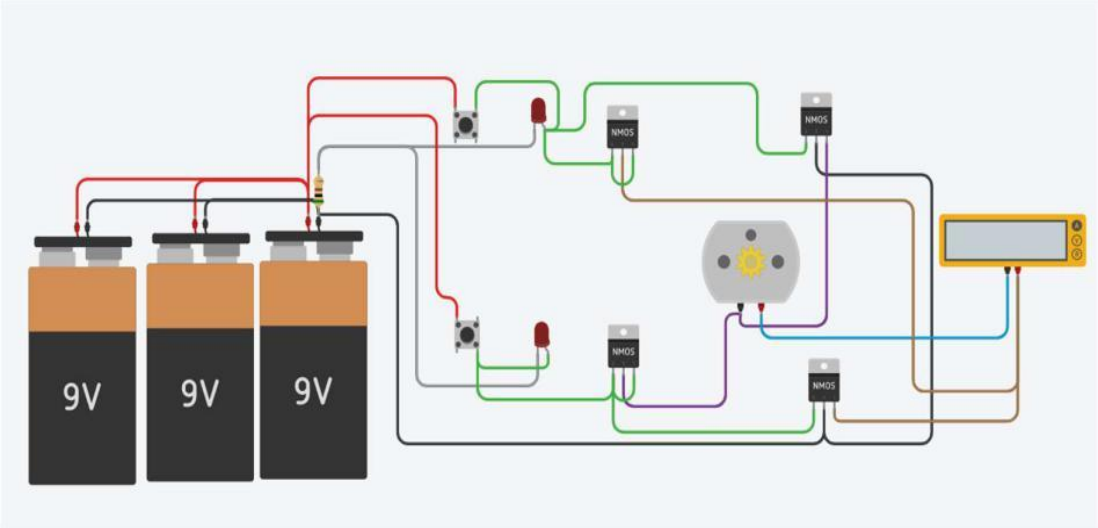

Figure 48 ANNEX15- 1: Circuit for reel mechanism

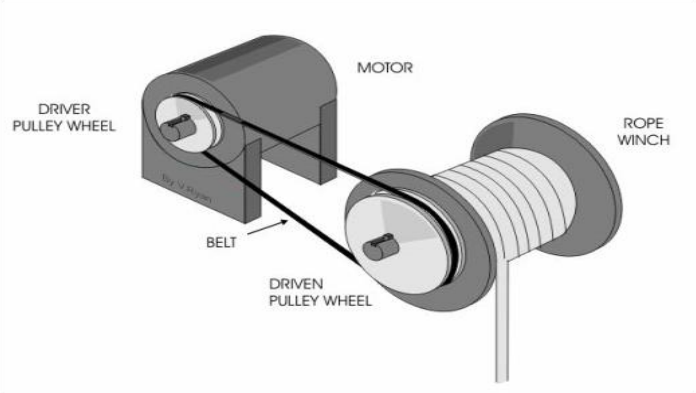

Figure 49 ANNEX15- 2:Part of the patented solution

7. Results

1) Aerial view of experimental setup is shown in above Figure 48 ANNEX15- 1.
2) Treated (Green), Untreated (red) plants are visible when we visualize using the drone fitted with camera. (as shown in Figure 50 ANNEX15- 3)
3) Image taken on the rear side of the leaf (Figure 51 ANNEX15- 4), indicating the problems.

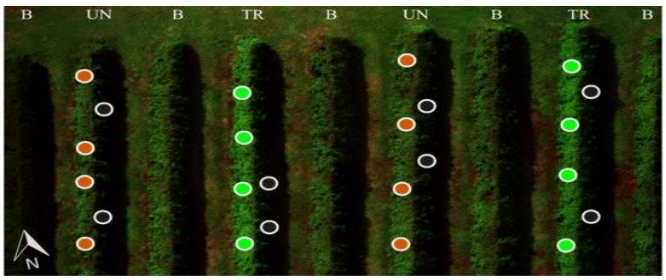

Figure 50 ANNEX15- 3: Treated (Green), Untreated (Red)

Figure 51 ANNEX15- 4: Image taken on the rear side of the leaf

8. References

[1] UM Rao Mogil and B B V L Deepak, “Review on Application of Drone Systems in Precision Agriculture”, Procedia Computer Science, 133 502 - 509, 2018

[2] R. Murugesan, Sudarsanam. S.K *et al.*, “Artificial Intelligence and Agriculture 5.0”, IJRTE, Vol - 8, Issue - 2, July 2019

[3] Gerald sylvester, “Drones for agriculture”, FAO, 2018

[4] J. Su *et al*., "Aerial Visual Perception in Smart Farming: Field Study of Wheat Yellow Rust Monitoring," in *IEEE Transactions on Industrial Informatics*, doi: 10.1109/TII.2020.2979237.

[5] Y. Guo *et al*., "A Drone-Based Sensing System to Support Satellite Image Analysis for Rice Farm Mapping," *IGARSS 2019 - 2019 IEEE International Geoscience and Remote Sensing Symposium*, Yokohama, Japan, 2019, pp. 9376-9379, doi: 10.1109/IGARSS.2019.8898638

[6] Full Patent has been filed, for publishing **“**Drones for Smart Farming” by Vellore Institute of Technology on 23rd July 2020 (Docket Number: 63714; Application Number: 202041031483)

[7] Fernando H. Iost Filho, Wieke B. Heldens, Zhaodan Kong and Elvira S. de Lange, “Drones: Innovative Technology for use in Precision Pest Management”, Journal of Economic Entomology, 1-29- 2019

Annexure: 16

Use Case: A complete smart village model

a) Company: SunMoksha Power Pvt Ltd
b) Website: www.sunmoksha.com
c) Contact: info@sunmoksha.com, +91 944 922 0231

1. Introduction

Villages can learn from the shortfalls and mistakes of the urban development models. They can look at alternative models to enhance their socio-economic development and bridge the rural and urban divide. They can leapfrog in this journey by using technology as an accelerator. They can also sustain their development model without harming the climate. SunMoksha Power Pvt. Ltd., Bangalore, is one such company, which has successfully developed and deployed a technology enabled, sustainable smart village development model.

SunMoksha's Smart Village model is built around three major pillars: people, planet and profit. It balances the three elements and helps communities leapfrog on the socio-economic path of development. Their solutions are anchored in either adapting to climate change or helping to mitigate it.

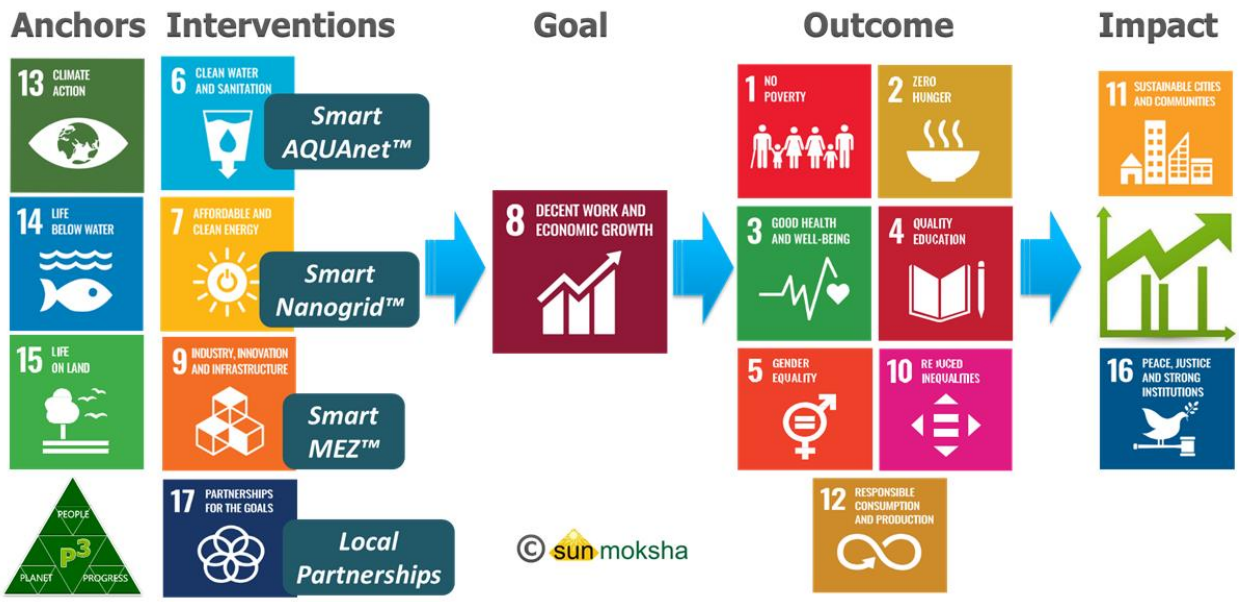

Figure 52 ANNEX16-1: SunMoksha's Smart Village model

SunMoksha's road map of holistic village development is primarily focused on sustainable livelihood creation, adding value to the produce and finally connecting it to the markets. Its approach usually starts by increasing the farmer's produce, through its innovation ***Smart AQUAnet™***, which is a smart irrigation solution; followed by enhancing the value of the produce by processing it, using energy enabled microenterprises through its technology ***Smart Nanogrid™;*** and finally link the produce to the markets through its holistic model ***Smart MEZ™***. Based on the village conditions, their needs and funding constraints, these interventions can be done simultaneously or in phases.

Figure 53 ANNEX16-2: Systematic Transformation to Sustainable Smart Villages model

Each of these interventions is made self-sustainable. M/s SunMoksha creates a sense of ownership among the communities by using local resources to a large extent, including manpower, during the project design and deployment stage. This propels the local economy, also equips the community to support the project during its life cycle and increases the sense of ownership among the locals for the interventions. Its approach is modular and customizable based on what immediate interventions are needed in the villages. Not all villages need the same interventions at the same time, and therefore, along with the customisation of the interventions, their stages of implementation also vary depending on the ground requirement. To add, their model is also scalable and replicable.

Below are the interventions done by SunMoksha in four different villages using their technologies, and catalysed these communities on the path of sustainable development.

Intervention 4		MEZ™ 2 Other services		
Intervention 3	Nanogrid™ Agriculture	MEZ™ 1 Agri-produce	Nanogrid™ Micropreneurs	Nanogrid™ Sustainable Energy for Micropreneurs
Intervention 2	Nanogrid™ Micropreneurs	AQUAnet™ Irrigation	MEZ™ 1 Agri-outlet	AQUAnet™ Irrigation
Intervention 1	Nanogrid™ Domestic	Nanogrid™ Domestic	AQUAnet™ Irrigation	MEZ™ 1 Micropreneurs
	Village 1	**Village 2**	**Village 3**	**Village 4**

Figure 54 ANNEX16-3: Interventions done by SunMoksha in different villages

2. Smart Microgrid – Kudagaon

Kudgaon, an Island on Mahanadi river in Odisha is completely cut off from the mainland. Its inhabitants (85 Households, 300 people) were deprived of all services, especially energy. SunMoksha Power Pvt. Ltd., with financial assistance from CSTEP, Bangalore, set up a solar based smart microgrid system of 20kWp. The uniqueness of the system is in its smartness called ***Smart Nanogrid™***. The entire electrical infrastructure including generation and distribution is remotely monitored and controlled over the internet using IoT devices and its cloud software.

The remoteness of the site and the complex operations and challenges of running a rural microgrid led to the development and deployment of SunMoksha's ***Smart Nanogrid™***. It has eased the day-to-day operations of the microgrid such as real-time and dynamic demand-supply management, load limiting, billing, collection of payments etc., without compromising on the quality of service provided to the consumers. The ***Smart Nanogrid™*** system has helped SunMoksha to provide day-to-day support to this remote microgrid from their command centers in Bangalore and Bhubaneswar with minimum operational expenses.

Smart Nanogrid™ won the Diamond Award from India Smart Grid Forum[93] (A Govt of India PPP) for Best Smart Grid Project in India by Technology Company the Millennium Alliance Award[94] jointly funded by US-AID and Government of India.

Figure 55 ANNEX16-4: Smart Nanogrid

3. Smart Irrigation – Maudiguda

Farmers in Maudiguda, a small remote village in Rayagada district of Odisha, were dependent on rain for agriculture. They had no access to any source of water for irrigation. They could practice agriculture only once a year despite having fertile farmlands. The farmers approached a local company and under the company's CSR intervention SunMoksha's ***Smart AQUAnet™,*** an IoT based smart irrigation system, along with a solar pumping unit was selected and deployed.

From the initial survey it was found that borewell was the only source, and it had limited quantity of water. The field challenges were equitable distribution of water among 45 farmers with different landholdings, optimized usage of water to produce more yield, build a sustainable business model and support the remote installation. ***Smart AQUAnet™,*** through its IoT device and the cloud software is able to measure the quantity of water delivered to each farmer and thereby ensures equitable distribution among each of the 45 farmers. Its billing module helps build a sustainable business model. ***Smart AQUAnet™*** with its sensors is able to measure the moisture content, ambient conditions, soil temperature and based on the type of the crop, it recommends the quantity of water required, hence ensuring optimized usage. With

[93] http://www.isgw.in/isgf-innovation-awards-2020/

[94] http://www.millenniumalliance.in/awardee_details.aspx?8qiaANQw0id9o+xDv/Ydk82Na2oe0xCeNOdqELoEH3hKr2+ynO2n5kTn+TMkWqXJ

real-time data and remote control features, SunMoksha is able to support this installation from their command center in Bangalore and Bhubaneswar.

Smart AQUAnet™ won GEF/UNIDO/BEE's FLCTD Award [95] (Facility for Low Carbon Technology Deployment) jointly managed by UNIDO and BEE and funded by Global Environmental Facility (GEF).

Figure 56 ANNEX16-5: Smart AQUAnet

4. Smart Village – Kantashol

Under CM Smart Gram Yojana (CMSGY), SunMoksha is working with the NGO Kalamandir in the village Kantashol, Jharkhand, to transform it into a Smart Village. Several interventions were identified such as water for irrigation, agriculture & non-agriculture based livelihood, reliable & clean energy, e-governance, skill & job training, to name only a few. For each intervention ICT solutions are deployed.

Lack of a reliable source of energy is a major problem in the village. Livelihood activities need reliable supply of power, hence it is decided to integrate multiple sources of energy (Solar and Grid). SunMoksha's ***Smart Nanogrid™*** an IoT and cloud based system will supply and control power to each livelihood activity which will be operating in the Smart Micro Economic Zone (***Smart MEZ™***). Other interventions are being done in the surrounding villages of the ***Smart MEZ™*** to ensure adequate supply of raw materials, volume and scale of livelihood activities. SunMoksha's ***Smart AQUAnet™,*** an IoT based smart irrigation system, along with solar pumping is deployed at the village level to bring water efficiency in the water-strained hilly region. The complete electrical and water infrastructure including the health of the machines will be monitored and if required controlled over the internet**.** The smart village will ensure sustainable livelihood and employment opportunities in and around the village.

[95] https://www.low-carbon-innovation.org/winners

Figure 57 ANNEX16-6: Smart MEZ

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Annexure: 17

List of meetings of the WG

S. No.	Date
1.	Meeting through GoToMeeting bridge, 12th Feb 2020
2.	Meeting through GoToMeeting bridge, 21st Feb 2020
3.	Meeting through GoToMeeting bridge, 12th March 2020
4.	Meeting through GoToMeeting bridge, 29th April 2020
5.	Meeting through GoToMeeting bridge, 29th May 2020
6.	Meeting through GoToMeeting bridge, 3rd July 2020
7.	Meeting through GoToMeeting bridge, 4th August 2020
8.	Meeting through GoToMeeting bridge, 4th September 2020
9.	Meeting through GoToMeeting bridge, 5th October 2020
10.	Meeting through GoToMeeting bridge, 29th October 2020
11.	Meeting through GoToMeeting bridge, 25th November 2020

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