सत्यमेव जयते

Bharat Lal
Addl. Secretary & Mission Director

Har Ghar Jal
Jal Jeevan Mission

National Jal Jeevan Mission
Government of India, Ministry of Jal Shakti
Department of Drinking Water and Sanitation

D.O. No. W-11042/ 101/ 2020-JJM.IV-DDWS dated 06.05.2021

To

Addl. Chief Secretary/ Principal Secretary/ Secretary
RWS/ PHED (all States/ UTs)

Subject : Rolling-out of sensor-based IoT solution to measure & monitor water supply in rural areas – regarding.

Madam/ Sir,

As you are aware, Jal Jeevan Mission – Har Ghar Jal was announced by Hon'ble Prime Minister on 15th August, 2019 to make provision of assured, potable, tap water supply to every rural home on regular and long-term basis. It is envisaged under the mission that all the households in rural areas to get minimum of 55 lpcd of water, of prescribed quality on a regular and long-term basis. Any disruption in water supply cause huge inconvenience to the people. It is needless to mention here that such disruptions are reported through informal channels, social media, etc. even before the corrective action is initiated by the departments/ agencies. Thus, with the advent of IT and communication technology, the power of monitoring of service delivery has been taken over by the people.

2. In such a scenario, the assurance of drinking water supply that meet all the benchmarks in terms of quality, quantity and regularity over long-term will be possible only if we are able to measure and monitor the service levels in villages on regular and daily basis. The growth of IT, sensor-electronics and ever-increasing inter-connectivity in villages has made it possible to create network of sensor and gateways that can capture the data on quantity of water supply, its quality and regularity in an automatic fashion and transfer the data and store it to internet cloud servers. This data can be analysed to increase the efficiency of water supply system, reduce cost of operation & maintenance, reduce duration of outages and non-revenue water. The alerts generated at village level will help to ensure timely repair and restoration of water supply. The monitoring of trend at water supply will also help us to understand the patterns of demand and supply, based on which schedules can be generated and we can increase the efficiency of water supply infrastructure.

3. To help States/ UTs, an expert committee was constituted to suggest the roadmap and way forward. The committee has done exceptional work, especially during the pandemic and has finalized the report. A copy of the same is enclosed. The committee's report i.e. **'roadmap for the measurement & monitoring of water service delivery system in rural areas'** has provided basic framework to design, develop and establish a coherent system that is able to exchange the data

at local and central level. The report has addressed the several variations of schemes, capacity of community, various type of networking and communication technology, governance framework, etc. The broad framework provided by the report will help in firming up the desired standards to meet the requirement of change from mere infrastructure development to ensuring water service delivery.

4. In order to understand the approach, seven pilots of such sensor-based measuring and monitoring system has already been successfully deployed. Furthermore, in order to nudge the eco-system of sensor-electronics, IoT, data storage capacities, an IoT grand challenge has been launched with Ministry of Electronics & IT (MEITY). Several States like Bihar, Punjab, Gujarat, West Bengal, Sikkim, etc. have already taken the initiatives to roll-out such a system.

5. Today, in the country about 89 thousand villages, 725 blocks and 60 districts have become 'Har Ghar Jal'. These blocks and districts should be immediately taken up for immediate installation of smart measurement and monitoring systems. The State/ UT should start the survey and prepare the detailed plan for implementation that can be approved as part of water supply schemes in the SLSSC.

6. The National Jal Jeevan team is committed to provide technical assistance and knowledge support to help the States to finalise the solution design, prepare detailed plan and estimates to start the implementation. In order to facilitate the implementation, a central platform/ cloud for aggregating the data will be made available to all the States/ UTs.

7. I urge all the States and UTs to set up a support unit consisting of 3-5 persons that can lead the implementation to assist the implementation of measurement and monitoring system of water service delivery to ensure potable water supply to every rural home. I am sure that you will find this report extremely useful in planning and operationalizing sensor-based IoT solution to measure and monitor water supply in villages.

Yours sincerely,

[Bharat Lal]

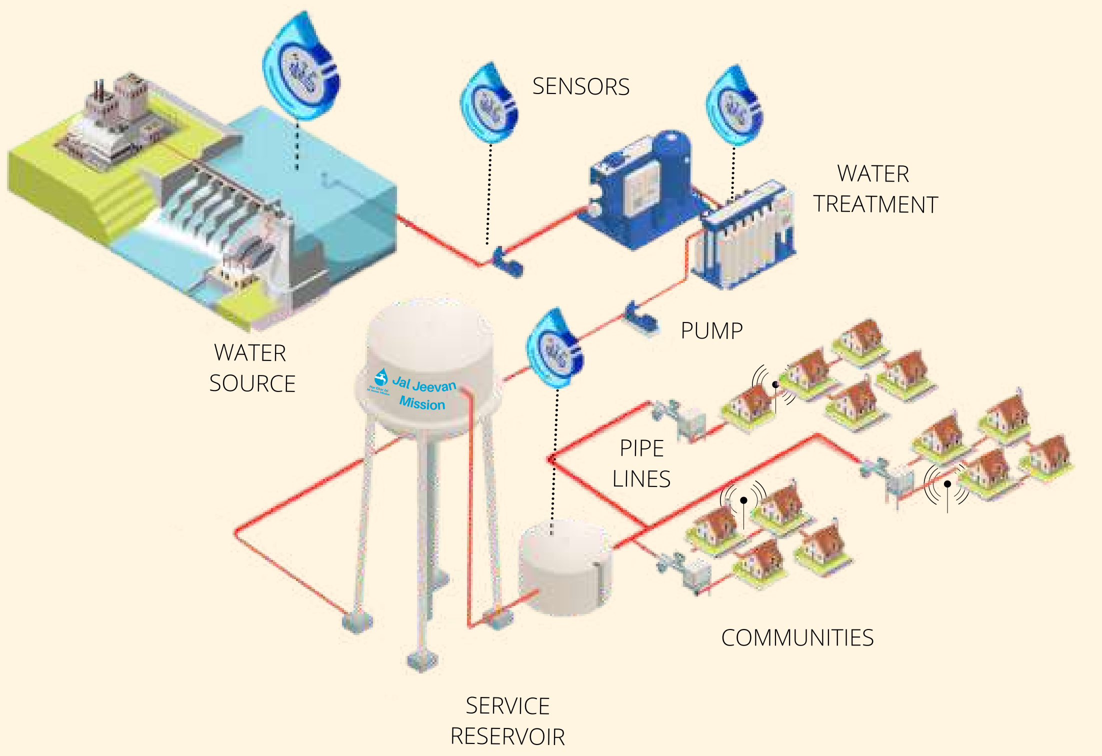
Encl.: as above

Government of India, Ministry of Jal Shakti
Department of Drinking Water & Sanitation
National Jal Jeevan Mission

Har Ghar Jal
Jal Jeevan Mission

Technical/ Expert Committee Report

Roadmap for the measurement & monitoring of water service delivery in rural areas



Jal Jeevan Mission

Har Ghar Jal

Har Ghar Jal
Jal Jeevan Mission

Jal Jeevan Mission

(Har Ghar Jal)

Technical/ Expert Committee Report

Measurement and monitoring of water service delivery in rural areas

Government of India
Ministry of Jal Shakti
Department of Drinking Water and Sanitation
National Jal Jeevan Mission
New Delhi - 110003
March, 2021

Preface

The Hon'ble Prime Minister of India launched an ambitious National Jal Jeevan Mission in 2019, with an objective to connect each and every rural household in the country with functional taps, supplying regular drinking water of prescribed quality at the rate of minimum 55 LPCD. The Government of India has allocated at outlay of Rs. Three Lakh Sixty Thousand Crore over a period of 5 years for this purpose. Though several rural drinking water programmes where implemented in the past involving massive infrastructure investment, commensurate result were not achieved, as the focus of those programme was largely on infrastructure development and not as much on the operation and maintenance of the schemes developed.

The National Jal Jeevan Mission has made a path-breaking change from conventional paradigm to bring focus on service delivery. With this change in orientation, it is incumbent upon the water supply operators to regularly measure and monitor the quantity and quality parameters of drinking water. This would help in ensuring service delivery to the households on one hand, and on the other hand facilitate reduction of physical and commercial loses in water distribution systems and improve recovery of water charges as well.

The operational guidelines for the implementation of the Jal Jeevan Mission released by the Ministry of Jal Shakti – Department of Drinking Water and Sanitation (DDWS) in December 2019 mandate the use of sensors for monitoring water level discharge, water quantity and quality, and automate motor operation and pressure management in the water distribution system. The guidelines recommend the use of IoT for capturing and transmitting the above data captured from the sensors by using suitable networks for analytics and decision making for the O&M of the scheme.

In the above backdrop the DDWS set up an expert committee vide its order dated 24th August 2020, with the following mandate -

I.) to study ways of capturing the data on the quality, quantity, and regularity of water supply;

ii.) to recommend the solution design;

iii.) to define standards and protocols;

iv.) to develop governance framework and implementation plan; and

v.) to prepare a roll out plan of the selected solution.

The committee comprised of the following -

The committee held fourteen meetings and after extensive discussion with the members, representatives of the various stakeholder departments, agencies and experts has concluded its recommendation. The committee considered a technology solution that is sustainable, modular, and scalable and that captures data on functionality in a seamless and objective way. The committee deliberated basic, intermediate, and advanced levels of application of IoT technology, which could be adopted by states depending on the availability of resources and preparedness of the community.

Considering that around 85% water supply systems are serviced by the ground water sources, measurement of ground water levels has been considered as an essential feature of the solution design.

The committee has considered well established options of GSM and RF based systems for networking with cloud server and data analytics and application dashboard facilitating bi-directional flow of data for both measurement of performance parameters and management of the water supply systems.

The committee has examined and considered the learnings from the ongoing pilot projects in a variety of villages executed under the aegis of the Department of Water Supply and Sanitation, and also the application of the proposed technology under the Smart City Mission

Jal Jeevan Mission makes another major policy shift in terms of focus on the community as the owner and operator of the drinking water schemes. In line with the spirit of 73rd constitutional amendment, it seeks to devolve planning construction, operation, and maintenance of drinking water schemes on the Gram Panchayats (Gps), and Village Water and Sanitation Committees (VWSC). The committee has considered the new paradigm while recommending the solution design of IoT based system, The GPs and VWSC or Water Supply Operators have accordingly been as considered as the primary stakeholders in the application of IoT technology.

The committee has recommended that the technology proposed should help in both monitoring, as well as operation of the schemes including trouble shooting. The committee has proposed a system architecture which facilitate monitoring and supervision through the hierarchy (Block, District and State level authority) and intervention whenever required. This will ensure objective reporting, transparency and accountability of the PRIs and other operators.

We hope that the report will help the Department of Drinking Water and Sanitation in evolving an effective monitoring system.

Ajit Kumar Jain
Chairman
Technical/ Expert Committee

Acknowledgement

On behalf of the Expert Committee, I express my gratitude to the National Jal Jeevan Mission, Ministry of Jal Shakti – Department of Drinking Water and Sanitation for constituting the committee to prepare a road map for measurement and monitoring of to assure water service delivery in 7.5 lakh villages. I want to thank Additional Secretary and Mission Director, Shri Bharat Lal for lending his support in constitution of committee and providing the vision. I also want to thank Shri U P Singh, Secretary, DDWS for being constant source of guidance and encouragement.

The Jal Jeevan Mission aims at ensuring the delivery of quality drinking water to all rural households within their dwellings as per the benchmarks prescribed. We sincerely hope that the recommendations of our committee will contribute to developing a framework for application of the IoT technology for effective performance management and help in the operations and maintenance of the schemes.

The committee is grateful to the officers of the Department of telecommunication, the team of National Informatics Centre, Bureau of Indian Standards, and the representatives of Smart City Mission, CDAC, Xylem, Amazon, TCS, and Ericsson for sharing their wisdom and experience on the subject. The committee also acknowledges Tata Community Initiative Trust and Tata Trusts in sharing pilot learnings on the application of IoT technology to drinking water supply systems across different states.

I express my sincere thanks to Chairman of the committee, Shri A K Jain for regularly conducting the deliberations effectively through VC and accommodating different point of views. I express my deep appreciation to all the esteemed members of the committee, for their active participation in the deliberations. The contribution of Shri Devendra Singh, Addl. Chief Secretary, Water Supply, Haryana, Shri Dhananjay Dwivedi Secretary, Water Supply and Sanitation, Gujarat, Shri D C Mishra, Dy. Director General, NIC and Shri T P Singh, Director, Bhaskaracharya Institute for Space Applications and Geoinformatics, Gandhi Nagar, Gujarat, and Shri Rajendra Holani former Member Secretary Maharashtra Jeevan Pradhikaran for their special contribution to the deliberations. I also express my thanks to Ms. Seemantinee Sengupta, Dy. Director General, NIC for providing technical insights in framing architecture for IoT systems.

On behalf of committee, I am also thankful to Dr. Pradeep Kalbar, Assistant Professor IIT Bombay, Shri. Sridhar Kumar Narsimhan IIT Madras, Shri S V Deshpande, Joint Director (Retd.) GSDA, Government of Maharashtra and Consultant, for sharing the information of the pilot projects initiated by them, on the application of IoT to water supply systems.

The committee also acknowledges the contribution of Shri K. Ambarish supporting NJJM in effectively organizing the meeting of the committee.

Last but not the least the committee places on record its deep appreciation and acknowledges the phenomenal contribution of Shri Siddhant Masson, supporting NJJM in anchoring the entire technical discussion in the committee meetings and giving vital technical support and putting together this report.

Pradeep Singh
Member Secretary
Technical/ Expert Committee

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Abbreviations and Glossary of Terms

Abbreviation	Description
AI	Artificial Intelligence
AMC	Annual Maintenance Contract
AMQP	Advanced Message Queuing Protocol
APDU	Application Protocol Data Units
API	Application Programming Interface
BRS	Bank Reconciliation Statement
CAPEX	Capital Expenditure
CDAC	Centre for Development of Advanced Computing
CE	Conformitè Europëenne
CISPR	Comité International Spécial des Perturbations Radio
CoAP	Constrained Application Protocol
CSV	Comma-Separated Values
DB	Database
DC	Data Centre
DDWS	Department of Drinking Water and Sanitation
DLMS	Device Language Message Specification
DMA	District Metering Area
DOS	Denial of Service
DTLS	Datagram Transport Layer Security
DWSM	District Water and Sanitation Mission
EPC	Engineering, Procurement and Construction
ESR	Elevated Service reservoir
ETL	Extract, Transform, Load
FAT	Factory Acceptance Test
FCC	Federal Communications Commission
FCRI	Fluid Control Research Institute
FHTC	Functional Household Tap Connections
FRS	Functional Requirement Specification
GIS	Geographic Information System

Abbreviation	Description
GoI	Government of India
GP	Gram Panchayat
GR	General Registered
GSM	Global System for Mobile
HDD	Hard Disk Drive
HTTPS	Hypertext Transfer Protocol Secure
IDS	Intrusion Detection Systems
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
IP	Internet Protocol
IPS	Intrusion Prevention Systems
ISO	International Organization for Standardization
ITI	Industrial Training Institute
JJM	Jal Jeevan Mission
KPI	Key Performance Indicators
LPCD	Litres per capita per day
LORA	Long Range
LPWAN	Low-Power Wide-Area Network
MAC	Media Access Control
MID	Measuring Instruments Directive
MieTY	Ministry of Electronics and Information Technology
ML	Machine Learning
MQTT	Message Queuing Telemetry Transport
MSME	Micro, Small and Medium Enterprise
MVS	Multi Village Scheme
NB IoT	Narrow band- Internet of things
NIC	National Informatics Center
NJJM	National Jal Jeevan Mission
NRW	Non-Revenue Water

Abbreviation	Description
O&M	Operation and Maintenance
OIML	International Organization. of Legal Metrology
OMS	Open Metering System
OS	Operating System
Pdf	Portable Document Format
PHED	Public Health Engineering Department
PMO	Prime Minister's Office
QC	Quality Control
RAM	Random Access Memory
RF	Radio Frequency
RFP	Request for Proposal
RHEL	Red Hat Enterprise Linux Operating System
RTU	Remote Terminal Unit
RWS	Rural Water Supply
SAT	Site Acceptance Test
SDC	State Data Centre
SITC	Supply, Install, Test and Commission
SLA	Service Level Agreement
SLSCC	State Level Scheme Sanctioning Committee
SMS	Short Message Service
SOP	Standard Operating Procedure

Abbreviation	Description
SQL	Structured Query Language
SQuaRE	Systems and software Quality Requirements and Evaluation
SR	Service reservoir
SSL	Secure Sockets Layer
SWSM	State Water and Sanitation Mission
TCP/IP	Transmission Control Protocol/Internet Protocol
TDS	Total dissolved solids
TLS	Transport Layer Security
TUV	Technischer Überwachungsverein, (English translation: Technical Inspection Association)
UAT	User Acceptance Testing
UDP	User Datagram Protocol
UL	Underwriter Laboratories
vCPU	Virtual Central Processing Unit
VWSC	Village Water and Sanitation Committees
WTP	Water Treatment Plant
WUG	Water User Group
Xlsx	Excel Microsoft Office Open XML Format Spreadsheet file
OEM	Original Equipment Manufacturers

Executive Summary

1. The Jal Jeevan Mission (JJM) envisages to provide assured and potable water through taps to all the households in the villages by 2024. The focus of JJM is to provide water through taps as a service with clear benchmarking of service level. The specific term 'Functional Household Tap Connection' (FHTC) has been used to signify this aspect of service delivery. It refers to providing assured water supply at 55 LPCD (litres per capita per day), of prescribed quality (BIS 10500: 2012) on regular and long-term basis;

2. Assuring supply of potable water to all the households requires a robust system of monitoring the service level failure in an objective and accurate manner. The data on failure of service benchmarks on quality, quantity and regularity can be captured in two ways:
   - I.) Entering data using systems using mobile app or web application, IVRS or other systems;
   - ii.) Through automated sensors capturing data directly and transmitting this data through web applications.

3. The monitoring of system using manual entry is possible for smaller systems with few parameters for entry. The quality and regularity of such entry depends on awareness level and capability of person. With recent advances in electronics, communication, and data analytics; the cost of sensors, data transfer and analysis has come down. Such physical devices that can connect to internet and share the collected information based on stipulated protocol are referred to as Internet of things (IoT). Such devices have opened the possibility of monitoring service level parameters objectively, regularly and over a long period;

4. The water supply system has multiple stakeholders responsible for ensuring the functionality of systems. In such scenario objectivity of data capture on service level becomes even more important. Continuous monitoring enables the availability of actionable information in a timely manner and ensures responsibility of each stakeholder in identifiable manner;

5. It is commonly observed that the rural water schemes fail due to poor operations and maintenance of schemes for reasons like outages due to pump faults, pipe bursts/ leakages, contamination, source exhaustion etc. This can be overcome if objective information on failure is available in a timely manner and provided to responsible person in identifiable way;

6. It is expected that investment on measurement and monitoring of water service delivery results in saving on O&M cost, improve service delivery and instil necessary behaviour change in rural water supply departments and VWSC/ Paani Samiti towards better service delivery. It can help solve several issues in rural water supply such as – high scheme failure rate, contamination, source drying up, frequent outages, inequitable distribution, non-revenue water and wastage. It can help provide near real-time alerts and reports to community, engineers, and officials to provide quick response to mitigate outages and reduce scheme failure.

7. Recommended design for measurement and monitoring of rural water supply

I.) The PHED/RWS and VWSC/ Paani Samiti can decide the type of measurement and monitoring system suited for them. Three alternative designs have been suggested that can be chosen based on size of village, complexity of distribution network and capacity of local public utility like VWSC. The options vary in terms of cost and number of parameters they can measure:

   a. **Basic solution:** This consists of a volumetric flow meter at outlet of service reservoir to provide aggregated data on quantity and periodicity of water to the distribution network. It also includes a chlorine sensor at the service reservoir to determine disinfection process compliance and measure free chlorine. Further, it consists of a ground water level sensor (wherever applicable) to ensure source sustainability. This is cheapest option that may be used for all the schemes in village. The outages in supply can be monitored on continuous basis. Such solution may be used in areas with simple distribution network without much of quality issues. To monitor quality parameters (other than chlorine) the FTK based methods shall be used conjunctively;

b. **Intermediate solution:** In addition to basic solution the pump controller unit, flow meters at DMA inlet or habitations (or DMAs), and pressure sensor at furthest point / tail-end may be added. This will help ensure equitable supply to DMAs/habitations and operational excellence (automation, predictive maintenance). This solution is cost effective and can provide value addition for O&M to a large extent. Committee recommends that for most villages this solution should be used;

c. **Advanced solution:** In addition to intermediate solution, consumer level water metering may be added. This solution will automate the water service delivery and grievance of each user will be addressed through such systems.

ii.) Intermediate design is recommended to ensure high value addition by collecting information on source sustainability, quality monitoring – i.e., chlorination, equitable supply, predictive maintenance of assets, leakage detection and adequate pressure at tail-end. It comes at lower cost and easier deployment as compared to Advanced solution option;

iii.) As there are several diverse regions in the country (hilly, desert (hot/ cold), coastal, plains etc.), there are numerous variations in rural water supply scheme based on source type, gravity/ pumping based distribution and type of water treatment (e.g., spring source gravity based with basic chlorination, ground water source with solar-powered pump with advanced water treatment). The type and location of sensors may vary depending on the type of water scheme and have been detailed in section 4(c)(iv) and 9(a);

iv.) VWSCs and RWS departments should also capture data on grievance, O&M, quality parameters through a mobile/ web-based system – This will help them to truly function as water service utility.

8. Common functional requirements of solution design

Once the appropriate solution design is chosen the data from sensors should be sent to cloud and visualised. The IT system should have the following features:

I.) Dashboards with metrics/ KPIs and GIS enabled views/ reports for block/ district officials and aggregated dashboard at district/ State level for remote monitoring. Data analytics (AI/ML) should be standardized across country based on the sensor data we are receiving;

ii.) Automated alerting mechanism to determine outages, quality conformance issues etc. with an escalation matrix (SMS, notifications on mobile/web);

iii.) The solution should send data from the village via device directly or via gateway to both cloud (central server at State level) as well as the local operator (at Gram Panchayat level) through local area network to ensure redundancy (in case of connectivity failure from gateway to cloud); the solution should have provisions for fraud detection (e.g., identify if real device is sending data from the actual installed location);

iv.) The solution should be able to store data locally on gateway for a minimum of 6 months to prevent any data loss in case of failure of connectivity via internet to cloud (through cellular network or fixed broadband); devices should store data for 30 days in case of connectivity issues to gateway or cloud;

v.) The solution should support bi-directional data flow (wherever possible), with over-the-air firmware updates (changing frequency of data transmission, remote calibration, security patches, fixing bugs etc.) and enable remote control.

9. Technical architecture and specifications for IT hardware and software

I.) The implementation agencies may follow global standards in case Indian standards are not defined for IoT hardware or sensors (such as CE/FCC for IoT devices with communication modules). Hardware specifications have been detailed in section 9(b);

ii.) The solution design of IT systems should adhere to open standards and be technology neutral. It can use a variety of networking technologies as per local conditions and availability of services, such as fixed broadband / Wi-Fi, local area RF (e.g., LoRa), and/or cellular technologies (2G/3G/4G; including upcoming NB-IoT / 5G);

iii.) In villages, where Wi-Fi is already available (e.g., BharatNet, WANI, private broadband), IoT devices can directly connect to a Wi-Fi enabled gateway/router that communicates to cloud. However, Wi-Fi enabled IoT devices may not be suited for battery-based operations due to high power consumption (especially at DMA inlet/ tail-ends) where getting power supply may not be possible. For such scenarios, RF-based first-mile network can be leveraged for low-power long range communications such as LoRa / LoRaWAN (or any other recognized technology such as Zigbee, Sigfox etc.);

iv.) RF-LoRa may be preferred where getting power, right of way, approvals, availability of other network etc. is difficult. The RF- LoRa should comply with DOT's guidelines on private RF network in the ISM band of 865-867 MHz or via licensed LoRaWAN operators. It is preferred as it consumes low power, has long range, can be used for battery operated devices;

v.) For majority of the rural villages in India which currently do not have Wi-Fi, cellular technology should be leveraged for communication to cloud. In case of an 'Intermediate' or 'Advanced' level of deployment, where there are more than 4-5 devices, it is recommended to leverage RF (e.g., LoRa) for first-mile communications to a gateway and cellular (2G/3G/4G) for gateway to cloud communications;

vi.) In scenarios, where only a limited number of IoT devices are deployed (e.g., Basic level implementation with a single flow meter, or less than 4-5 devices), a direct to cloud cellular communication can be used. Such IoT devices should have a cellular (GSM/4G) compatible communication module (RTU – remote terminal unit). This should ideally be 4G-based with backward compatibility (with 2G/3G SIMs) and extensible to upcoming technologies such as NB-IoT / 5G;

vii.) The telemetry data from devices placed in villages should directly be sent to State or Central Cloud and data from State Cloud should be pushed to Centre Cloud. A hybrid model is preferred for data transmission from State Clouds to Central Cloud. This enables flexibility to ingest data into the Central Cloud directly from the IoT Devices (sensors) or indirectly through the States who have developed such system to ingest IoT data. In cases IoT data are first collected at the State Cloud / Data Centre, then the aggregated data shall be pushed to the Central Cloud using Open APIs;

viii.) The communications to cloud can be done via several IoT compatible and specialized protocols (e.g., MQTT, AMQP, HTTPs, CoAP). Device connectors and device agents should use standard transport layer security (TLS) or Datagram transport layer security (DTLS) protocols for network security. Device management should be based on LWM2M protocol which in turn uses DTLS for network security and device connector libraries should use SSL/TLS connections to make calls to services such as 'Sensor Services';

ix.) Common data standards are required pan-India for successful scale-up. Data standards for device to State Cloud and from State Cloud to Central Cloud using APIs have been detailed in section 5(f) and 9(c).

10. Governance framework

In accordance with operational guidelines for the Jal Jeevan Mission the governance framework of measurement and monitoring system should enable de-centralised monitoring, control, and action at G.P/ VWSC level for water supply systems. It should enable data-driven decisions on ground for VWSC/ G.P for example, address outages, redress grievances, ensure equitable supply, predictive maintenance etc. The framework should enable officials at Block/ District/ State/ Centre level to remotely monitor service delivery through aggregated reports and alerts, and take necessary response upon non-conformance of service level benchmarks/ KPIs. The role of various stakeholders in establishing and operating the measurement and monitoring systems is as under;

I.) Role of NJJM

a. Develop centralized platform for aggregating data from States by appointing / hiring a master system integrator;

b. Support States in execution of the IoT-based measurement and monitoring system fo rural smart water management by conducting trainings, workshops, and providing knowledge support to PHED/RWS;

c. Setup a support cell or appoint an agency/ monitoring committee within NJJM e.g., National Smart Rural Water Monitoring Cell/ Agency comprising of members from centre and state government, technical experts from academia and industry. This committee/ Cell/ Agency should help to implement the sensor-based monitoring system and publish revisions or enhancements of technical specifications based on evolving technologies and feedback from on-ground deployments. It should also monitor the roll-out of measurement and monitoring system across all the villages and set up a system for post implementation monitoring and support for tracking service delivery, reviewing performance across States and publish rankings/ score cards and facilitate data-driven decision making and innovation.

ii.) Role of SWSM / PHED / RWS

a. Develop common platform including the State Cloud (or data centre) for ingesting data from Districts/ Blocks by appointing/ hiring a master system integrator. This is a critical pre-requisite so that all block/districts follow common data standards and to facilitate easy integration at state level;

b. Transmit data from State Cloud to Centre Cloud in standard format;

c. Setup a help desk for vendor onboarding and management with blocks/districts;

d. Facilitate clearances and approvals that may be required by the vendor (e.g., right of way, location to place gateway device, power connection)

e. Monitor rural water service delivery across State by tracking service delivery (quality, quantity, duration), reviewing performance and taking corrective measures.

f. Set up a support unit to coordinate the implementation and provide support and monitor the system after the implementation for tracking service delivery reviewing performance and facilitate data-driven decision making and innovation.

iii.) Role of Districts/Blocks - DWSM / PHED / RWS

a. To implement the IoT sensor- based monitoring of rural water supply (Supply, Install, Test, Commission, O&M) with procurement of IoT solution provider/ vendors;

b. Facilitate clearances and approvals that may be required by the vendor (e.g., right of way, location to place gateway device, power connection);

c. Facilitate tripartite agreement if needed between the DWSM/ PHED/ RWS, the vendor, and the GPs in the cluster of villages (block/ district) – which may clearly include responsibilities for GPs (e.g., ensure prevention of any vandalism/ theft, providing power supply and location for gateway at GP office or pump cabin/ ESR from existing pump connection or apply for new power connection etc.);

d. Create a new role/ re-skill existing IT / PHED/RWS resources for IoT remote monitoring engineer at District and Blocks;

e. Monitor rural water service delivery across villages by tracking service delivery quality, quantity, duration, outages, source sustainability, grievances, and O&M tariff collection;

f. Take timely and corrective actions for issues flagged by system (e.g., supply outages, water contamination, leakage), communicate with Paani Samiti / VWSC / Operators for on-call support and resolution and allocate work to JE/AE for grievance redressal and track to closure.

iv.) Role of GP / PRI / VWSC / Paani Samiti / MVWSS

a. Establish a display unit at a prominent place of village for example, Panchayat office, School, PHC/ CHC etc.

b. Facilitate deployment of IoT solution in village, provide support and approvals that may be required by the vendor (e.g., right of way, location to place gateway device, power connection);

c. Monitor and control water service delivery in village by tracking service delivery (quality, quantity, periodicity), carry out water budgeting, determine non-revenue water (leakage, wastage), ensure upkeep of IoT devices;

d. Capture O&M Data (Water tariff and expenses) and periodic water quality testing results (other than free chlorine) in mobile app.

11. Operational guideline for Jal Jeevan Mission provides for establishment of such systems under support funds and also under flexi funds. The State Budget, 15th Finance commission, Community contribution, CSR Funds etc may also be used to establish such systems;

12. Several new skills are required to successfully execute this project (e.g., data entry operator, IoT device maintenance vendor, IoT remote-monitoring engineer) and a need for enhancing availability of traditional skills such as electricians, plumbers, and masons. This initiative will also require creation of new roles or re-skilling of existing PHED/RWS engineers (and IT cells) for the role of 'IoT Remote Monitoring Engineer' to understand dashboards, track metrics, troubleshoot and take corrective action;

13. There is also an opportunity to create local entrepreneurship for new work areas such as IoT asset O&M, data-entry operator, water quality testing etc. Officials should leverage several available skilling initiatives such as National Skill Development Corporation (NSDC), Skill India, Common Services Centres Scheme (CSC), etc. Further, the departments should focus on change management and build awareness among all stakeholders along with trainings/workshops.

14. Roll-out plan

I.) In order to roll out the measurement and monitoring system across the villages three levels of implementations are required

a. At the village level, IoT-devices will be installed and maintained.

b. Data from these devices will be directly transmitted to State Cloud, where data from all villages within the State will be ingested and end-user applications be made.

c. Further, this data will be pushed to Centre Cloud for aggregation from all States and dashboards will be exposed;

ii.) To enable this architecture, 3-types of implementation agencies should be appointed/hired across district/block level, state level and at centre level.

a. IoT Solution Provider (at Block/District level) to supply, install, configure, test, commission, and maintain IoT assets in all villages in that block to send data to State Cloud;

b. State – Master System Integrator (at State level) to ingest IoT data from villages, provide cloud services and analytics, build reports and applications;

c. Centre – Master System Integrator (at National level) to aggregate IoT data from all States, provide cloud services and analytics, build reports and applications.

iii.) The States should setup State Cloud (or use existing data centre) to initiate this roll-out;

iv.) The award of contracts for an IoT solution provider (i.e., IoT asset installation and maintenance) should ideally be at block level (or higher) with 50-100 or above villages;

v.) Both capex and opex models could be explored by States. In a capex model an upfront capex payment for hardware and installation is followed with annual O&M payments. In an opex model a lower upfront amount is charged, followed by monthly/annual device and service rental is paid as per SLAs;

vi.) After completion of 5 years, respective states may consider to continue with the system or use improved systems available.

vii.) Further, fixed and performance-based payments can be made to vendor evaluated from system data (e.g., uptime of IoT system, system health, data accuracy, time to resolution).

15. Way forward

I.) In the last one year, several IoT-based smart rural water management pilots have been conducted across India by non-profits, academia, as well as government departments. There are several success stories of using IoT for improving water service delivery in Rajasthan, Uttarakhand, Gujarat, Maharashtra, Andhra Pradesh, and Odisha. Further, state rural water supply departments from Gujarat, Arunachal Pradesh, and Bihar have already initiated such IoT deployments in several blocks/districts;

ii.) States are encouraged to refer this report and initiate IoT-based smart rural water management rollouts starting with few blocks in coming months and then scale-up to entire districts.

1. Introduction

a. Background: JJM mandate on service delivery measurement and monitoring

"Har Ghar Jal" through Functional Household Tap Connections is the core objective of the Jal Jeevan Mission (JJM), which envisions that - every rural household having drinking water supply by 2024 in adequate quantity of prescribed quality, on a regular and long-term basis at affordable service delivery charges, leading to improvement in living standards of rural communities. The aim is to provide safe and adequate drinking water to all rural households at the household level.

The 'functionality' of household connection, as the real goal of the Mission, is defined as providing drinking water in adequate quantity i.e., minimum 55 LPCD, and of prescribed quality i.e., BIS 10500:2012 standard on regular basis on a long term/ full design period of the scheme.

To ensure functionality, it is proposed to set up 'sensor-based monitoring system' that collects data from field locations of the rural water supply systems, transmits through network to a central server that analyses the data to monitor and manage functionality both at operational level and at different administrative levels in the States, and at the national level.

The objective of sensor-based monitoring is not only to monitor Key Performance Indicators, but also ensure quick response, minimum service delivery outage, minimum water loss, optimise efficiency and monitor the quantity and quality on sustainable basis. The additional advantage of this data would be to analyse the demand pattern of the user groups over time and use this information for demand management at aggregate level, minimise non-revenue water, ensure proper management and effective operation and maintenance of water supply systems in the villages.

The mission objective is to shift the focus from physical infrastructure and highlight the importance of "developing a utility mindset to focus on service delivery". This shift can be achieved by designing "sustainable O&M of the systems, undertaking water budgeting and audits at regular intervals, cost recovery, reducing the energy charges by adopting conjunctive use of water as well as use of conventional and non-conventional energy specifically solar, measuring the water withdrawal and accounting for the same, addressing the grievances proactively, etc."

b. Constitution of the Expert Committee

With the above objectives in view, the DDWS decided to constitute a Technical / Expert Committee to prepare a road map for measurement and monitoring of water service delivery system in rural areas.

The composition of the committee is as under:

I.)	Shri Ajit Kumar Jain, Director, Centre for Sustainable Governance, All India Institute of Local Self-Government, Mumbai	-	Chairman
ii.)	Shri Devender Singh, Addl. Chief Secretary (Irrigation, WR & PHE) Govt. of Haryana.	-	Member
iii.)	Shri Dhananjay Dwivedi, Secretary, Water Supply Government of Gujarat and Chairman, GWSSSB	-	Member
iv.)	Dr. T. P. Singh, Director, Bhaskaracharya Institute for Space Application and Geoinformatics, Gandhi Nagar, Gujarat	-	Member
v.)	Shri D. C. Mishra, DDG (RD, MoPR and DDWS) – NIC	-	Member
vi.)	Dr. Narendra Ahuja, Director, Information Technology Research Academy (ITRA), Deity, Government of India	-	Member

vii.) Shri Rajendra G. Holani, Former Member-Secretary, Maharashtra Jeevan Pradhikaran, Govt. of Maharashtra - Member

viii.) Shri Animesh Bhattacharya, Chief Engineer, PHED Government of West Bengal - Member

ix.) Shri Pradeep Singh, Director, NJJM, DDWS - Member Secretary

Ms. Seemantinee Sengupta Dy. Director General, NIC, continuously assisted the committee in deliberations. The committee was assisted by Shri Siddhant Masson, Consultant, DDWS and Shri K Ambarish, Consultant, DDWS. The terms of reference of committee, as mentioned in the order of 24th August 2020 are as under:

I.) to study ways of capturing the data on the quality, quantity, and regularity of water supply;

ii.) to recommend the solution design;

iii.) to define standards and protocols;

iv.) to develop governance framework and implementation plan; and

v.) to prepare a roll out plan of the selected solution.

The committee held fourteen meetings and discussed all the aspects of the IoT technology to conclude its recommendations.

(Please refer Annexure for 'Record of discussions of committee meetings' for details on meetings and consultative process)

2. Internet of Things (IoT) for water service delivery

a. Water Supply Systems

Drinking water supply systems across India are based either on Ground Water or Surface Water sources. 85% are dependent on ground water. The surface water sources such as rivers, lakes, and other water bodies are used. The ground water quality has challenges in specific areas where there are issues of Salinity (TDS), Iron (Fe), Fluoride (F), Arsenic (As) and Hardness in ground water. Water is treated for such specific chemicals. However, most of the ground water with adequate disinfection is potable. The Surface sourced water need physico-chemical treatments to remove turbidity, suspended solids, correct pH and disinfect to supply. Thus, to ensure every household gets 55 LPCD water of quality as per IS 10500, it is essential to monitor the service delivery daily. With the advent of technology, it is possible to do the same in real time using IoT enabled sensors for quantity and quality on the physical infrastructure layer. It is to observe that there can be multiple operating water supply sources and systems to provide water to a village. The monitoring system will have to take care of all of them.

b. Description of IoT Technology

Internet of Things (IoT) refers to physical devices being connected to the internet and thereby collecting and sharing information. It essentially is about adding sensors to objects and connecting these sensors to internet so that real-time data can be relayed without human intervention for various use-cases. The Internet of things refers to a type of network to connect anything with the Internet based on stipulated protocols through information sensing equipment, to achieve smart monitoring, and administration. IoT is a concept and a paradigm that considers pervasive presence in the environment of a variety of things/objects that can interact with each other, through a wireless and wired connections and unique address schemes to create new applications or services in pursuance of common goals.

The Internet of Things is a major contributing factor of the new Data Management. Sensors are the source of IoT data. Furthermore, sensors and actuators in IoT can work together to enable automation at industrial scale. Analysis of the data that these sensors produce can provide valuable governance insights to manage and monitor the service standards. IoT has been witnessing rapid adoption across the globe in all the industries/ sectors e.g., retail, transportation, manufacturing, healthcare, and of course utilities like water, and electricity. Recent technological advancements (such as IoT, Big Data Analytics, AI/ML, Cloud) and declining costs[1] of mobile data, hardware (sensors), and software, provide an opportunity to digitise water supply infrastructure in rural India.

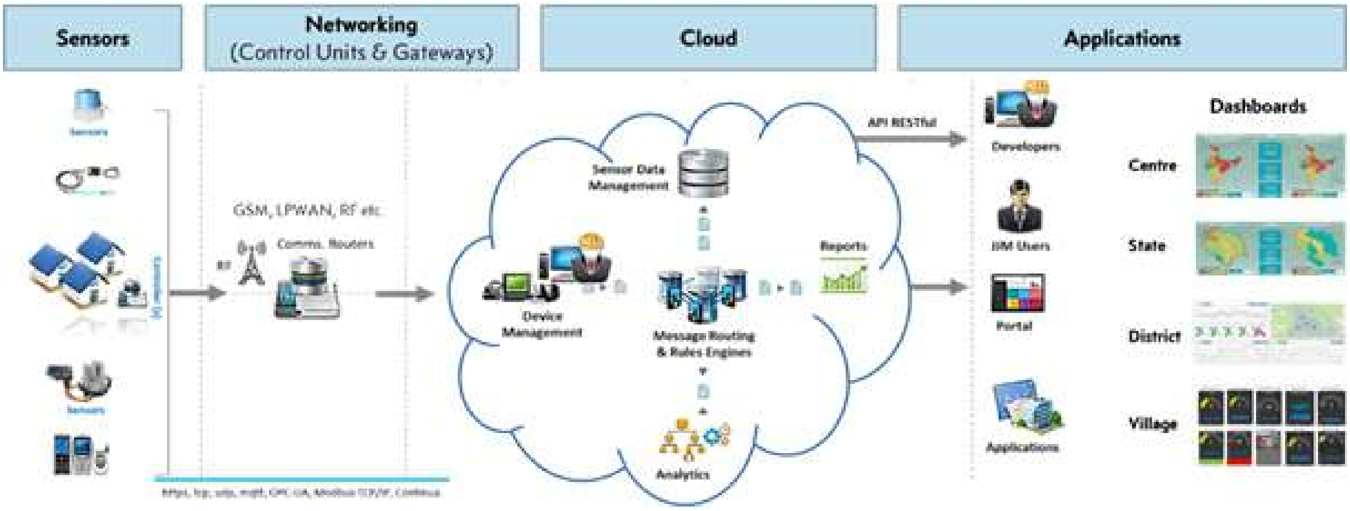
Digitally enabled water supply infrastructure will help in near real-time monitoring and evidence-based policy making. There is an opportunity to deploy frugal IoT based system to monitor quantity, quality, and periodicity of water delivery. Digital near real time monitoring of water supply infrastructure has the potential to solve some of the biggest societal problems facing the nation. More importantly, it will help anticipate and address future challenges.

c. High-level IoT architecture

An IoT enabled remote monitoring solution will comprise of 4 broad components (Sensors, Networking, Cloud and Applications).

[1] (2019, June). Future of IOT report. EY FICCI. ‘Over the last 15 years, average cost of IoT sensor has reduced from $1.3 to $0.3 and transfer cost of 1GB data has decline from $0.47 to $0.04’.

Figure 1: Illustrative IoT Architecture



I.) **Sensors:** Devices that detect and responds to input from physical environment. Multiple parameters related to water supply network can be captured through such sensors. Bulk flow meters and consumer water meters (or flow switches) capture quantity delivered and velocity. Quality sensors measure attributes like pH, Residual Chlorine, Turbidity etc. Several other sensors like level sensors and pressure sensors can be utilized across the water supply scheme for monitoring

ii.) **Networking:** Multiple communication technologies exist for transmission of sensor data to cloud (internet), these include cellular (2G/3G/4G/5G/NB-IoT), RF (LoRa, Zigbee, Sigfox), Wi-Fi etc. These technologies vary in terms of their performance (range, power consumption – which impact battery life of sensors, latency, data limit, interference, security etc.); and their choice may depend on local conditions (topology, existing network availability) and affordability of user groups. The networking components typically comprise data loggers or gateway. Depending on the choice of networking technology, these might further require repeaters/concentrators for increased coverage.

iii.) **Cloud:** Data received from sensors via internet is stored on cloud infrastructure (public or private data centres), on which multiple applications may be hosted. The cloud platform enables sensor device management, configurations, message routing and event processing. Cloud platform can integrate with GIS for tracking geo-tagged assets on a map.

iv.) **Applications:** Multiple applications may be hosted on the cloud to enable remote monitoring (e.g., dashboards and alerting mechanisms). Advanced analytics (including AI/ML) and visualisations can be custom developed for diverse use-cases (e.g., leak detection, predictive asset maintenance, demand projections)

d. Key issue areas in rural water supply scheme

Village water supply in India encounters several issues in the Operation and Maintenance (O&M) phase across the water value chain. These issues range from premature exhaustion of source (drying up of source) to irresponsible usage at households and unauthorized connections. These issues have been listed in table below.

Table 1 Key issue areas in rural water supply scheme

Water Value Chain	Key Issues
Source	Premature exhaustion of source (drying up of source)
	Poor raw water quality
	Pump assembly failure or insufficient intake by pump
Water Treatment	Insufficient water output (quantity) or poor-quality water produced
Pipeline and Storage	Pump assembly failure
	Overflowing/ empty storage unit (e.g., ESR)
	Frequent leakages and difficulty in detecting minor leakages; inadequate pressure in pipe
Distribution Network	Inconsistent service delivery (outages, quality, low pressure, hours of supply)
	Irresponsible/ excess usage at household (HH) level; unauthorized connections resulting in high NRW

Above issues lead to several direct and indirect costs for all the stakeholders involved – government, utility, and citizens:

I.) High scheme failure rate leads to wastage of initial investment by government and/ or community and lack of trust of community in water supply schemes;

ii.) High repair and maintenance costs due to frequent failures, poor upkeep, and absence of preventive maintenance;

iii.) Health issues faced by users due to supply of poor-quality water;

iv.) Low user satisfaction due to poor service delivery and poor grievance redressal mechanism;

v.) High non-revenue water/ high burden on users paying O&M charges – unauthorized connections, leakage/ overflow, and unwillingness of users to pay O&M charges due to poor service delivery;

vi.) High/ wastage of environmental costs e.g., carbon footprint of electricity wasted for leaked/ overflown water, and adverse impact on long term sustainability of water resource due to excess usage/ wastage/ leakage;

- High cost borne by citizens (wage loss and healthcare expenses) due to scheme failure (temporary/ permanent) and supply of poor-quality water;

e. IoT use-cases for water service delivery

IoT can play an important role in addressing the O&M issues and thereby leading to significant savings in direct and indirect costs. There are several uses cases for IoT across the water value chain in the O&M phase. These use-cases are detailed below:

I.) Source and Intake

a. Monitor water level in source and predict sustainability issues – the source can be accordingly augmented and managed effectively if required, to ensure long term sustainability of the source and that of the overall water supply scheme;

b. Automate pumping operations and monitor pump health to enable predictive maintenance and reduce repair and maintenance issues.

ii.) Water Treatment Plant (WTP)

a. Monitor output of WTP (quantity and quality of water) to ensure standards are being met – adequate quantity, i.e., 55 LPCD of prescribed quality i.e., BIS 10500:2012 standard on regular basis i.e., continuous supply in long term/ full design period of the scheme;

b. Enable regular preventive and predictive maintenance to minimize repair and maintenance costs and reduce/ eliminate impact on environment and citizens iii.) Pipeline and Storage

a. Ensure scheme functionality through continuous monitoring and visibility to different Govt. levels and citizens to ensure issues, if any, are escalated and resolved within defined SLAs

iv.) Distribution Network

a. Ensure consistent service delivery at habitation/ household level to ensure high user satisfaction

b. Identify leakages, unauthorized connections, and lower NRW to maximize value for money paid by users (O&M charges)

f. Benefits of IoT based water service delivery monitoring

IoT based remote monitoring is likely to benefit all stakeholders (government, utility, and citizens) across multiple dimensions like economic, social, environmental, health and safety.

I.) Improved success rate of water supply schemes due to end-to-end visibility of water supply to village, district, state, and national level at near real-time (for quick response corrective actions);

ii.) Equitable access to all sections of the society by monitoring water delivery across habitations;

iii.) Alleviation of issues (social, economic and health) in village resulting from inaccessibility to potable water in adequate quantity; improved transparency and accountability;

iv.) Reduced cost of operations and improved life of water supply schemes (e.g., leak detection, preventive maintenance, optimising resource requirements);

v.) Better customer satisfaction with improved service levels through faster response time and lesser number outages (e.g., remote dashboards across levels and preventive maintenance);

vi.) Data-driven and evidence-based planning for new schemes/ modifications through advanced analytics (e.g., demand patterns, electricity reliability, source reliability, temporal water quality variation etc.);

v.) Long term sustainability of water sources through improved source monitoring;

vi.) Efficient and responsible use of water by end customers by measuring quantity consumed.

3. Key functional requirements for smart rural water management

a. User Research: Stakeholder issues and needs

The primary stakeholders (beneficiaries) for IoT based applications would be the ground level stakeholders of the water service schemes i.e., the execution layer of government officials (e.g., PHED field engineers) and the utility (e.g., Village Water and Sanitation Committee - VWSC/ Paani Samiti/ Water User Group – WUG/ MVWSS management). Other stakeholders include senior government officials (e.g., NJJM, state government, district, senior engineers), scheme operators/ employees of utility (e.g., pump operators, linemen), citizens/ users, activists, and media professionals.

The key issues faced by these stakeholders and the potential benefits are listed below:

I.) Execution layer of government officials (e.g., PHED / RWS / PRI field engineers) – a Field Engineer (FE)/ Junior Engineer in PHED is typically directly responsible for water supply schemes in 50-200 villages and many of these villages may have more than one schemes. In the absence of adequate supporting digital infrastructure, these officials have to make regular field visits to inspect and ensure functionality of schemes. Therefore, it becomes difficult for officials to closely monitor all the schemes under them. IoT helps such officials as listed below:

ii.) Ease of monitoring – with one dashboard the officials will be able to monitor scheme on real-time basis on various parameters e.g.:

a. Scheme functionality status;

b. Service delivery – quantity of water supplied, hours of supply;

c. Water quality;

d. Faster issue resolution – instead of waiting for the issue to be escalated (which is often not done in a timely manner), the officials can be abreast with all the relevant issues via rule based automated alert systems (e.g., pump failure);

e. Facilitates predictive versus reactive approach to service delivery management – by enabling pre-emptive steps using advanced analytics in combination with alerts system, the officials guide the utility (VWSC/ Paani Samiti/ WUG) in the right direction. For example, if required, officials can motivate and guide the village community to take source augmentation steps thereby averting a source failure and increasing scheme success rate. Similarly, the officials can guide the utility and pump operators on applicable predictive maintenance steps using the inputs received from the advanced analytics.

iii.) Utility (e.g., Village Water and Sanitation Committee - VWSC/ Paani Samiti/ Water User Group - WUG) – lack of adequately trained manpower and lack of resources are two of the biggest constraints of a utility in a rural setting in India. These constraints translate into an inability to adequately monitor and a lack of technical know-how. Together these result in several problems e.g., irregular disinfection of water, scheme failure due to source drying up because of lack of monitoring and inability to take pre-emptive steps. Other problems include lack of adequate monitoring of service delivery (quantity supplied, hours of supply, and quality supplied), high non-revenue water, frequent pump failure, inefficient and/ or ineffective grievance redressal, and difficulty in collecting O&M charges. IoT can significantly improve the performance of a rural water utility in India as listed below:

a. Improves scheme life/ success by enabling pre-emptive source augmentation steps via predictive analytics (e.g., by calculating the expected life of source using several inputs like forecasted demand, current source level, recharge patterns, and usage patterns);

b. Reduces repair and maintenance expenses by enabling predictive maintenance electrical components of the scheme (e.g., pump) by monitoring and analysing key equipment health parameters which are otherwise very difficult to monitor let alone analyse (e.g., pump vibrations and voltage);

c. Improves service delivery by continuously monitoring and highlighting (via alerts) in case of any issues e.g., lower quantity of supply, inconsistency in hours of supply in a particular habitation, low residual chlorine levels;

d. Increases community support and reduces effort required for collecting O&M charges by improving user satisfaction (achieved by increasing scheme life/ success, improving service delivery, and reducing repair and maintenance expenses).

iv.) Senior government officials (e.g., NJJM, state government, district, senior engineers) – a senior official at district level (e.g., District Magistrate/ CEO ZP/ district officer of PHED/WSSD) and at state government level (e.g., Principal Secretary/ Engineer-in-Chief) are responsible for all aspects of administration in the district and state respectively – drinking water supply schemes being one of the priority areas. Even for senior engineers, the vast number of schemes under supervision make it difficult for them to make regular field visits which are necessary in the absence of digital modes for monitoring. Similarly, NJJM officials are responsible for overseeing the water supply schemes in India. They rely on data being manually entered by on-ground workforce. This process has several issues – flow of information is slow and data quality may be poor (e.g., old, or incorrect data may be shared). In the absence of adequate digital infrastructure, these officials are required to make field visits to inspect and ensure schemes are functioning properly and the JJM's objectives are being met. Therefore, an effective and efficient way of remotely monitoring the water supply schemes is very important for these officials. IoT can aid senior officials to effectively monitor the rural water supply schemes and intervene in a timely manner as and when required:

a. Ease of monitoring – with one dashboard the officials will be able to monitor scheme on near real-time basis on various parameters e.g.:
   - Scheme functionality status;
   - Service delivery – quantity of water supplied, hours of supply;
   - Water quality.

b. Faster issue resolution – instead of waiting for the issue to be escalated (which is often not done in a timely manner), the officials can be abreast with all the relevant issues via rule based automated alert systems (e.g., scheme failure);

c. Enables data backed planning for future interventions thereby improving impact per rupee of public expenditure e.g.:
   - Source augmentation interventions can be planned/ prioritized where ground water level is low or falling rapidly;
   - Intensive community mobilization and awareness campaigns can be planned where water consumption per capita is very low or very high;
   - Repair and upgradation work for old schemes can be prioritized on basis of proportion of Non-Revenue Water (leakage/ unauthorized connections);
   - Government/ Gram Panchayat sponsored advanced grey water management and/ or sewage schemes can be planned where water consumption per capita is high or where the total quantity of water used is large.

b. Key IoT applications

The IoT applications for water service delivery in the context of rural India can be divided into 3 broad categories:

I.) Reports, Dashboards, and KPIs tracking;

ii.) GIS (Geographical Information System) based monitoring;

iii.) Alert mechanism and control systems;

iv.) Advanced analytics (AI/ ML).

i. Reports, Dashboards, and KPIs tracking

Monitoring on real-time/ near real-time basis is one of the key applications of any IoT setup. For a water supply scheme in rural India, following are some of the reports and KPIs that can be monitored:

Level	Sample Dashboard Reports / KPIs
Centre Government	I.) Scheme functionality statistics by States / Districts (Number of functional vs. non-functional schemes, number of non-functional days); ii.) Number of schemes at >=55 LPCD across States; iii.) Average time duration of water supplied per day by State; iv.) Number of water quality non-conformance incidents per month at a state level.
State Government	I.) Scheme functionality statistics by Districts (Number of functional vs. non-functional schemes, number of non-functional days); ii.) Number of schemes at >=55 LPCD across Districts; iii.) Average time duration of water supplied per day by District; iv.) Number of outages / water contamination incidents over time per District.
District (or Division, Block, Tehsil)	I.) Scheme functionality statistics by Blocks / Villages / Habitations (Number of functional vs. non-functional schemes, number of non-functional days); ii.) Number of outages / water contamination incidents over time per Village; iii.) Demand vs. supply by Blocks / Villages; iv.) Non-revenue water by Blocks / Villages.
Execution layer of government officials (e.g., PHED field engineers)	I.) Scheme functionality by Villages/ Habitations/ Schemes (detailed view on individual schemes, number of functional vs. non-functional schemes, number of non-functional days); ii.) Service delivery by Villages/ Habitations/ Schemes – LPCD supplied, hours of supply, and quality of water; iii.) Demand vs. supply by Villages/ Habitations/ Schemes; iv.) Ground Water level.
Utility and Scheme Operators/ employee of utility (e.g., pump operators, linemen)	I.) Water source level, Daily ground water withdrawal; ii.) Scheme functionality (status and number of non-functional days); iii.) Quality of water supplied (pH, Turbidity, Residual Chlorine); iv.) Total water supplied per day per habitation (KL); v.) Quantity consumed per household (LPCD); vi.) Time-duration of water supplied per day (Hours); vii.) Pump performance (throughput, hours of operation, temperature, electricity consumed, vibrations); viii.) Process loss due to leakage, Pressure at end-nodes; ix.) Water outage (line disruption) / water contamination incidents.

Level	Sample Dashboard Reports / KPIs
Citizens/ Users	I.) Scheme functionality (status and number of non-functional days); ii.) Quality of water supplied (pH, Turbidity, Residual Chlorine); iii.) Total water supplied per day per habitation (KL); iv.) Quantity consumed per household (LPCD); v.) Time-duration of water supplied per day (Hours);
Activists and media professionals	I.) Scheme functionality by States / Districts/ Villages (Number of functional vs. non-functional schemes, number of non-functional days). ii.) Number of schemes at >=55 LPCD across States; iii.) Average time duration of water supplied per day by State; iv.) Number of water quality non-conformance incidents per month at a state level; v.) Demand vs. supply by State/ District/ Villages.

Below are illustrative snapshots for dashboards:

Figure 2 Illustrative dashboard for VWSC / Paani Samiti / WUG

Figure 3 Illustrative dashboard for officials / engineers (Block / District)

ii. Geographical Information System (GIS)

The Geographic Information System (GIS) is a software system with which location-based mapping and characterization of the geographic features can be integrated into a Decision Support System (DSS) for planning, execution, and management of any spatial both the manmade and natural features. Geographical Information System will play an important role in mapping, monitoring and operation of water supply schemes under JJM on IoT based sensors. The areas in which the GIS can be used in the water supply system from planning till operation and management monitoring are mentioned below:

I.) Mapping of Surface and Ground Water Sources and Infrastructure including mapping of IoT sensors;

ii.) Water resources availability estimation and determining carrying capacity through GIS;

iii.) Water budgeting and audit at different levels of hierarchy;

iv.) Planning of Water supply infrastructure up to home;

v.) Management of System (Resources, Assets, Functionary);

vi.) Use in day-to-day effective maintenance management by locating the areas for trouble shooting in pipe network and infrastructure through GIS based simulated hydraulic models;

vii.) Real time monitoring of Services using IoT based sensors and analytical tools with GIS linkage for water quantity, quality, operations, and maintenance management. Dissemination of information to beneficiaries/ public and system management group;

viii.) GIS based Consumer Relations Management (CRM) using Geo-spatial database of consumers and using several electronic media like mobile, e-mails, social media etc;

ix.) Monitoring of the CRM and grievance redressals in relation to KRAs of concerned official;

x.) Nation, State, District, Taluka, Village level Visualization of Status of Services through GIS enabled Dashboards in the map form;

xi.) Decision Support System (DSS) development on daily and seasons basis for policy makers. In the present context of IoT sensors-based monitoring in JJM water supply schemes, it is envisaged that major thrust will be on use of

GIS for mapping and Geo-coding of water supply schemes, its sources, geographical boundaries of beneficiary areas viz. village, hamlets, IoT based sensors deployed for the scheme for monitoring, areas under influence of a sensor. This shall after analytics shall display visually on the GIS map-based dashboards about the quantity and quality of water supply in an area under the influence of Geo-coded sensor.

The analytics will further be used to give the Geospatial status of performance of number of villages complying with the quantity and quality benchmarks prescribed by JJM in Administrative Units such as a Taluka, District, State and Nation as a whole. This shall be possible to be viewed as colour coded areas and/or statistical display of Geo-Spatial data generated through IoT devices and manual inputs for quality parameters for which no such sensors are available and analysed using application software on dashboard for the chosen Administrative Units specified by the viewer.

Though it is not envisaged under this IoT based monitoring tool being rolled out to map the entire infrastructure, it will be essential to map the Geo-spatial boundaries of the beneficiary areas represented by each of the geo-coded sensor. Further the Taluka, District, State and National boundaries will also have to be mapped using GIS which may already be there. Here, it has to be appreciated that the beneficiary areas will be a subset within the geographical administrative boundaries of villages as may be available in GIS today. We do not envisage planning of water supply schemes and infrastructure using GIS as a compulsory feature; however, it is encouraged.

The data from Geo-coded ground water level measurement sensors and its GIS based analysis will have to be projected on the maps as dashboard for use of water scarcity management measures and decision support system for the different Administrative Units.

Development of modules for use of the Geo-spatial IoT sensor based available data for effective operations management of individual water supply system by mapping the entire transmission and distribution network and using GIS based simulated hydraulic models with real time flow and pressure data inputs through sensors can be taken up by interested system managements as second phase.

Similarly, the GIS based CRM and its monitoring and display on the maps will require every consumer/ household and its database to be taken in Geo-spatial database can be separately done in subsequent phases when each of the household and its data is brought on GIS by the states. However, in the meanwhile the statistical data can be uploaded for the village through mobile / web apps periodically and represented on GIS based dashboard for that Village.

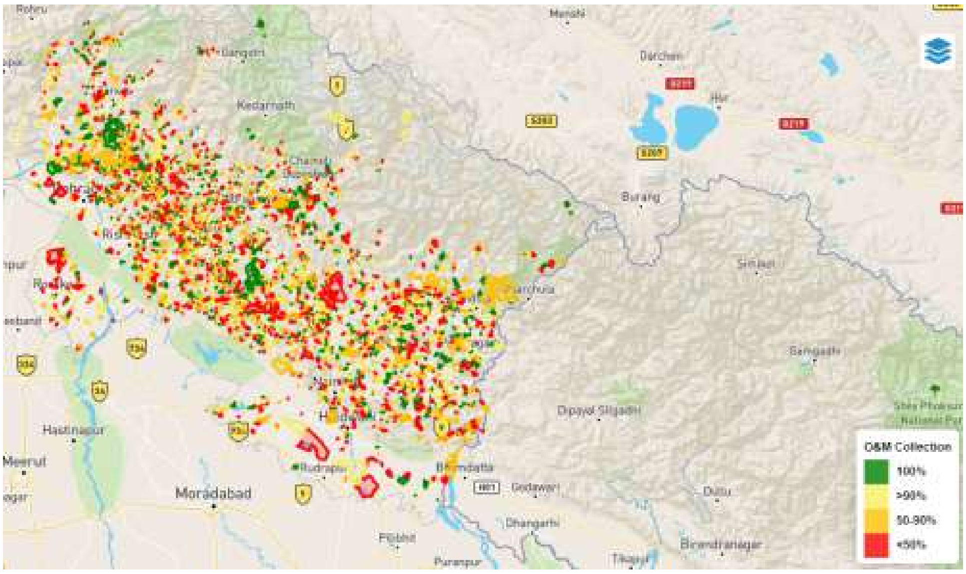
Below is a snapshot of village level tracking using data from IoT sensors:

Below are illustrative GIS thematic maps that can help officials to monitor KPIs at multiple villages, blocks, and districts:

District wise: Non-revenue water % (Illustrative - with sample data)

Sub-district / Division / Block wise: Average LPCD (Illustrative – with sample data)

GP / Village / Habitation wise: O&M Tariff Collection % (Illustrative – with sample data)



Several other metrics can be represented in aggregated basis to expose thematic maps across the following metrics/KPIs:

I.) Functionality

a. Quantity (LPCD) - <40, <55, 55-70, >70 etc.

b. Quality (type of contamination) – Arsenic, Fluoride, Iron, etc.

c. Regularity (Hours of supply) – 2-3 hours, 3-5 hours, >5 hours

d. Non-functional schemes - <5%, 5-10%, >10%

ii.) Operations and Maintenance

a. Average outage days – <2 days, 2-5 days, >5 days

b. Unresolved grievances (ageing) - <2 days, 2-5 days, >5 days

c. Non-revenue water – <5%, 5-10%, >10%

d. Water tariff collection (%) - <50%, 50-90%, >90%, 100%

iii.) System Health

a. Non-functional IoT assets (%) - <5%, 5-10%, >10%

b. Battery level (low indicator) - <5%, 5-10%, >10%

iii. Alert mechanism and control systems

IoT based alerts help improve the efficiency of the water supply scheme (manpower, electricity, water consumption) by supporting the utility and its human resources. Several applications of IoT alerts can be leveraged in the context of water supply scheme in rural India:

I.) Water level in source – used for pre-emptive source augmentation steps in the long run and switching off pump to avoid dry-runs and resulting pump failure in the short run;

ii.) Pump operations – alerts to switch the pump on/ off basis alerts regarding water level in source, water treatment plant, and service reservoir to avoid dry-runs and overflows;

iii.) Pump health – alerts to operate the pump and/ or undertake repair & maintenance basis parameters like hours of operations, voltage, vibrations etc;

iv.) Water treatment plant operations – alerts to regulate the quantity of water supplied and purification steps basis alerts on water level in the supply value chain and water quality at source, distribution network, and user endpoint;

v.) Water treatment plant health – alerts on health of equipment (in case of electrical equipment) and on quality of water;

vi.) **Water quality –** alerts on various water quality parameters (e.g., pH, turbidity, chlorine) throughout the water value chain (source to user endpoint);

vii.) **Quantity of water supplied and duration of supply –** alerts to ensure that at least 55 LPCD of water is being supplied;

viii.) **Non-revenue water –** alerts for leakage/ unauthorized connections (applicable in case water meters are installed at household level also).

Alerts on mobile for engineers / officials and community:

iv. Advanced analytics (AI/ ML)

Advanced analytics enable more effective decision making. In case of a rural water supply scheme in India, these can play a critical role in bridging the crunch of trained and skilled manpower. Some of the applications of advanced analytics in the water supply scheme of rural India are as follows:

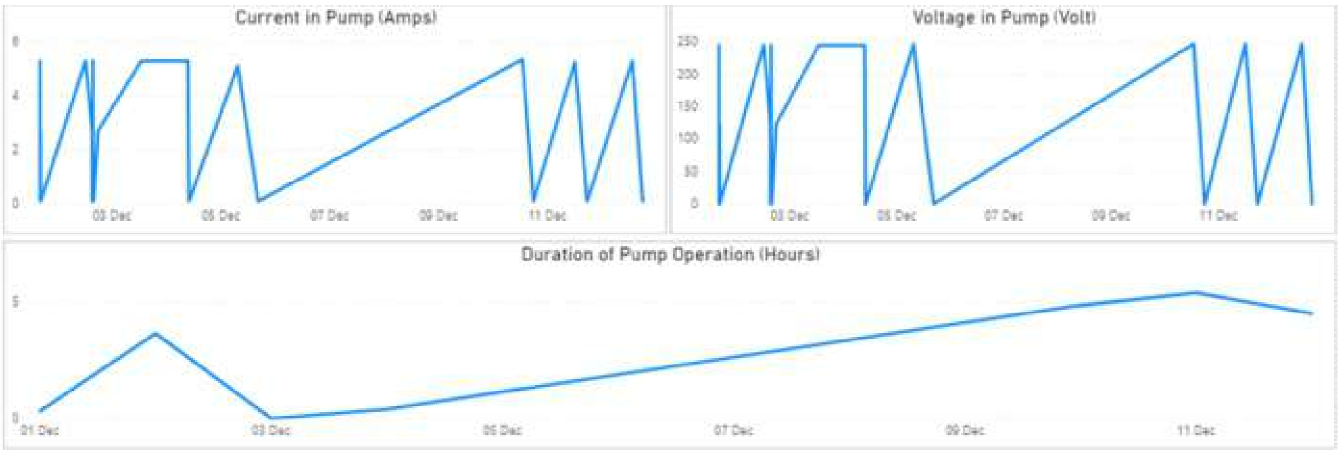
I.) **Projected life of source** thereby taking pre-emptive steps for source augmentation – basis inputs on several parameters like source water level patterns, consumption patterns, source recharge patterns, projected demand etc;

Figure 4 Groundwater level depth (actual versus predicted)

ii.) Non-revenue water detection (leakage/ unauthorized connections) – using data from bulk flow meters at outlet of service reservoir and at DMA/habitations to compute leakages through water balancing and network management

iii.) Predictive maintenance alerts for equipment (e.g., pump, water treatment plant) – basis inputs from several parameters like hours of operations, voltage, vibrations etc;

Figure 5 Pump health monitoring and current signature analysis



iv.) Demand estimation based on historical usage of water, seasonality, weather conditions etc.

4. Solution design

a. Guiding principles

The following principles should be followed while deploying an IoT-based smart rural water management solution:

I.) **Affordability:** Low cost IoT monitoring (capital and operating expenses);

ii.) **Scalability:** Highly scalable and standardized framework;

iii.) **Ease of adoption:** Acceptance from State Govt. and local communities;

iv.) **Ease of deployment:** Ease of installation and configuration; minimally invasive;

v.) **Transparency:** Provides end-to-end visibility;

vi.) **Extensibility:** Integration with cross sectoral use-cases; common data lake;

vii.) **High Security:** Multi-level hardware and software security frameworks across levels;

viii.) **Data privacy:** Stringent controls of data privacy and security;

ix.) **Automation:** Elimination of manual repetitive tasks prone to human error;

x.) **Innovation:** Promotes innovation and R&D among academia, start-ups, and industry (analytics, AI/ML, sensor, and networking technology);

xi.) **Open architecture:** Enables diverse technology and open standards to leverage an open platform;

xii.) **Ecosystem development:** Promotes start-ups, developers, and local vendors with indigenous quality manufacturing.

b. Design options: Basic, Intermediate, and Advanced levels of applications

To attain all potential smart-water management use-cases (e.g., water source sustainability, quality monitoring, bulk water quantity measurement, pressure management, consumer metering), several different sensors and communication units (RTUs, gateways) may be required (see below table). This may increase complexity, escalate costs, and impact scalability of such a solution.

S. No.	Device type	Measurement/Application
1	**Bulk Flowmeter**	Measure quantity and periodicity of water supplied (L) to entire village and nodes to compete aggregate LPCD
2	**Consumer Flowmeter**	Measure quantity and periodicity of water supplied (L) to household to compute household level LPCD
3	**Chlorine analyzer**	Measure free chlorine in water (mg/L or PPM) to determine quality and disinfection process conformance
4	**Pressure sensor**	Measure tail-end pressure (Bar) to ensure equitable supply and water system health
5	**Ground water level sensor**	Measure depth of water from ground (Feet) to determine withdrawal rates and estimate remaining useful life (source sustainability)
6	**Remote Terminal Units (RTU)**	Communicate digital signal to gateway/concentrator or cloud
7	**Gateway / Edge device**	Receive digital signal from nodes and transmit to cloud
8	**Energy sensor**	Measure voltage (V) and current (A) of pump to determine health and predictive maintenance
9	**Pump Controller and Service reservoir level sensor**	Measure SR level (%) or (m) to enable auto-cut / remote operations (optional)

Three solution options have been developed to account for benefits, cost, and complexity.

i. Basic design

The objectives of the Basic design are as follows:

I.) Monitor the functionality of scheme;

ii.) Ensure adequate quantity of water is being supplied (55 LPCD);

iii.) Ensure prescribed water quality as per BIS-10500;

iv.) Monitor the frequency and periodicity of supply;

v.) Monitor the ground water level and ensure timely intervention (e.g., source augmentation) as and when required.

Table 2 Basic Design: Type of Sensors and Location

Sensor	Source	Service reservoir	Distribution	Connections
Bulk Flow Meter (with RTU)		1 (At outlet of SR)		
Chlorine sensor		1 (Submerged probe in SR)		
Ground water level sensor	1 (For ground water-based schemes)			

ii. Intermediate design

The objectives of the Intermediate design are as follows:

I.) Monitor the functionality of scheme;

ii.) Ensure adequate quantity of water is being supplied (55 LPCD);

iii.) Monitor the frequency and periodicity of supply;

iv.) Ensure that basic water treatment (chlorination) is being done regularly;

v.) Enable effective management of the entire scheme by VWSC/ Paani Samiti/ WUG/MVWSS management;

vi.) Ensure equitable distribution of water across habitations/ clusters including backward habitations/ clusters;

vii.) Monitor the ground water level and ensure timely intervention (e.g., source augmentation) as and when required;

viii.) Enable pump automation thereby reducing repair/ replacement cost and minimizing water wastage;

ix.) Reduce Non-Revenue Water (leakage/ unauthorized connections) from SR to distribution DMA inlets (entry point of a cluster);

x.) Ensure adequate pressure of water throughout the water supply network.

Table 3 Intermediate Design: Type of Sensors and Location

Sensor	Source	Service reservoir	Distribution	Connections
Bulk Flow Meter (with RTU)		1 (At outlet of SR)	N (At entry of each cluster/ DMA/ habitation)	
Chlorine sensor		1 (Submerged probe in SR)		
Ground water level sensor	1 (For ground water-based schemes)			
Pressure sensor (with RTU)				1 (At tail-end furthest point in network or low-pressure area
Pump controller	1 (Pump cabin – for pumping based schemes)			
Gateway (edge device)		1 (At SR/ pump cabin room)		
Display unit for village level Dashboard		1 (At SR/ pump cabin room)		

iii. Advanced design

The objectives of the Advanced design are as follows:

I.) Monitor the functionality of scheme;

ii.) Ensure adequate quantity of water is being supplied (55 LPCD);

iii.) Monitor the frequency and periodicity of supply;

iv.) Ensure that basic water treatment (chlorination) is being done regularly;

v.) Enable effective management of the entire scheme by VWSC/ Paani Samiti/ WUG;

vi.) Ensure equitable distribution of water across habitations including backward habitations;

vii.) Monitor the ground water level and ensure timely intervention (e.g., source augmentation) as and when required;

viii.) Enable pump automation thereby reducing repair/ replacement cost and minimizing water wastage;

ix.) Minimize Non-Revenue Water (leakage/ unauthorized connections) throughout the network;

x.) Ensure adequate pressure of water in every habitation/ cluster including backward habitations/ clusters;

xi.) Monitor household level consumption;

Table 4 Advanced Design: Type of Sensors and Location

Sensor	Source	Service reservoir	Distribution	Connections
Bulk Flow Meter (with RTU)		2 (1 At inlet of SR i.e., outlet of pump and 1 at outlet of SR)	N (At entry of each cluster/ DMA/ habitation)	
Consumer Flow Meter (with RTU)				N (At every household)
Chlorine sensor		1 (Submerged probe in SR)		
Ground water level sensor	1 (For ground water-based schemes)			
Pressure sensor (with RTU)				1 (At tail-end of every cluster/ DMA/ habitation)
Pump controller	1 (Pump cabin – for pumping based schemes)			
Gateway (edge device)		1 (At SR/ pump cabin room)		
Display unit for village level Dashboard		1 (At SR / pump cabin room)		

iv. Other non-sensor data sources

In addition to above sensor-based data, across all three solution options above (Basic, Intermediate, Advanced), the following data will be integrated from web/mobile applications (e.g., IMIS, WQMIS)

I.) Water quality data not captured via sensors – Should be collected periodically on-field using FTKs or lab tests and this data should be fed into WQMIS/IMIS/mobile app; this will be integrated with the centre IoT platform at backend (using APIs);

ii.) Grievances – Any existing grievance redressal mechanisms at State level should be integrated with the IoT platform; and made available to central/national cloud through APIs;

iii.) O&M data – O&M tariff collection and expenses should be captured (via mobile or web application) and integrated with IoT platform; and made available for central/national cloud through APIs.

v. Comparison of solution options

Table 5 Comparison of Basic, Intermediate, and Advanced Design Options

Solution Options	Basic	Intermediate	Advanced
Scope	I.) Measure overall water supply to village (quantity and quality);	I.) Measure overall water supply to village (quantity and quality); ii.) Measure supply to all habitations and/or to each DMA for large villages (quantity); iii.) Enable automation & predictive maintenance.	I.) Measure overall supply to village (quantity and quality); ii.) Measure supply to all habitations and/or to each DMA for large villages (quantity); iii.) Enable automation & predictive maintenance; iv.) Measure consumption by all households.
Purpose	I.) Determine if scheme is functional; ii.) Ensure adequate quantity and periodicity of supply; iii.) Ensure prescribed quality; iv.) Ensure source sustainability;	I.) Determine if scheme is functional; ii.) Ensure adequate water quantity and periodicity of supply; iii.) Ensure prescribed quality; iv.) Ensure source sustainability; v.) Ensure equitable supply to all habitations; vi.) Reduce O&M costs;	I.) Determine if scheme is functional; ii.) Ensure adequate water quantity and periodicity of supply; iii.) Ensure prescribed quality; iv.) Ensure source sustainability; v.) Ensure equitable supply to all habitations; vi.) Reduce NRW vii.) Reduce O&M costs; viii.) Ensure acceptable service delivery to all households.

Solution Options	Basic	Intermediate	Advanced
Sensors	I.) **Source and Intake:** Ground Water level sensor*; ii.) **Service reservoir:** Bulk Flow Meter, Chlorine sensor.	I.) **Source and Intake:** Ground Water level sensor*, Bulk Flow Meter, Pump actuator*, Power meter*; ii.) **Service reservoir:** Level sensor, Quality sensors (Residual Chlorine, pH*, Turbidity*), Pump Actuator*, Power Meter*, Bulk Flow Meter at outlet; iii.) **District Metering Areas:** Bulk Flow Meters, Pressure sensors.	I.) **Source and Intake:** Ground Water level sensor*, Bulk Flow Meter, Pump actuator*, Power meter*; ii.) **Service reservoir:** Level sensor, Quality sensors (Residual Chlorine, pH*, Turbidity*), Pump Actuator*, Power Meter*, Bulk Flow Meter at outlet; iii.) **District Metering Areas:** Bulk Flow Meters, Pressure sensors; iv.) **Households:** Water meters/flow sensors.
KPIs Possible	I.) LPCD (aggregate for village); ii.) Periodicity (hours of supply per day); iii.) Chlorination conformance days; iv.) Ground water source level and avg. daily withdrawal.	I.) LPCD (aggregate for village, DMA, habitation level); ii.) Periodicity (hours of supply per day); iii.) Chlorination conformance days; iv.) Ground water source level and avg. daily withdrawal; v.) Pressure conformance at tail-end; vi.) Pump health (ampere, voltage, power).	I.) LPCD (aggregate for village, DMA, habitation level, household level); ii.) Periodicity (hours of supply per day); iii.) Chlorination conformance days; iv.) Ground water source level and avg. daily withdrawal; v.) Pressure conformance at tail-end; vi.) Pump health (ampere, voltage, power); vii.) Non-revenue water (NRW) loss.
Benefits	I.) Higher success rate of schemes (near real-time visibility); ii.) Reduced primary healthcare costs for community (lower incidents of water borne / contamination related diseases);	I.) Higher success rate of schemes (near real-time visibility); ii.) Reduced primary healthcare costs for community (lower incidents of water borne / contamination related diseases); iii.) Reduced energy consumption (pump auto on/off); iv.) Improved operator staff utilization;	I.) Higher success rate of schemes (near real-time visibility); ii.) Reduced primary healthcare costs for community (lower incidents of water borne / contamination related diseases); iii.) Reduced energy consumption (pump auto on/off); iv.) Improved operator staff utilization;

Solution Options	Basic	Intermediate	Advanced
		v.) Reduced maintenance and repair costs (prevent dry runs, predictive maintenance); vi.) Lower NRW (leakage detection, reservoir overflow).	v.) Reduced maintenance and repair costs (prevent dry runs, predictive maintenance); vi.) Lower NRW (leakage detection, reservoir overflow, thefts); vii.) Improved end-user behaviour (lesser wastage through metered connections); viii.) Improved service levels (grievance redressal).

**If applicable depending on local conditions (gravity / pumping based scheme, water contamination etc.)*

Table 6 Design Options Comparison – by type of devices used

S. No.	Device type	Measurement/ Application	Basic	Intermediate	Advanced
1	**Bulk Flowmeter**	Measure quantity and periodicity of water supplied (L) to entire village and nodes to compete aggregate LPCD	✓	✓	✓
2	**Consumer Flowmeter**	Measure quantity and periodicity of water supplied (L) to household to compute household level LPCD			✓
3	**Chlorine analyzer**	Measure free chlorine in water (mg/L or PPM) to determine quality and disinfection process conformance	✓	✓	✓
4	**Pressure sensor**	Measure tail-end pressure (Bar) to ensure equitable supply and water system health		MVS / Large SVS only*	✓
5	**Ground water level sensor**	Measure depth of water from ground (Feet) to determine withdrawal rates and estimate remaining useful life (source sustainability)	✓	✓	✓
6	**Remote Terminal Units (RTU)**	Communicate digital signal to gateway/concentrator or cloud		✓	✓
7	**Gateway / Edge device**	Receive digital signal from nodes and transmit to cloud		✓	✓
8	**Energy sensor (if required)**	Measure voltage (V) and current (A) of pump to determine health and predictive maintenance		✓	✓

S. No.	Device type	Measurement/ Application	Basic	Intermediate	Advanced
9	**Pump Controller and Service reservoir level sensor (if required)**	Measure SR level (%) or (m) to enable auto-cut / remote operations (optional)		✓	✓
10	**Invertor with battery back-up (If required)**	Provide power back for intermittent supply from mains or solar panels		✓	✓
11	**Solar panels (if required)**	To provide power for remote devices where mains are not available easily			

c. Recommended solution

i. Intermediate Design

The technical/expert committee recommends States to follow the 'Intermediate' design considering both value and costs of the system

Sensor	Source	Service reservoir	Distribution	Connections
Bulk Flow Meter (with RTU)		1 (At outlet of SR)	N (At entry of each cluster / DMA / habitation)	
Consumer Flow Meter (with RTU)				
Chlorine sensor		1 (Submerged probe in SR)		
Ground water level sensor	1 (For ground water-based schemes)			
Pressure sensor (with RTU)			*Only MVS or Large SVS (> 500 pop.)	1 (At tail-end furthest point in network or low-pressure area
Pump controller	1 (Pump cabin – for pumping based schemes)			
Gateway (edge device)		1 (At SR / pump cabin room)		
Display unit for village level Dashboard		1 (At SR / pump cabin room)		

For the above design, an RF based network could be leveraged where a RF gateway / concentrator collects data from node devices (e.g., flow meters, pressure sensors, ground water level sensor) and sends data to cloud via fixed broadband or cellular network. Node devices at distant points from the service reservoir/pump cabin (particularly flowmeters at DMAs) may have to be battery powered due to unavailability of power mains connection at distant point (or due to ground level challenges in getting a new power supply connection at the location). Such battery powered devices (e.g., flowmeters) shall transmit data twice a day to improve battery life. Other devices such as chlorine sensor, pressure sensor, ground water level sensor, and RF gateway may need continuous power supply to run and hence cannot be run alone on batteries. Such devices (if in proximity to service reservoir / pump cabin) shall leverage an existing power connection (e.g., pumping based schemes) or may get a new common power connection for all these devices. In cases, where this may not be possible – solar power can be leveraged with invertor/battery backup. In rare circumstances, where power supply is not available in the water supply scheme (e.g., gravity-based schemes), getting a new power connection is not possible, and there is low incidence of sunlight, the scheme may choose a 'Basic design' with a single battery powered flowmeter at the outlet of service reservoir.

ii. Key solution requirements:

I.) The solution should send data from the village via device directly or via gateway to both cloud (central server at State level) as well as the local operator (at Gram Panchayat level) through local area network to ensure redundancy (in case of connectivity failure from gateway to cloud); the solution should have provisions for fraud detection (e.g., identify if real device is sending data from the actual installed location);

ii.) The solution should be able to store data locally on gateway for a minimum of 6 months to prevent any data loss in case of failure of connectivity via internet to cloud (through cellular network or fixed broadband);

iii.) Device should store data for 30 days, in case of connectivity issues to gateway or cloud;

iv.) The solution should support bi-directional data flow (wherever possible), with over-the-air firmware updates (changing frequency of data transmission, remote calibration, security patches, fixing bugs etc.) and enable remote control;

v.) The solution should ensure high performance, availability, latency, compatibility, and security. It should also comply with data governance laws as per State/Central government on data privacy and ensure data-backup, disaster recovery, and archival;

vi.) The solution should include a display panel (20 inch or more) at the Gram Panchayat office or near the ESR/pump cabin (in case of individual schemes at a habitation level) for the community to monitor relevant data (LPCD, Quality, Ground Water Level, Pressure, Grievances, Financial Health).

iii. Data capture methodology

For an effective measurement and monitoring system, while most data will come from sensors (e.g., quantity, free chlorine, pressure, water level), some of the other critical data that needs to be captured for holistic monitoring include – grievances, O&M tariff and expenses, quality test reports (for quality attributes other than free chlorine, pH, turbidity). Such data may be captured via mobile app (upcoming JJM mobile app) and combined with sensor data to provide engineers and officials of the complete health of the rural water supply scheme. Below table lists the data to be collected, its granularity and collection methodology (sensor or via IMIS / WQMIS / JJM mobile app):

S. No.	Data	Granularity	Data Collection (Sensor or via mobile app)
1	**Quantity**	Village (SR/pump) + Nodes (DMA)	Sensor: Bulk flow meter at outlet of SR and at branches/nodes/DMAs
2	**Periodicity**	Village (ESR/pump) + Nodes (DMA)	Sensor: Bulk flow meter at outlet of SR and at branches/nodes/DMAs
3	**Quality**	Village (ESR) – RWS - before village entry & treatment outlet	Sensor: Chlorine sensor Manual: Other water quality attributes as per periodic water quality testing to be entered manually in JJM mobile app
4	**Grievances**	Household (GIS)	Manual via JJM mobile app (geo-tag / GIS)
5	**Source**	Village	Sensor: DWLR or ground water level sensor (piezo / hydrostatic based)

S. No.	Data	Granularity	Data Collection (Sensor or via mobile app)
6	**Asset condition**	Village	Sensor: Pump controller that captures current and voltage, and enables auto-cutoff using SR level sensor (float switch)
7	**Financial health**	Village	Manual via JJM mobile app (tariff collection and O&M expenses – staff, chemical, repair, energy etc.)
8	**System health**	Village	Sensor(s) up-time, last data received time, power supply, connection (signal strength) etc.

iv. Variations in design

As there are several diverse regions in the country, there are numerous variations that may exist in rural water supply scheme based on source type, gravity/pumping based schemes, type of water treatment etc. The PHED/RWS and VWSC/ Paani Samiti can decide the type of measurement and monitoring system (Basic, Intermediate, Advanced) suited for them basis size of village, complexity of distribution network, capacity of local public utility like VWSC.

Below table illustrates the proposed variation in 'Intermediate' design for different water supply scheme types in India:

Water Supply Scheme Variation	Sensors and Location
SVS - Ground water gravity based (spring) – with basic (chlorination) or advanced treatment	**Service reservoir:** I.) 1 Bulk flow meter at outlet of SR ii.) 1 Chlorine sensor submerged in SR **Distribution:** I.) N Bulk flow meters at entry of each cluster/ DMA/ habitation
SVS - Ground water pump based (spring/ shallow well/ tube well/ bore well) – with basic (chlorination) or advanced treatment	**Source:** I.) 1 Ground water level sensor in shallow/ tube/ bore well ii.) 1 pump controller (energy sensor and auto cut-off) in the pump cabin **Service reservoir:** I.) 1 Bulk flow meter at outlet of SR ii.) 1 Level sensor in SR iii.) 1 Chlorine sensor submerged in SR **Distribution:** I.) N Bulk flow meters at entry of each cluster/DMA / habitation
SVS - Surface water gravity based for raw water and pump based for treated water – with basic (chlorination) or advanced treatment	**Service reservoir:** I.) 1 pump controller (energy sensor and auto cut-off) in the pump cabin ii.) 1 Bulk flow meter at outlet of SR iii.) 1 Chlorine sensor submerged in SR **Distribution:** I.) N Bulk flow meters at entry of each cluster/ DMA/ habitation

Water Supply Scheme Variation	Sensors and Location
SVS - Surface water based on 2 pumps (1 for source to WTP and 1 for WTP to SR) – with basic (chlorination) or advanced treatment	**Source:** I.) 1 Pump controller (energy sensor and auto cut-off) in pump cabin ii.) 1 Bulk flow meter at outlet of pump **WTP** I.) 1 Pump controller (energy sensor and auto cut-off) in pump cabin **Service reservoir:** I.) 1 Bulk flow meter at outlet of SR ii.) 1 Level sensor at SR iii.) 1 Chlorine sensor submerged in SR **Distribution:** I.) N Bulk flow meters at entry of each cluster/ DMA/ habitation
MVS – Gravity based for source and pump based for transmission to other villages/ habitations – with basic (chlorination) or advanced treatment	**At Source of Scheme** I.) 1 Bulk flow meter at outlet of scheme's Source Pumps **Scheme's Master Balancing Reservoir (MBR):** I.) 1 Bulk flow meter at inlet of scheme's MBR ii.) 1 Bulk flow meter at outlet of scheme's main SR/WTP iii.) 1 comprehensive quality sensor or multiple individual quality sensors (for chlorine, pH, and Turbidity) submerged in scheme's main SR **Transmission of water from MBR to Village Service Reservoirs (SR for each village/ habitation):** I.) 1 pump controllers (energy sensor and auto cut-off) 1 at each pump cabin ii.) 1 Bulk flow meters at inlet of each village SR **Service Reservoirs (for each village/ habitation):** I.) 1 Chlorine sensor submerged in each village SR ii.) 1 Level sensor in each village SR iii.) 1 Bulk flow meters at outlet of each village SR **Distribution:** I.) N Bulk flow meters and N pressure sensors at entry of each cluster/ DMA/ habitation supplied by each SR **Connections:** I.) 1 Pressure sensor at farthest point/ low-pressure area (1 for each SR)
MVS – Pump based for source as well as for transmission of water to other villages/ habitations – with basic (chlorination) or advanced treatment	**Source:** I.) 1 Ground water level sensor in tube/ bore well OR one Water Level Sensor for Surface water source ii.) 1 pump controller (energy sensor and auto cut-off) at each pump cabin **WTP** I.) 1 Pump controller (energy sensor and auto cut-off) in pump cabin ii.) 1 Level sensor at WTP sump **Scheme's Master Balancing Reservoir:** I.) 1 Bulk flow meter at inlet of scheme's MBR ii.) 1 Bulk flow meter at outlet of scheme's main SR iii.) 1 comprehensive quality sensor or multiple individual quality sensors (for chlorine, pH, and Turbidity) submerged in scheme's main SR iv.) 1 water level sensor in SR

Water Supply Scheme Variation	Sensors and Location
	Transmission of water from MBR to Village Service Reservoirs (SR for each village/ habitation): I.) 1 pump controllers (energy sensor and auto cut-off) 1 at each pump cabin ii.) 1 Bulk flow meters at inlet of each village SR **Service Reservoirs (for each village/ habitation):** I.) 1 Chlorine sensor submerged in each village SR ii.) 1 Level sensor in each village SR iii.) 1 Bulk flow meters at outlet of each village SR **Distribution:** I.) N Bulk flow meters and N pressure sensors at entry of each cluster/ DMA/ habitation supplied by each SR **Connections:** I.) 1 Pressure sensor at furthest point/ low-pressure area (1 for each sub-SR)

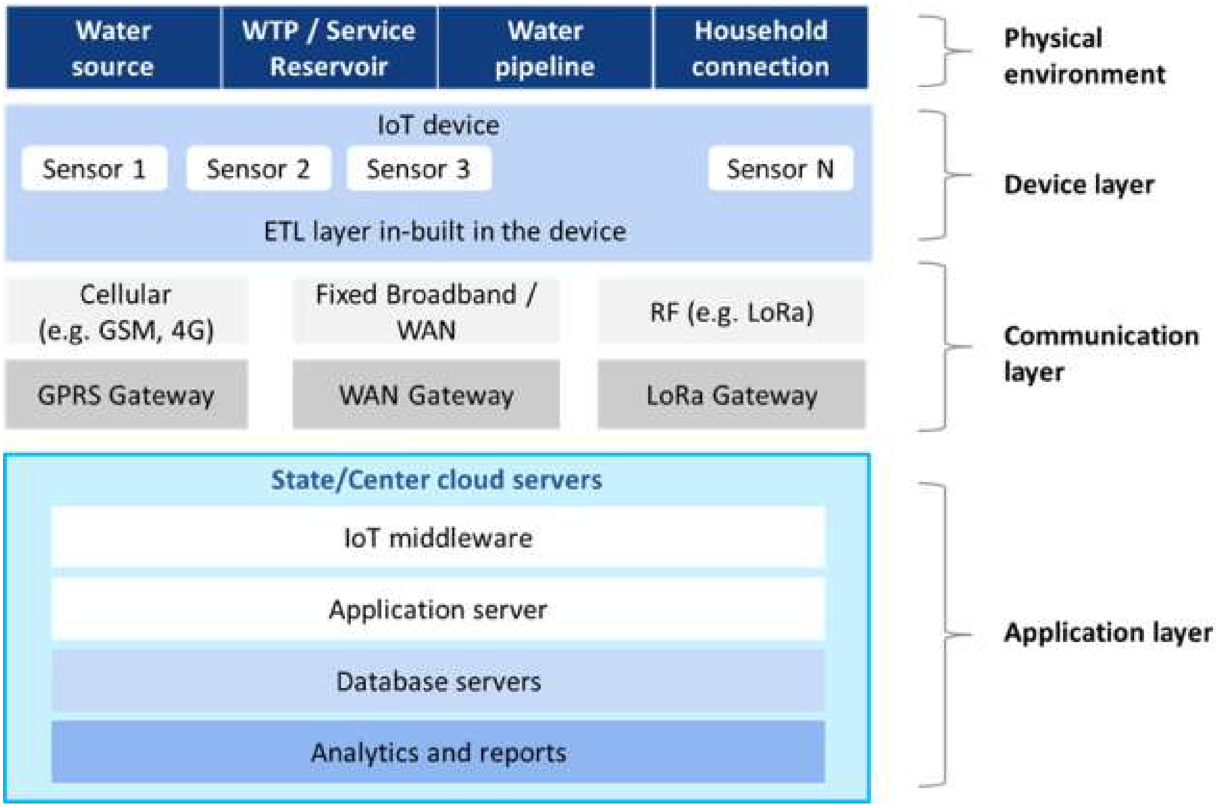
Detailed schematics of variations are in Annexure 9(a).

5. Overall architecture and technical specifications

a. High level solution architecture

IoT sensors will be fitted on the water supply infrastructure at appropriate points discussed in Chapter 7 and will be used to measure and monitor both qualitative and quantitative parameters of water supply distribution systems. A three-tier architecture diagram has been proposed with Device Layer, Communication Layer and Application layer as depicted below:

Figure 6 High level solution diagram



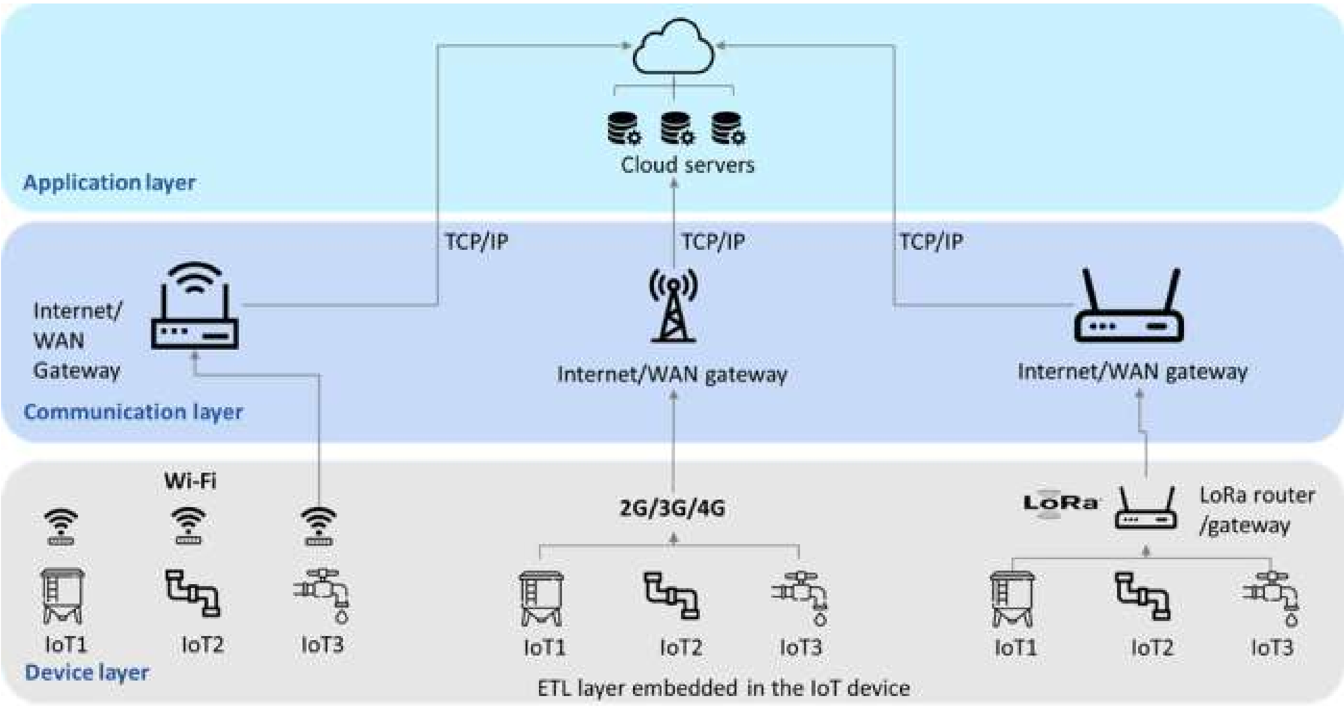
Device, communication, and application standards are detailed in sub-sequent sub-chapters/sections.

b. Networking technologies and information flow

i. Networking and communication standards

The solution design should adhere to open standards and be technology neutral. It can use a variety of networking technologies as per local conditions and availability of services, such as fixed broadband / Wi-Fi, local area RF (e.g., LoRa), and/or cellular technologies (2G/3G/4G/5G & NB-IoT). The communications to cloud can be done via several IoT compatible and specialized protocols (e.g., MQTT, AMQP, HTTPs, CoAP).

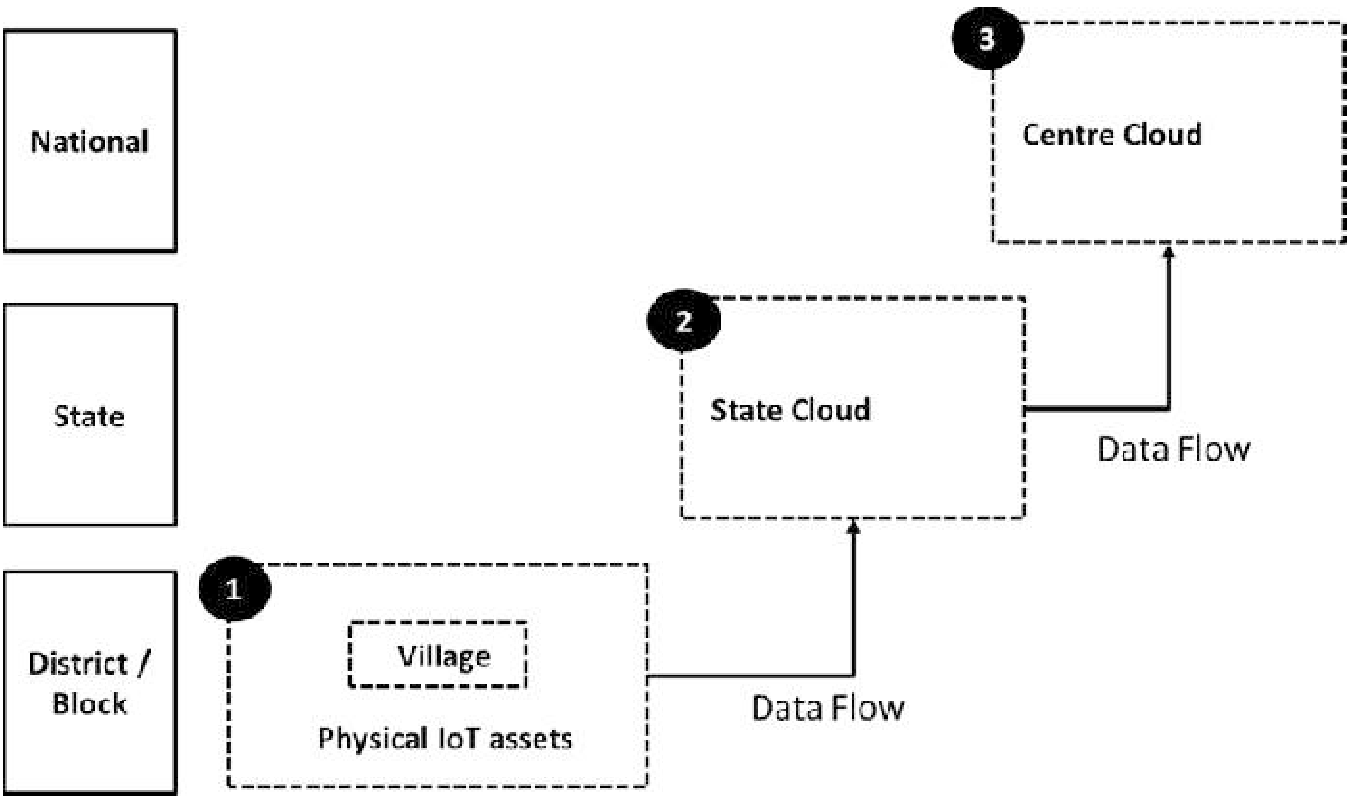
Figure 7 Networking technologies for data transmission



ii. **Information flow: Village to State Cloud to Centre Cloud**

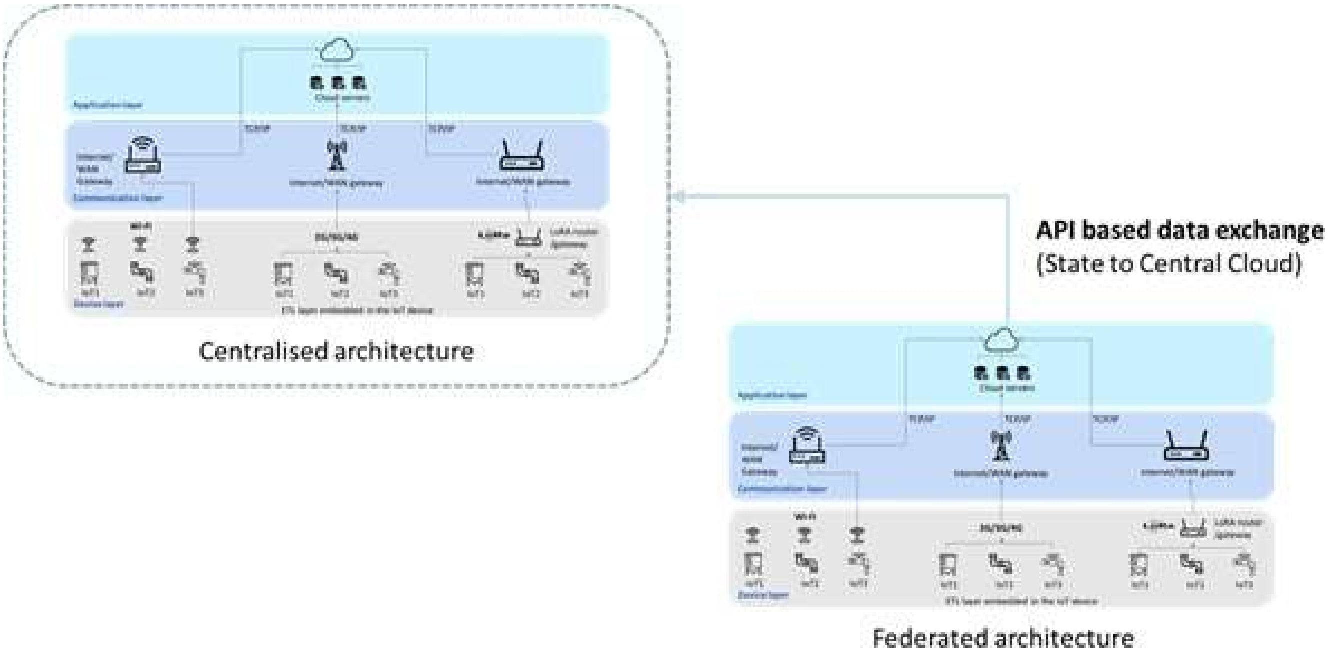
The telemetry data from devices placed in villages should directly be sent to State or Central Cloud. Data from State Cloud should be pushed to Centre Cloud.

Figure 8 Information Flow – Village to State to Centre



A hybrid model is preferred for data transmission from State Clouds to Central Cloud. This enables flexibility to ingest data into the Central Cloud directly from the IoT Devices (sensors) or indirectly through the States who have developed such system to aggregate IoT data. In cases IoT data are first collected at the State Cloud / Data Centre, then the aggregated data shall be pushed to the Central Cloud using Open APIs.

Figure 9 Hybrid model for State to Centre Data Exchange



c. Device layer and specifications

At the lowest layer above the physical infrastructure are the IoT sensors / devices. These sensors are the real-world objects and entities subject to monitoring, as well as having digital representations and identities. The sensors are instrumented with embedded technologies that provide the capability to monitor the water parameters in the physical environment – water storage, pipeline etc.

The data integration mechanism in an IoT based system, is one of the major challenges, arising out of the variety of IoT Device vendors and their varying standards of data exchange. This problem can be mitigated by deploying an ETL layer in the IoT device itself. All OEMs who would provide IoT devices will have to build the ETL layer in the sensor firmware, to translate/ convert the sensor data into meaningful data, as per the standards prescribed by JJM.

Table 7 Devices for smart rural water management

S. No.	Device type	High level variants / requirements
1	**Bulk Flowmeter**	Mechanical/ Ultrasonic/ Electromagnetic
2	**Consumer Flowmeter**	Mechanical / Ultrasonic
3	**Chlorine analyzer**	Probe type, Copper/Platinum/Gold electrode
4	**Pressure sensor**	Pressure transmitter (consumer distribution)
5	**Ground water level sensor**	Hydrostatic pressure / piezo
6	**Remote Terminal Units (RTU) / Communication module**	Built-in or separately attached to sensing devices - variations include RF (e.g., LoRa), Cellular (2G, 3G, 4G, 5G, NB-IoT) Wi-Fi based communication units

S. No.	Device type	High level variants / requirements
7	**Gateway / Edge device**	RF (e.g., LoRa), Cellular (2G, 3G, 4G, 5G, NB-IoT) Wi-Fi based communication units
8	**Energy sensor (if required)**	Energy sensor
9	**Pump Controller and Service reservoir level sensor (if required)**	Float type / Capacitance / Ultrasonic
10	**Invertor with battery back-up (If required)**	Remain on active mode without requiring manual intervention / restart
11	**Solar panels (if required)**	NA

The choice of specific technology/measurement principle used in device may depend on local conditions. For example, a mechanical flow meter may be used in schemes where water is clear, with minimal sediments, and where airflow within pipe is marginal. A float type level sensor may be used in low-capacity tanks and a copper electrode-based chlorine sensor can be utilized to keep costs low. In areas without existing power mains connection, a solar-panel setup (with battery backup) may be used for powering gateway and other sensors. Further, sensor devices may have an in-built communication module (RTU) or a separate RTU that can be attached to these devices to ensure data transmission to cloud.

It is critical to ensure proper protection of these IoT assets. The IoT devices shall be inside a ruggedized encasing (IP 65/66/67/68) for withstanding rain/ snow/ sand/ heat/ sound vibrations/ electromagnetic waves and industrial pollution. Further, devices such as chlorine sensor, level sensor, gateway should be placed at/inside existing water scheme infrastructure (e.g., Service Reservoir, Pump Cabin, Borewell/Tube-well housing) for safeguarding them against tampering/theft/vandalism. Flowmeters, should be placed in a protective casing (if pipeline above ground level, like in some hilly areas) or within a covered chamber (if pipe is underground).

These devices should be calibrated during supply or installation; and should have periodic/predictive maintenance schedules by the IoT solution vendor during O&M period. PHED/RWS/MVWSS/VWSC will play a key role in timely inspection of such devices to ensure data accuracy and upkeep.

The data from battery powered sensors shall be transmitted by the device to the cloud periodically i.e., two times per day to improve battery life. The device should be capable of storing data for minimum 30 days (in case of loss of connectivity).

Notes:

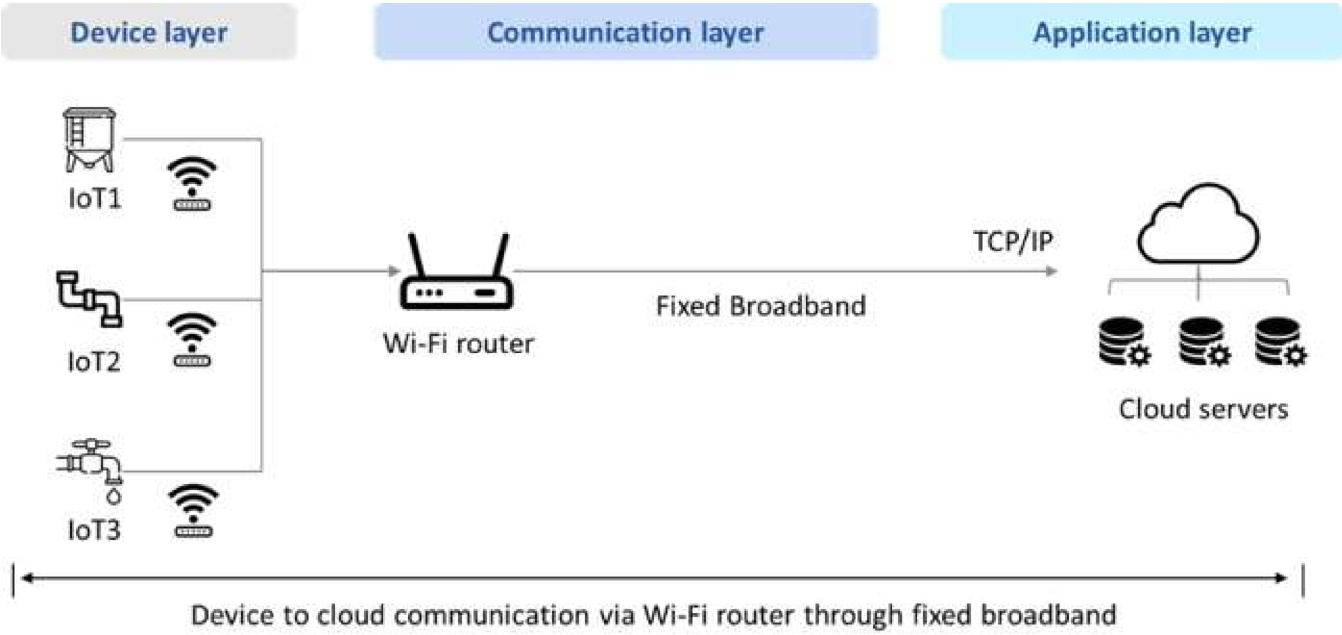
- **The implementation agencies may follow global standards in case Indian standards are not defined (such as CE/FCC for IoT devices with communication modules)**
- **Please refer Annexure 9(b) on reference hardware specifications.**

d. Communication and networking technologies

This layer consists of the medium of two-way communication between the IoT devices and the Cloud. Apart from the conventional media such as the WAN (wireless or wired), the following technologies can be leveraged for communications to cloud: RF (e.g., LoRa/LoRaWAN, Zigbee, Sigfox), Cellular (GSM/GPRS, 2G/3G/4G, NB-IoT) depending on local conditions and network / service provider availability.

In villages, where Wi-Fi is already available (e.g., BharatNet, private broadband), IoT devices can directly connect to a Wi-Fi enabled gateway/router that communicates to cloud.

Figure 10 Example 1: Wi-Fi / Fixed Broadband based communication

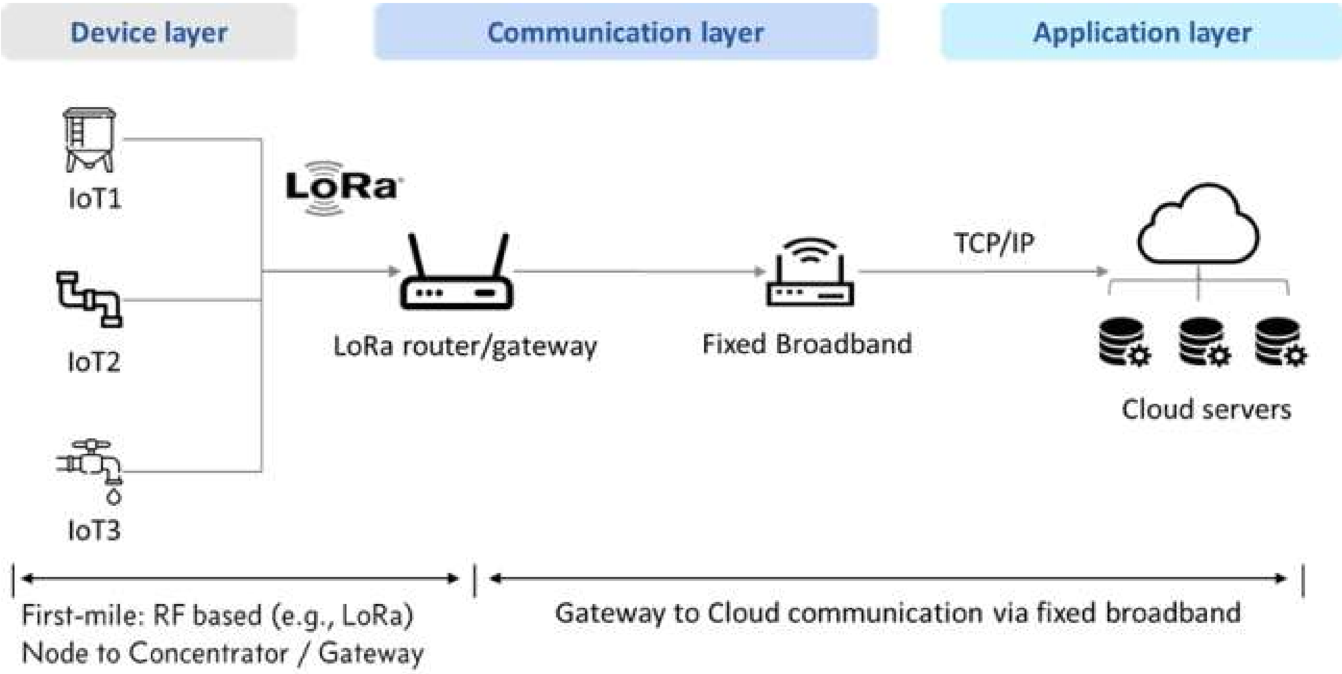


Wi-Fi enabled IoT devices may not be suited for battery-based operations due to high power consumption (especially at nodes / tail-ends) where getting power supply may not be possible. For such scenarios, RF-based first-mile network can be leveraged for low-power long range communications such as LoRa / LoRaWAN (or any other recognized technology such as Zigbee, Sigfox etc.). RF-LoRa is recommended (complying with DOT's guidelines on private RF network in the ISM band of 865-867 MHz or via licensed LoRaWAN operators). However, other recognized networking technologies may also be used (e.g., RF Mesh, Wi-Fi, Sigfox, Zigbee etc.). LoRa is preferred as it consumes low power, has long range, can be used for battery operated devices (especially in rural areas where getting power mains supply may be a challenge due to additional cost, right of way, approvals, etc.)

The LoRaWAN specification is a Low Power, Wide Area (LPWA) networking protocol designed to wirelessly connect battery operated 'things' to the internet in regional, national or global networks, and targets key Internet of Things (IoT) requirements such as bi-directional communication, end-to-end security, mobility, and localization services.[2] LoRa is an upcoming technology which is well-suited for the rural locations and can provide a scalable model. It can be effectively used for continuous data streaming and bidirectional data transmission. The power consumption is extremely low (nano Amperes). However, LoRa-based gateway devices may have a practical range of 200-800m without line of sight and may need additional boosters to enhance range.

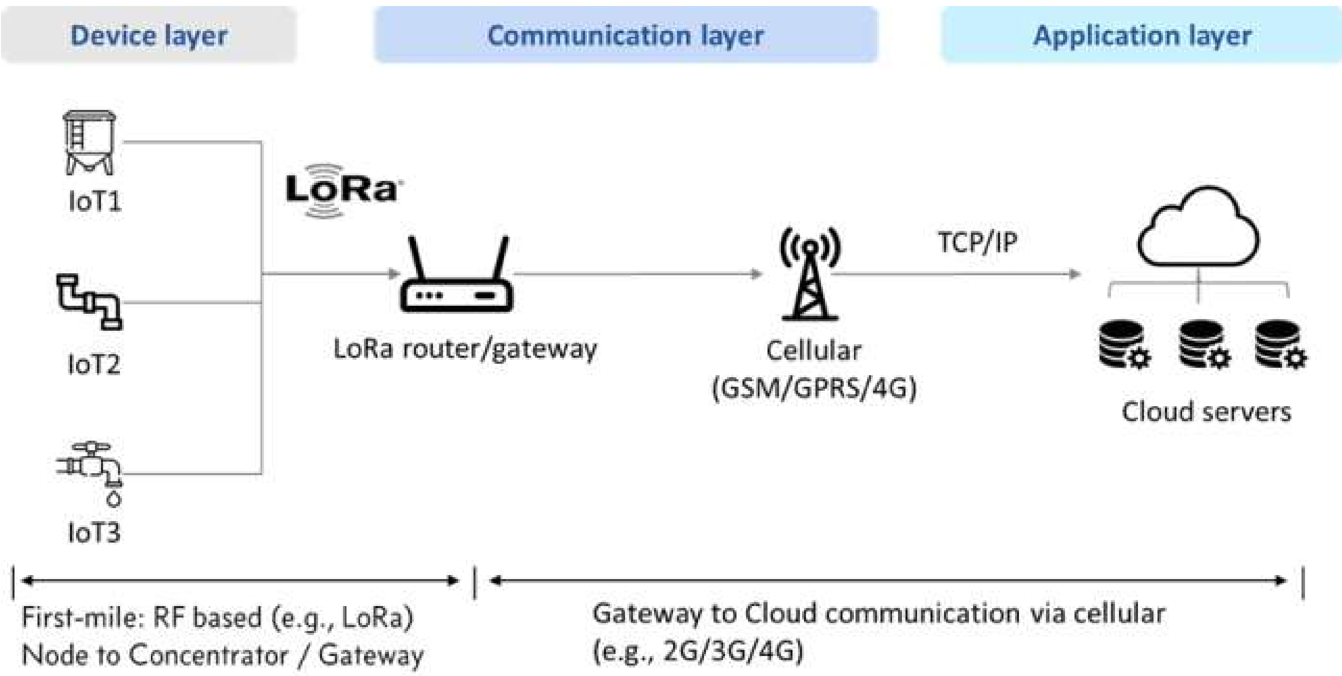
[2] https://lora-alliance.org/about-lorawan#:~:text=The%20LoRaWAN%C2%AE%20specification%20is,to%2Dend%20security%2C%20mobility%20and

Figure 11 Example 2: RF + Fixed Broadband based communication



For majority of the rural villages in India which currently do not have Wi-Fi, cellular technology should be leveraged for communication to cloud. In case of an 'Intermediate' or 'Advanced' level of deployment, where there are more than 4-5 devices, it is recommended to leverage RF (e.g., LoRa) for first-mile communications to a gateway and cellular (2G/3G/4G) for gateway to cloud communications.

Figure 12 Example 3: RF + Cellular based communication

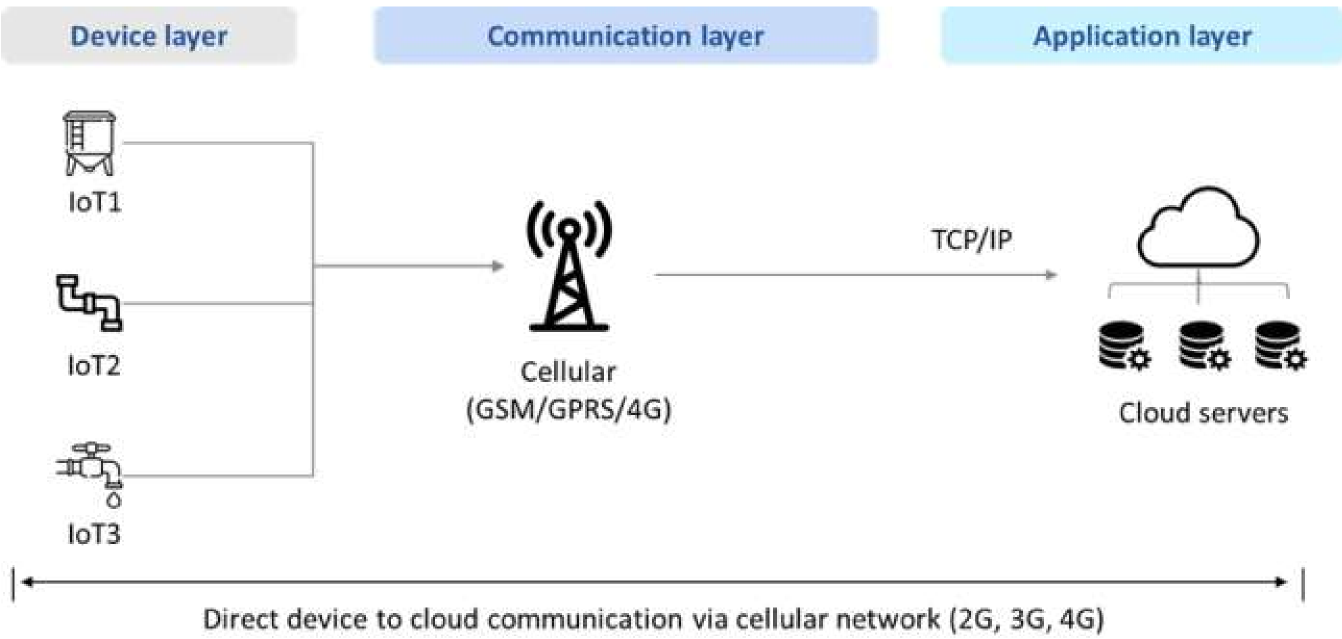


The IoT devices shall communicate to a LoRa gateway which may be installed in a government building like a local police station, post office, BDO office, panchayat office, pump cabin, ESR room etc. This gateway may cover a radius of almost 7-8 kms at clear line of sight and practical range maybe between 200-800m depending on the local topology. Additional boosters can be added to extend range. The gateway will have an internet connectivity via Ethernet (Fixed broadband) or via cellular (2G/3G/4G-based SIM) or connectivity depending on the availability. It will compile data packets from the IoT devices within its jurisdiction, create packets and transmit it to the cloud. The gateway device should have a minimum storage capacity of 6 months.

Cellular module in the gateway should support both M2M and 4G sim cards (backward compatible even for 2G sims) to ensure future proofing. Further, the vendors should consider a technology that enables 2-way communication and enables them to take remote control of gateway to fix bugs and make over-the-air firmware updates, change frequency of data transmission, calibration etc.

In scenarios, where only a limited number of IoT devices are deployed (e.g., Basic level implementation with a single flow meter, or less than 4-5 devices), a direct to cloud cellular communication can be used. Such IoT devices should have a cellular (GSM/4G) compatible communication module (RTU – remote terminal unit). This should ideally be 4G-based with backward compatibility (with even 2G/3G sims) and extensible to upcoming technologies such as NB-IoT / 5G.

Figure 13 Example 4: Cellular only (2G/3G/4G) based direct device to cloud communications



For large number of devices (e.g., Advanced level with consumer level metering) a cellular based implementation will incur high operating expenses (monthly data charges for each sim card). Further, GSM based modules consume high power and may reduce battery life. Hence, RF-based network for first mile is recommended for large number of devices in the same village (e.g., Intermediate, Advanced).

The GSM / RF power can be switched off when data is not being transmitted, as otherwise there would be higher power drainage, and this could lead to unwanted recurring expenses. The design of the IoT device should be such that by default the power remains OFF. The IC/Circuitry can be so designed by using a relay circuit to establish connectivity to the GSM module and CPU only when data needs to be transmitted. Anti-spoofing measures should be adopted for secure communication.

The implementation agency should have an option to choose among the best suited networking technologies dependent on local conditions (e.g., topology, existing infrastructure, presence of service providers, costs) and adopt new technologies and architectures (when available).

e. Protocols and security standards

Implementations should ensure high security standards across device, network, server, and applications:

i. Communication protocols

Implementations should follow one of the below communication protocols with adequate security: Message Queue Telemetry Transport (MQTT), Hypertext Transfer Protocol (HTTPs), Advanced Message Queuing Protocol (AMQP), or Constrained Application Protocol (CoAP).

ii. Network security

It is necessary to ensure that the traffic among IOT devices and cloud services are encrypted and secured against tampering of messages. To ensure this device connectors and device agents use standard transport layer security (TLS) or Datagram transport layer security (DTLS) protocols for network security. TLS is used when transport is TCP/IP and DTLS when transport is UDP/IP. TLS and DTLS are based on PUBLIC KEY CRYPTOGRAPHY to encrypt all communication between devices and servers.

iii. Device authentication

Device management should be based on LWM2M protocol which in turn uses DTLS for network security. Device connector libraries use SSL/TLS connections to make calls to services such as 'Sensor Services'.

iv. Server Authentication

It is responsibility of every client device to ensure it communicates to only trusted servers. This is ensured in the TLS/DTLS sessions when the server presents its certificates to the client devices. The clients verify server certificates by authenticating them against root certificates stored in the client devices.

v. Data Storage security on Platform

Device agents and connectors makes use of trusted platform for secure storage of device private keys, secrets and root certificates used for authenticating other certificates.

vi. API Gateway Security

All interactions to cloud services are via RESTful API calls. API authentication is done using a combination of API keys and authorization protocols. API keys are a set of public identities and secrets that are issued to IOT platform.

Data should be compliant to DLMS/ OMS (Open metering system). DLMS Stands for Device Language Message Specification and the syntax of the language is specified by the DLMS services. DLMS/COSEM uses a client-server paradigm where the end devices, typically meters are the servers, and the Head End Systems or concentrators are the clients.

Note: The solution architecture should conform to open standards and interoperability.

f. Data format

The below reference data format can be used for device to cloud communications:

1. Flow meter -

I.) Data to be captured: Flow meter ID, Quantity value (L), Flow rate (LPM), Battery level [if applicable] (0-100), Time Stamp (Date – Time), Error code (e.g., 00 – no error, 01 – leakage, 02 – tamper, 03 – other error, 11 – active status at end of day).

ii.) Data collection and transmission frequency

a. Battery powered

- Hourly data collection (or on consumption) and ability to store data in device for 30 days if there is no connectivity;
- Twice a day data transmission to gateway/cloud, ability to change data collection frequency on-site or over-the-air.

b. Power mains or solar powered (with battery backup)

- 15-min data collection (or on consumption) and transmission to gateway/ cloud;

- Ability to change data collection frequency on-site or over-the-air.

Note: Flow rate (LPM) data collection may only be possible in ultrasonic or electromagnetic flowmeters. In case of mechanical flowmeters, the flowrate value can be null

2. Ground water level sensor

I.) Data to be captured: Ground water level sensor ID, Ground Water Level (m), Battery level [if applicable] (0-100), Time Stamp, Error code (e.g., 00 – no error, 01 – tamper, 02 – other error, 11 – active status at end of day).

ii.) Data collection and transmission frequency

a. Battery powered

- Once a day data collection and ability to store data in device for 30 days if there is no connectivity;
- Once a day data transmission to gateway/cloud, ability to change data collection frequency on-site or over-the-air.

b. Power mains or solar powered (with battery backup)

- Hourly data collection and transmission to gateway/cloud;
- Ability to change data collection frequency on-site or over-the-air.

3. Service reservoir water level sensor

i. Data to be captured: Level sensor ID, Service reservoir Water Level Percentage (%), Service Reservoir Water Level Meters (m), Battery level [if applicable] (0-100), Time Stamp, Error code (e.g., 00 – no error, 01 – tamper, 02 – other error, 11 – active status at end of day)

ii. Data collection and transmission frequency

a. Battery powered

- Hourly data collection, ability to store data in device for 30 days if there is no connectivity;
- Once a day data transmission to gateway/cloud, ability to change data collection frequency on-site or over-the-air;

b. Power mains or solar powered (with battery backup)

- 15-min data collection and transmission to gateway/cloud;
- Ability to change data collection frequency on-site or over-the-air.

Note: In case of mechanical float devices, storage level to be measure in % of depth of tank (e.g., 30%, 60%, 90%), in case of ultrasonic level sensors – storage level to be measure in meters. Depending on the choice of sensor device – the other value may remain null.

4. Chlorine sensors

i. Data to be captured: Chlorine sensor ID, Chlorine value (mg/L), Time Stamp, Error code (e.g., 00 – no error, 01 – tamper, 02 – other error)

ii. Data collection and transmission frequency

a. Power mains or solar powered (with battery backup)

- 15 min data collection and transmission to gateway/cloud;
- Ability to change data collection frequency on-site or over-the-air;

Note: Similar logic for pH/Turbidity sensors

5. **Pressure transmitter**

   i. Data to be captured: Pressure sensor ID, Pressure value, Time Stamp, Error code (e.g., 00 – no error, 01 – tamper, 02 – other error).

   ii. Data collection and transmission frequency

      a. Power mains or solar powered (with battery backup)

         - 5 min data collection and transmission to gateway/cloud;
         - Ability to change data collection frequency on-site or over-the-air.

6. **Pump controller**

   i. Data to be captured: Voltage (V), Ampere (A), Power consumed (KWH), Power factor (Cos ɸ) Pump on/off status (1, 0), Vibration [optional] in hertz, Time Stamp, Error code (e.g., 00 – no error, 01 – tamper, 02 – other error);

   ii. Data collection and transmission frequency

      a. Power mains or solar powered (with battery backup)

         - Data collection and transmission to gateway/cloud every hour or on change event of pump on /off;
         - Ability to change data collection frequency on-site or over-the-air;
         - Ability to support auto-cutoff (optional).

Data Format: Payload Example –

{"gid": "AP_D01_B01_V01", "did": "fm01", “dty”: “fm”, "dt": "2020-11-03T00:00:00",

"p": {"t": "100.22", "f": "21.5", "b": "99", "e": "00", "p5": “”, "p6": “”}}

Where,

I.) gid = Gateway or Location ID (that includes State/District/Block/Revenue Village and Scheme ID), did = device id, dty = device type, dt = time stamp, p = parameter;

ii.) Parameters (p) = Quantity (t), Flow rate (f), Battery Level (b), Error code (e), Ground water level (g), Service reservoir level (l), Pressure (pr), Chlorine (c), Turbidity (tb), pH (ph), Conductivity (cd), Ampere (a), Voltage (v), Vibration (vb), Pump Status (s) etc.

Refer Annexure 9© for detailed data format samples for device to cloud communications, metadata to be populated post-installation, and data exchange between State Cloud to Centre Cloud.

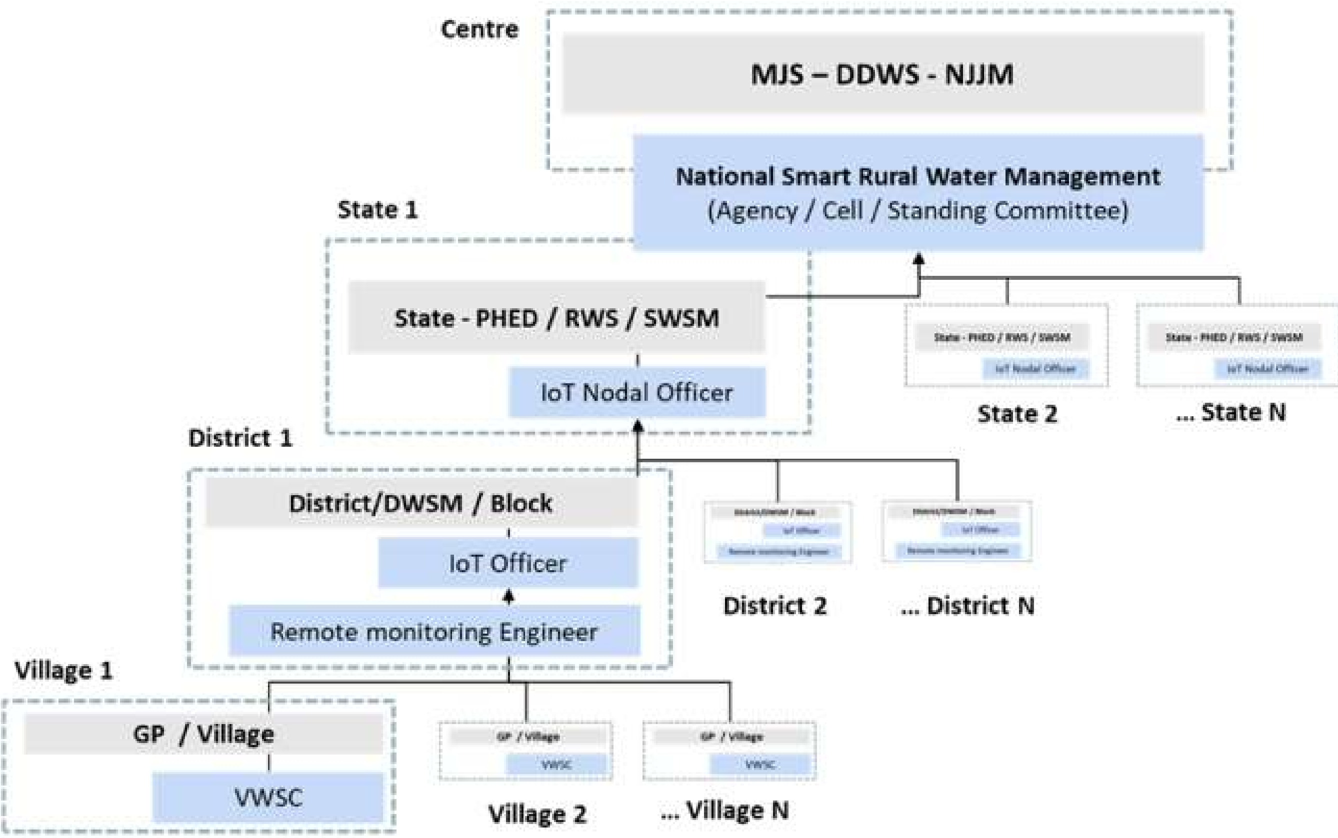
6. Governance framework: roles and responsibilities

The governance mechanism should enable de-centralised monitoring, control, and action at G.P / VWSC level. It should enable data-driven decisions on ground for VWSC / G.P (e.g., reduce outages, fix grievances, ensure equitable supply, predictive maintenance etc.) and enable officials at Block/District/State/Centre level to remotely monitor service delivery through aggregated reports and alerts, and take necessary quick-response upon non-conformance of SLAs/KPIs.

a. Organisation structure

Below is a proposed organisation structure across levels for governing IoT-sensor based smart rural water management.

Figure 14 Proposed organisational structure



b. Role of Government of India / NJJM

Following roles have been proposed at Government of India / Ministry of Jal Shakti (Department of Drinking Water and Sanitation) level.

I.) Develop centralized platform for aggregating data from States

a. Setup a central Command and Control Centre for remote monitoring and interfaces with other government departments / portals / dashboards;

b. Appoint an implementing agency (i.e., Master System Integrator for Centralized IoT Platform) for developing the platform;

ii.) Support States in execution of the IoT-based measurement and monitoring system for rural smart water management

a. Conduct trainings and workshops with PHED/RWS;

b. Provide knowledge support and advisory;

c. Prepare and release model RFP with clarity on scope of work and specifications;

d. Facilitate skilling programmes through relevant centre and state level institutions;

e. Oversee speed of rollout and quality of execution across States.

iii.) Setup a new agency / cell / standing committee within DDWS (e.g., National Smart Rural Water Monitoring Cell/Agency):

a. Overseeing the centralized smart rural water management platform;

b. Recommend enhancements to the sensor-based monitoring system;

c. Publish revisions of technical specifications and improvements based on evolving technologies and feedback from on-ground deployments;

d. Leverage data and analytics for driving open data access for research, innovation, and a forum for knowledge sharing;

e. Comprise of centre and state officials (e.g., IoT Nodal Officer) as well participants from academia and industry;

iv.) Monitor rural water service delivery pan India:

a. Track scheme functionality status of villages across States;

b. Track service delivery status (quality, quantity, duration);

c. Review performance of service delivery with States / Publish rankings / score cards;

d. Maintenance and enhancement of IoT platform (new features/functionalities based on user feedback);

v.) Facilitate data-driven decision making and innovation

a. Data driven long term infrastructure planning and advisory to States including best practices;

b. Integrate IoT platform with other government portals / dashboards (e.g., Umang, MyGov, MieTY, PMO, NITI Aayog);

c. Drive innovation by organizing hackathons on public datasets among academia, start-ups, and industry.

c. Role of State Government / SWSM

Following roles have been proposed at State / SWSM level.

I.) Develop centralized platform for direct ingestion of device data from Districts/Blocks

a. Identify IoT nodal officer (and related resources) at State level to coordinate with Centre and with districts within states for roll-out;

b. Setup a central Command and Control Centre (IoT platform) for aggregating data from all IoT installations across block/district level;

c. Setup a help desk for vendor onboarding and management at block/district level;

d. Appoint/hire a master system integrator for a developing a centralized IoT platform;

e. Publish standard data format for all IoT implementations within state across blocks/districts;

f. Send standardized data to Centre Cloud (via APIs or other mechanisms).

This is a critical step as the centralized platform at a State level needs to be operational so that all block/districts follow the common data standards and to facilitate easy integration at state level

ii.) Support Districts/Blocks in execution of the IoT-based measurement and monitoring system for rural smart water management

a. Provide knowledge support and advisory;

b. Oversee speed of rollout and quality of execution across Districts/Blocks;

c. Oversee training and change management across Districts;

d. Capacity building of IT resources in PHED at State/District level;

e. Facilitate skilling programmes through relevant state level institutions;

f. Oversee speed of rollout and quality of execution across Districts/Blocks;

g. Facilitate tripartite agreement if needed between the District/Block, the Vendor, and the GPs in the cluster of villages (block/district) – which may clearly include responsibilities for GPs (e.g., ensure prevention of any vandalism/ theft, providing power supply and location for gateway at GP office or pump cabin / ESR from existing pump connection or apply for new power connection etc.).

iii.) Monitor rural water service delivery across State

a. Track scheme functionality status of villages across Districts;

b. Track service delivery status (quality, quantity, duration);

c. Review performance of service delivery with Districts / Publish rankings / score cards;

d. Take corrective measures to improve service delivery indicators with Districts;

e. Leverage datasets, insights, and knowledge from National Smart Rural Water Monitoring Agency and contribute States learnings and experiences;

f. Facilitate data-driven infrastructure planning for source sustainability, Multi-village schemes, demand/supply gap etc.

g. Maintenance and enhancement of IoT platform

d. Role of Districts/Blocks: DWSM / PHED / RWS

Following roles have been proposed at District / DWSM and Block level.

I.) Rollout tenders for implementation of IoT based smart water management

a. Identify IoT officer (and related resources) at a district level to coordinate with State IoT nodal officer and blocks within the district;

b. Determine scope and design of the IoT implementation based on local conditions – type of schemes, connectivity availability, power availability, availability of service providers, costs etc;

c. Roll out RFP for implementation of IoT sensor- based monitoring of rural water supply (Supply, Install, Test, Commission, O&M);

d. Provide all required documents (e.g., site layouts, DPRs) of schemes to IoT solution provider vendors.

ii.) Oversee execution by IoT solution provider vendors

a. Facilitate clearances and approvals that may be required by the vendor (e.g., right of way, location to place gateway device, power connection);

b. Accompany vendor during site visits to develop solution design and provide necessary on-field support to enable installation, testing, commissioning, and conduct periodic inspection;

c. Facilitate tripartite agreement if needed between the District/Block, the Vendor, and the GPs in the cluster of villages (block/district) – which may clearly include responsibilities for GPs (e.g., ensure prevention of any vandalism/ theft, providing power supply and location for gateway at GP office or pump cabin / ESR from existing pump connection or apply for new power connection etc.).

iii.) Capacity building of PHED/RWS and IT resources

a. Create a new role / re-skill existing IT / PHED/RWS resources for IoT remote monitoring engineer at District and Blocks;

b. Oversee training, skilling, and change management across blocks/GPs for JE to SE level roles.

ii. Monitor rural water service delivery across District/Block

a. Track scheme functionality status (quality, quantity, duration) across all villages in District/Block;

b. Ensure equitable supply to all villages, habitations, and households;

c. Track water source levels, prepare sustainability reports and take corrective measures;

d. Track Grievances – number of outages, time to resolution, ageing of open issues;

e. Monitor water supply infrastructure and asset health (e.g., pump, flow rate in pipes), track alerts for outages and predictive maintenance;

f. Communicate with Paani Samiti / VWSC / Operators for predictive maintenance and on-call support and resolution;

g. Allocate work to JE/AE for grievance redressal and track to closure;

h. Take timely and corrective actions for issues flagged by system (e.g., supply outages, water contamination, leakage);

i. Identify cost reduction and quality improvement areas;

j. Monitor functionality of IoT sensors, system-uptime, and data accuracy; and track SLAs for IoT Solution Provider vendor during O&M period.

e. Role of GPs / VWSC / MVWSS management

Following roles have been proposed at GP and VWSC level

I.) Facilitate execution by IoT solution vendors for deployment in village

a. Provide clearances and approvals that may be required by the vendor (e.g., right of way, location to place gateway device, display panel, power connection);

b. Mobilize community to bring awareness about benefits of IoT-sensor based monitoring system and instil ownership to ensure proper upkeep of assets and safeguard against tampering / vandalism.

ii.) Monitor and control water service delivery in village

a. Carry out water budgeting (supply-demand gap) based on IoT data;

b. Track service delivery status (quality, quantity, duration);

c. Track grievances and resolve outages/issues;

d. Determine non-revenue water sources – leakage, wastage;

e. Track water level in source and take corrective measures for source sustainability;

f. Correlate consumption with tariff collection;

g. Ensure upkeep of IOT Sensors / Prevent damage/theft etc;

h. Pre-empt asset failures, monitor pump operation (e.g., duration), health (e.g., vibration) and preventive maintenance steps required;

i. Capture O&M Data (Water tariff collected, O&M expenses across staff, energy, disinfectants, repair, misc.) in mobile app;

j. Conduct periodic quality testing and capture results in mobile app;

k. In MVS – the PHED/RWS shall be responsible for maintain service delivery up to the delivery point of village.

f. Funding options for sustenance

To ensure sustainability of sensor-based monitoring system for rural water supply, the following funding options have been proposed for central and state governments to explore.

I.) Funding from Centre / NJJM (Capex, Capitalized O&M for first 5 years, i.e.– capital grants);

ii.) State funded - Dedicated budget head in AAP / SLSCC (including O&M);

iii.) 15th Finance commission (to GPs – cut at source / recover) / Convergence;

iv.) Incentive fund – Any of the above an incentive linked grant;

v.) Community recovery in lieu of gains from IoT.

g. Capacity building, skilling, and change management

Success of this initiative greatly depends on the ability to build capacities across levels to understand and adopt this technology. As a next step the NJJM/SWSM/DWSM should develop training material for all users of this monitoring system and conduct workshops with PHED/RWS officials who will be rolling-out and operating this system.

Several new skills are required to successfully execute this project (e.g., data entry operator, IoT device maintenance vendor, IoT remote-monitoring engineer) and a need for enhancing availability of traditional skills such as electricians, plumbers, and masons. This initiative will also require creation of new roles or re-skilling of existing PHED/RWS engineers (and IT cells) for the role of 'IoT Remote Monitoring Engineer' to understand dashboards, track metrics, troubleshoot and take corrective action.

There is also an opportunity to create local entrepreneurship for new work areas such IoT asset O&M, data-entry operator, water quality testing etc. Officials should leverage several available skilling initiatives such as National Skill Development Corporation (NSDC), Skill India, Common Services Centers Scheme (CSC), State level training centers etc. Further, the departments should focus on change management and build awareness among all stakeholders along with trainings/workshops.

7. Roll-out plan for IoT based remote monitoring of rural water schemes

Three levels of implementations are required for successful scale-up of IoT-based smart rural water management. At the village level, IoT-devices will be installed and maintained. Data from these devices will be directly transmitted to State Cloud, where data from all villages within the State will be aggregated and end-user applications be exposed. Further, this data will be pushed to Centre Cloud for aggregation from all States and dashboards will be exposed.

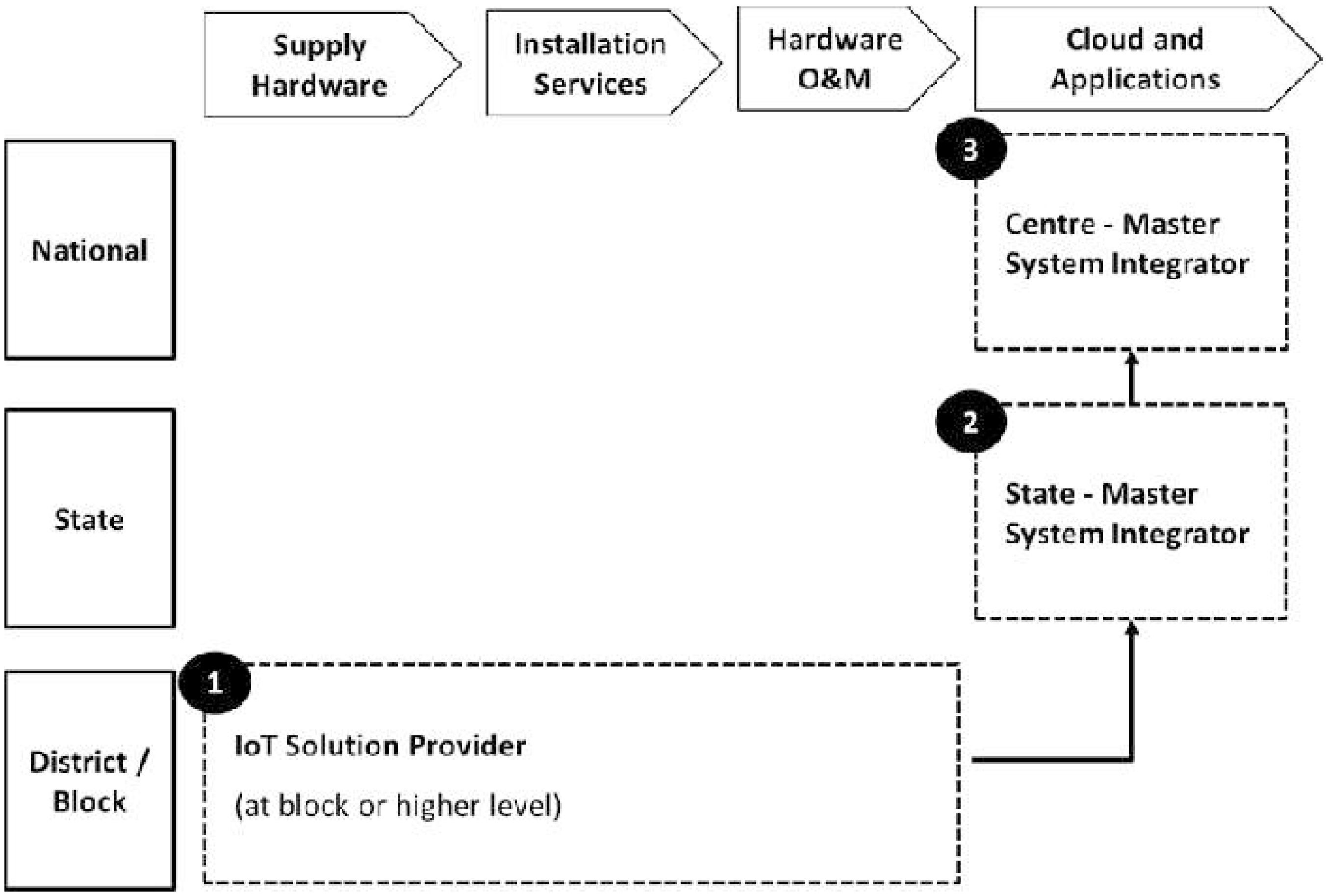
To enable this architecture, 3-types of implementation agencies should be appointed/hired across district/block level, state level and at centre level.

I.) **IoT Solution Provider (at Block level)** to supply, install, configure, test, commission, and maintain IoT assets in all villages in that block to send data to State Cloud;

ii.) **State – Master System Integrator (at State level)** to ingest IoT data from villages, provide cloud services, and build reports and applications for end-users;

iii.) **Centre – Master System Integrator (at National level)** to aggregate IoT data from all States, provide cloud services and build reports and applications for end-users.

Figure 15 Implementation Areas



a. IoT solution provider at Block (or District) level

Key responsibilities (or scope of work):

I.) Supply IoT sensors and other devices as per the requirement;

ii.) Conduct site survey to finalize the design and location of sensors and other IoT devices in consultation with the engineer in-charge from PHED;

iii.) Install devices by performing necessary civil work, plumbing work, electrical work, and other responsibilities to calibrate, test, and commission the entire IoT solution

iv.) Setup communication network (including necessary software deployment at RTU and gateway level);

v.) Ensure continuous data transmission from device to State Cloud as per define data standards, security, and protocols (vendor may not be liable for disruptions caused by cellular or fixed broadband networks);

vi.) Configuration of sensors and networking equipment to send data to State Cloud complying with data and security guidelines;

vii.) Ensure regular transmission of data to the state/central cloud directly from device (without routing via an intermediary server);

viii.) Operations and maintenance of IoT assets for at least 5 years post commissioning (maintenance, calibration, repair/replacement, software bugs fix, etc. as per SLAs); including insurance of these IoT assets;

ix.) Support PHED/RWS engineers troubleshoot system issues.

Type of implementation agency:

I.) IoT solution providers with prior experience in supplying (procured or own manufactured), installing, configuring, operating, and maintaining IoT assets in water or any other sector. Experience in rural IoT or smart cities preferred. Start-ups / MSMEs with relevant prior experience in IoT / electronics as well local indigenous quality manufacturing should be promoted;

ii.) Agencies may participate through consortiums/joint-ventures bringing some of the above key capabilities such as Original Equipment Manufacturers (OEM), IoT System Integration, Annual maintenance contracts for operations and maintenance etc. Further, the agency may sub-contract work to other / local vendors.

The award of contracts for an IoT solution provider (i.e., IoT asset installation and maintenance) should ideally be at block level (or higher) with 50-100 or above villages. In case of upcoming/new smaller single village schemes, it may be challenging to combine IoT deployment with water EPC work due to different skillsets and introduction of cross-dependencies resulting in logistical challenges or delays. Further, the IoT deployment will require at least a 5-year O&M period, whereas EPC work for SVS typically does not include O&M period. In such cases, the IoT deployment can be a retrofitting on top of existing functional water supply schemes or be deployed post completion of works for new/upcoming water schemes. However, for new MVS schemes that have an O&M period, the same contract could be used for both water EPC and IoT solution deployment (e.g., same large entity does both water EPC and IoT, or hires an IoT solution provider as a sub-contractor). States may choose to combine EPC and IoT if feasible, depending on maturity of EPC vendors.

Both capex and opex models could be explored by States. In a capex model an upfront capex payment for hardware and installation is followed with annual O&M payments. In an opex model a lower upfront amount is charged, followed by monthly/annual device and service rental is paid as per SLAs. After completion of 5 years, respective states may consider an asset refresh capital expense that can be taken up in the next 5-year plan (State Action Plan, District Action Plan). Further, fixed and performance-based payments can be made to vendor evaluated from system data (e.g., uptime of IoT system, system health, data accuracy, time to resolution).

b. Master system integrator at State/National level

Each state and central government will require a master system integrator to aggregate data, provide cloud services, and build end-user applications.

Key responsibilities (or scope of work):

I.) Define data standards (e.g., data payload format) for each type of sensor so that data from every village in the State is consistent and compliant with Centre Cloud APIs;

ii.) Integrate IoT data from all blocks/districts (direct from device) by interacting and coordinating with block/district level IoT solution provider vendors (testing, configuration etc.);

iii.) Provide cloud services (storage, compute, IoT, security) and host IoT services across multiple protocols (e.g., MQTT, HTTPs, AMQP, CoAP) for vendor compatibility;

iv.) Integrate data from other sources such as IMIS/WQMIS/JJM mobile for state level holistic dashboards;

v.) Provide interface for remote monitoring to community, PHED/RWS, officials; as well as IoT solution provider vendors for onboarding, testing, configuring, performance management and SLA tracking;

vi.) Operate and maintain the central IoT platform (e.g., enhancements, issue resolution);

vii.) Build analytics-engine and create reports (GIS, dashboards, alerts, reports, AI/ML) for key stakeholders within department;

viii.) Build and operate a Command-and-Control Centre (CCC) / Digital wall;

ix.) Provide help desk for vendor onboarding, management, and troubleshooting; have a dedicated coordinator(s) for each district/block with the state.

Type of implementation agency:

I.) Tier-1 IT/technology capabilities: System integration (SI), Cloud integration/ hosting, Internet-of-Things (IoT) deployment experience, Geographical Information Systems (GIS), Artificial Intelligence and Machine Learning (AI/ML), Command and Control Centres (CCC) / Remote monitoring, Support/maintenance. Prior experience in large-scale deployments with extensive experience should be preferred;

ii.) Agencies may participate through consortiums/joint-ventures bringing some of the above key capabilities such as System Integration, Cloud hosting/integration, Internet-of-Things, Command and Control Centres.

8. Summary of Recommendations

I. Assuring supply of potable water to all the households requires a robust system of monitoring the service level failure in an objective and accurate manner. The data on failure of service benchmarks on quality, quantity and regularity can be captured in two ways:

a) Entering data using systems using mobile app or web application, IVRS or other systems;

b) Through sensors capturing data, transmitting to cloud and visualised through dashboards.

II. Recommended design

Three alternative designs have been suggested. The options vary in terms of cost and number of parameters they can measure:

a) Basic solution: This consists of a volumetric flow meter at outlet of service reservoir to provide aggregated data on quantity and periodicity of water to the distribution network. It also includes a chlorine sensor at the service reservoir to determine disinfection process compliance and measure free chlorine. Further, it consists of a ground water level sensor (wherever applicable) to ensure source sustainability. This is cheapest option that may be used for all the schemes in village. The outages in supply can be monitored on continuous basis. Such solution may be used in areas with simple distribution network without much of quality issues. To monitor quality parameters (other than chlorine) the FTK based methods shall be used conjunctively;

b) Intermediate solution: In addition to basic solution the pump controller unit, flow meters at DMA inlet or habitations (or DMAs), and pressure sensor at furthest point / tail-end may be added. This will help ensure equitable supply to DMAs/habitations and operational excellence (automation, predictive maintenance). This solution is cost effective and can provide value addition for O&M to a large extent. Committee recommends that for most villages this solution should be used;

c) Advanced solution: In addition to intermediate solution, consumer level water metering may be added. This solution will automate the water service delivery and grievance of each user will be addressed through such systems.

III. The solution design (i.e., type and location of sensors) may vary depending on the type of water scheme and has been detailed in section 4(c)(iv) and 9(a);

IV. VWSCs and RWS departments should also capture data on grievance, O&M, quality parameters through a mobile/ web-based system – This will help them to truly function as water service utility.

V. Common functional requirements

a) Standardised Dashboards;

b) Automated alerting mechanism;

c) Data sharing to both State Cloud as well as the local operator (at Gram Panchayat level) through local area network;

d) The solution should be able to store data locally on gateway for a minimum of 6 months. The device should store data for 30 days, in case of connectivity issues to gateway or cloud;

e) The solution should support bi-directional data flow (wherever possible), with over-the-air firmware updates (changing frequency of data transmission, remote calibration, security patches, fixing bugs etc.) and enable remote control.

VI. Technical architecture and specifications

a. The implementation agencies may follow global standards in case Indian standards are not defined for IoT hardware or sensors (such as CE/FCC for IoT devices with communication modules). Hardware specifications have been detailed in section 9(b);

b. The solution design should adhere to open standards and be technology neutral. It can use a variety of networking technologies as per local conditions and availability of services, such as fixed broadband / Wi-Fi, local area RF (e.g., LoRa), and/or cellular technologies (2G/3G/4G; including upcoming NB-IoT / 5G);

c. In villages, where Wi-Fi is already available (e.g., BharatNet, WANI, private broadband), IoT devices can directly connect to a Wi-Fi enabled gateway/router that communicates to cloud. However, Wi-Fi enabled IoT devices may not be suited for battery-based operations due to high power consumption (especially at DMA inlet / tail-ends) where getting power supply may not be possible. For such scenarios, RF-based first-mile network can be leveraged for low-power long range communications such as LoRa / LoRaWAN (or any other recognized technology such as Zigbee, Sigfox etc.);

d. RF-LoRa is recommended in such a scenario (complying with DOT's guidelines on private RF network in the ISM band of 865-867 MHz or via licensed LoRaWAN operators). It is preferred as it consumes low power, has long range, can be used for battery operated devices (especially in rural areas where getting power mains supply may be a challenge due to additional cost, right of way, approvals, etc.);

e. For majority of the rural villages in India which currently do not have Wi-Fi, cellular technology should be leveraged for communication to cloud. In case of an 'Intermediate' or 'Advanced' level of deployment, where there are more than 4-5 devices, it is recommended to leverage RF (e.g., LoRa) for first-mile communications to a gateway and cellular (2G/3G/4G) for gateway to cloud communications;

f. In scenarios, where only a limited number of IoT devices are deployed (e.g., Basic level implementation with a single flow meter, or less than 4-5 devices), a direct to cloud cellular communication can be used. Such IoT devices should have a cellular (GSM/4G) compatible communication module (RTU – remote terminal unit). This should ideally be 4G-based with backward compatibility (with 2G/3G sims) and extensible to upcoming technologies such as NB-IoT / 5G;

g. The telemetry data from devices placed in villages should directly be sent to State or Central Cloud and data from State Cloud should be pushed to Centre Cloud. A hybrid model is preferred for data transmission from State Clouds to Central Cloud. This enables flexibility to ingest data into the Central Cloud directly from the IoT Devices (sensors) or indirectly through the States who have developed such system to aggregate IoT data. In cases IoT data are first collected at the State Cloud / Data Centre, then the aggregated data shall be pushed to the Central Cloud using Open APIs;

h. The communications to cloud can be done via several IoT compatible and specialized protocols (e.g., MQTT, AMQP, HTTPs, CoAP). Device connectors and device agents should use standard transport layer security (TLS) or Datagram transport layer security (DTLS) protocols for network security. Device management should be based on LWM2M protocol which in turn uses DTLS for network security and device connector libraries should use SSL/TLS connections to make calls to services such as 'Sensor Services';

i. Common data standards are required pan-India for successful scale-up. Data standards for device to State Cloud and from State Cloud to Central Cloud using APIs have been detailed in section 5(f) and 9(c).

VII. Governance framework

The role of various stakeholders in establishing and operating the measurement and monitoring systems is as under;

a. Role of NJJM

I.) Develop centralized platform/ central cloud for aggregating data from States by appointing / hiring a master system integrator;

ii.) Support States in execution of the IoT-based measurement and monitoring system fo rural smart water management by conducting trainings, workshops, and providing knowledge support to PHED/RWS;

iii.) Setup a support cell or appoint an agency/ monitoring committee within NJJM.

b. Role of SWSM / PHED / RWS

I.) Develop common platform / State Cloud (or data centre) for ingesting data;

ii.) Transmit data from State Cloud to Centre Cloud in standard format;

iii.) Setup a help desk for vendor onboarding and management with blocks/districts;

iv.) Facilitate clearances and approvals that may be required by the vendor (e.g., right of way, location to place gateway device, power connection);

v.) Monitor rural water service delivery across State by tracking service delivery (quality, quantity, duration), reviewing performance and taking corrective measures;

vi.) Set up a support unit to coordinate the implementation.

c. Role of Districts/Blocks - DWSM / PHED / RWS

I.) To implement the IoT sensor- based monitoring of rural water supply (Supply, Install, Test, Commission, O&M) with procurement of IoT solution provider/ vendors;

ii.) Facilitate clearances and approvals that may be required by the vendor (e.g., right of way, location to place gateway device, power connection);

iii.) Facilitate tripartite agreement if needed between the DWSM/ PHED/ RWS, the vendor, and the GPs in the cluster of villages (block/ district);

iv.) Create a new role/ re-skill existing IT / PHED/RWS resources for IoT remote monitoring engineer at District and Blocks;

v.) Monitor rural water service delivery across villages by tracking service delivery quality, quantity, duration, outages, source sustainability, grievances, and O&M tariff collection;

vi.) Take timely and corrective actions.

d. Role of GP / PRI / VWSC / Paani Samiti / MVWSS

I.) Establish a display unit at a prominent place of village for example, Panchayat office, School, PHC/ CHC etc.

ii.) Facilitate deployment of IoT solution in village, provide support and approvals that may be required by the vendor (e.g., right of way, location to place gateway device, power connection);

iii.) Monitor and control water service delivery in village by tracking service delivery (quality, quantity, periodicity), carry out water budgeting, determine non-revenue water (leakage, wastage), ensure upkeep of IoT devices;

iv.) Capture O&M Data (Water tariff and expenses) and periodic water quality testing results (other than free chlorine) in mobile app.

VIII. Operational guideline for Jal Jeevan Mission provides for establishment of such systems under support funds and also under flexi funds. The State Budget, 15th Finance commission, Community contribution, CSR Funds etc may also be used to establish such systems;

IX. Several new skills are required to successfully execute this project (e.g., data entry operator, IoT device maintenance vendor, IoT remote-monitoring engineer) and a need for enhancing availability of traditional skills such as electricians, plumbers, and masons. This initiative will also require creation of new roles or re-skilling of existing PHED/RWS engineers (and IT cells) for the role of 'IoT Remote Monitoring Engineer' to understand dashboards, track metrics, troubleshoot and take corrective action;

X. There is also an opportunity to create local entrepreneurship for new work areas such IoT asset O&M, data-entry operator, water quality testing etc. Officials should leverage several available skilling initiatives such as National Skill Development Corporation (NSDC), Skill India, Common Services Centres Scheme (CSC), etc. Further, the departments should focus on change management and build awareness among all stakeholders along with trainings/workshops.

XI. Roll-out plan

a. In order to roll out the measurement and monitoring system across the villages three levels of implementations are required. The sensors, cloud and data visualisation at NJJM and SWSM level.

b. To enable this architecture, 3-types of implementation agencies should be appointed/hired across district/block level, state level and at centre level.

   I.) IoT Solution Provider (at Block/District level) to supply, install, configure, test, commission, and maintain IoT assets in all villages in that block to send data to State Cloud;

   ii.) State – Master System Integrator (at State level) to ingest IoT data from villages, provide cloud services and analytics, build reports and applications;

   iii.) Centre – Master System Integrator (at National level) to aggregate IoT data from all States, provide cloud services and analytics, build reports and applications.

c. The States should setup State Cloud (or use existing data centre) to initiate this roll-out;

d. The award of contracts for an IoT solution provider (i.e., IoT asset installation and maintenance) should ideally be at block level (or higher) with 50-100 or above villages;

e. Both capex and opex models could be explored by States. In a capex model an upfront capex payment for hardware and installation is followed with annual O&M payments. In an opex model a lower upfront amount is charged, followed by monthly/annual device and service rental is paid as per SLAs;

f. After completion of 5 years, respective states may consider to continue with the system or use improved systems available.

g. Further, fixed and performance-based payments can be made to vendor evaluated from system data (e.g., uptime of IoT system, system health, data accuracy, time to resolution).

XII. Way forward

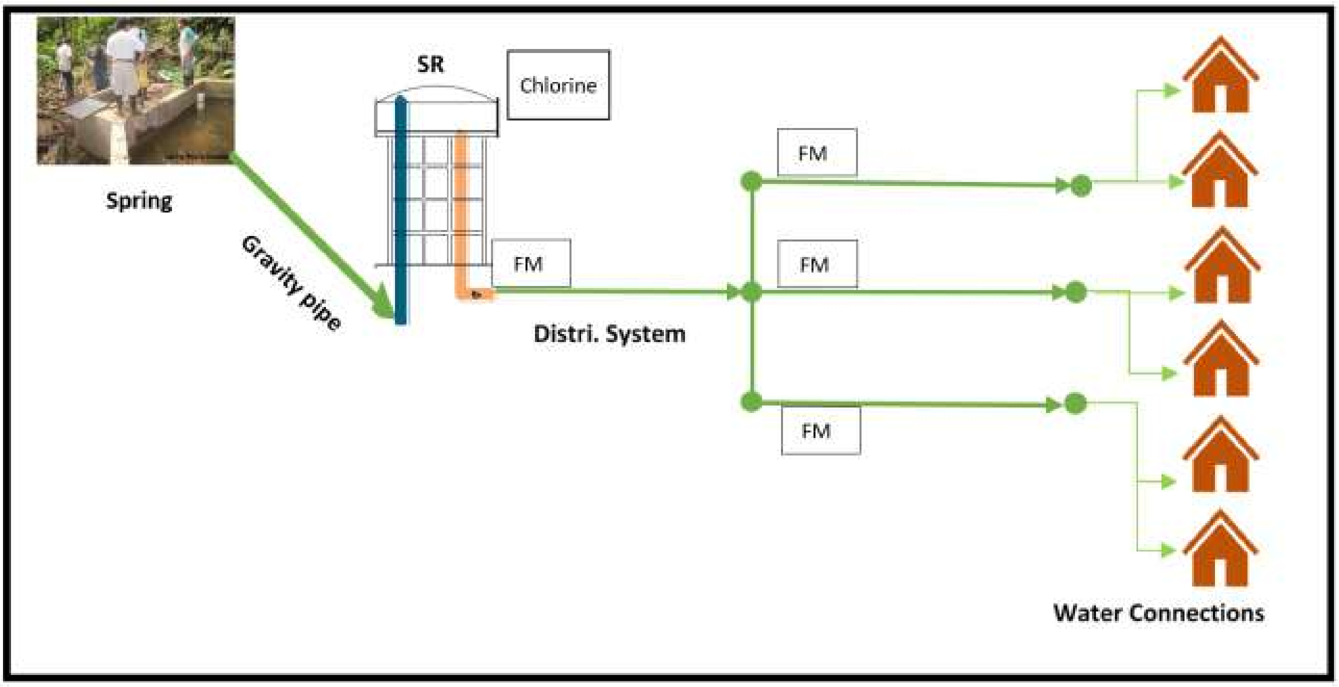
States are encouraged to refer this report and initiate IoT-based smart rural water management rollouts starting with few blocks in coming months and then scale-up to entire districts.

9. Annexures

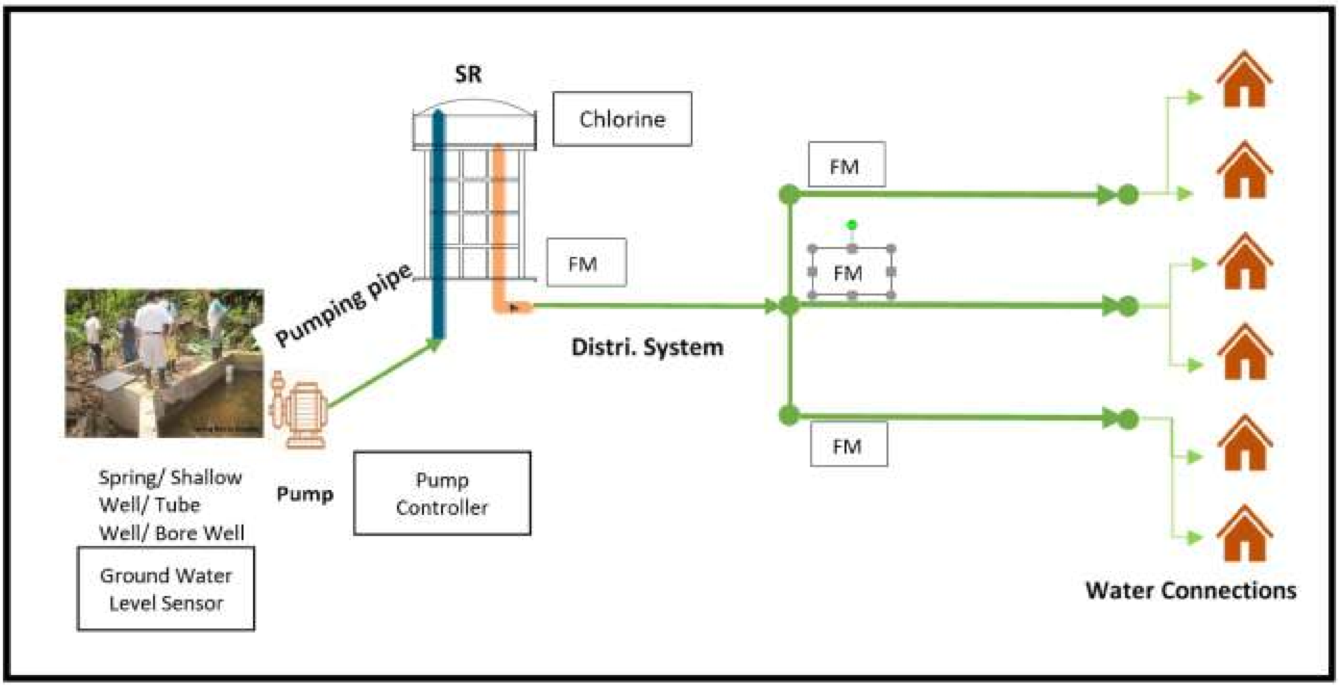
a. Variations in water supply schemes

i. Scheme Type – 1) SVS - Ground water gravity based (spring) – with basic (chlorination) or advanced treatment

Figure 16 Spring in mountain as source with basic treatment and gravity- based scheme



ii. Scheme Type – 2) SVS - Ground water pump based (spring/ shallow well/ tube well/ bore well) – with basic (chlorination) or advanced treatment



iii. **Scheme Type – 3) SVS - Surface water gravity based for raw water and pump based for treated water – with basic (chlorination) or advanced treatment**

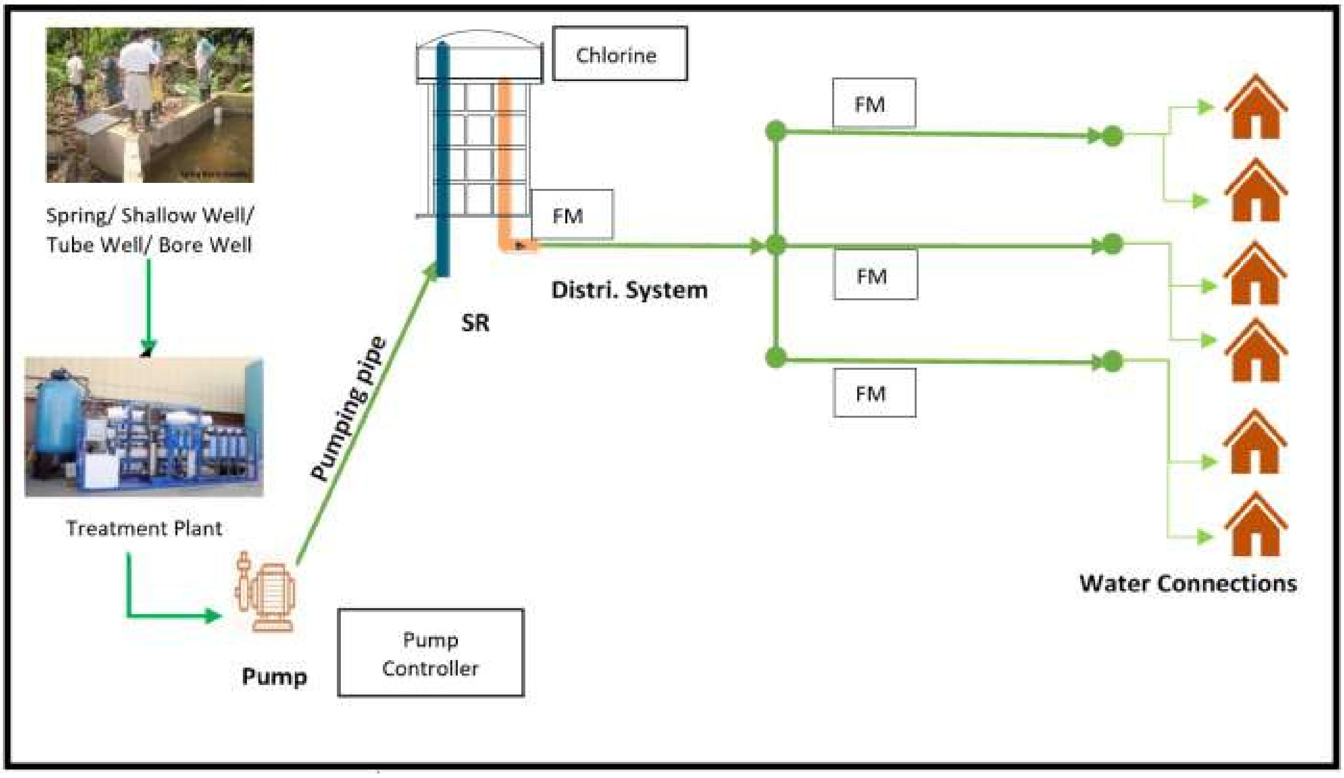


Figure 17 Spring source (gravity based) with advanced treatment and pump based for SR

iv. **Scheme Type – 4) SVS - Surface water based on 2 pumps (1 for source to intake chamber and 1 for intake chamber to SR) – with basic (chlorination) or advanced treatment**

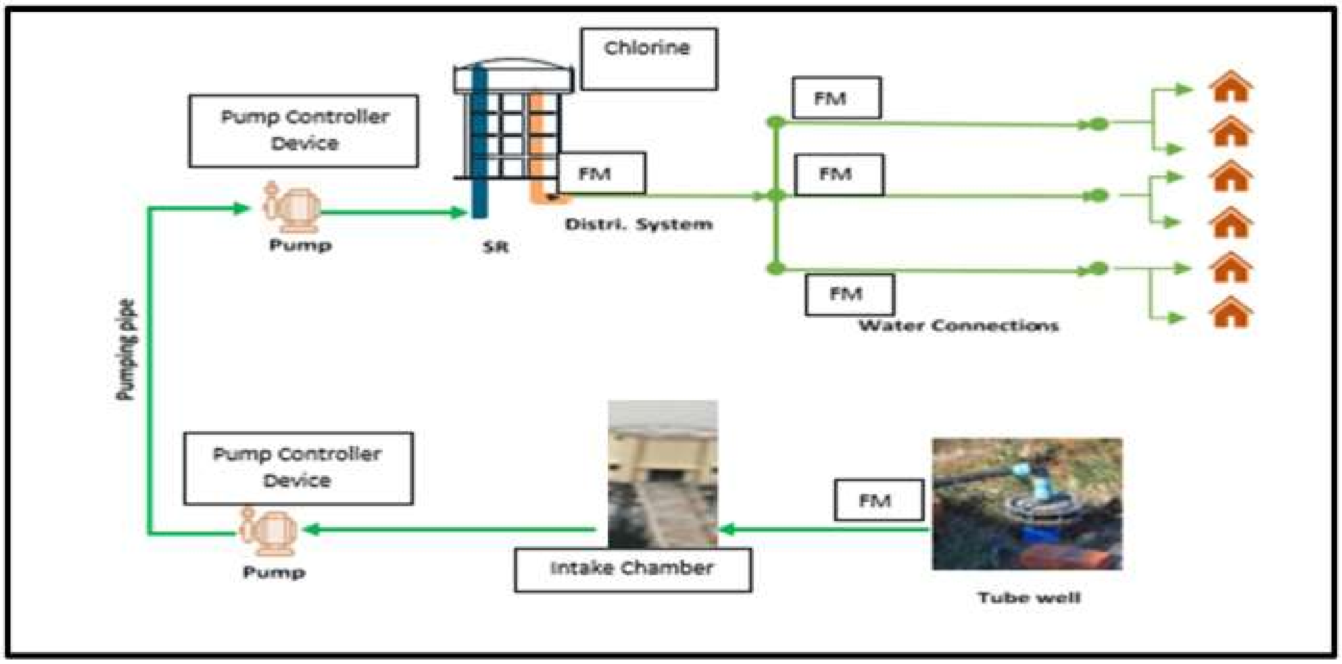


Figure 18 Tube Well as Source with basic treatment (chlorination only) based on 2 pumps

v. **Scheme Type – 5) MVS – Gravity based for source and pump based for transmission to other villages/ habitations – with basic (chlorination) or advanced treatment**

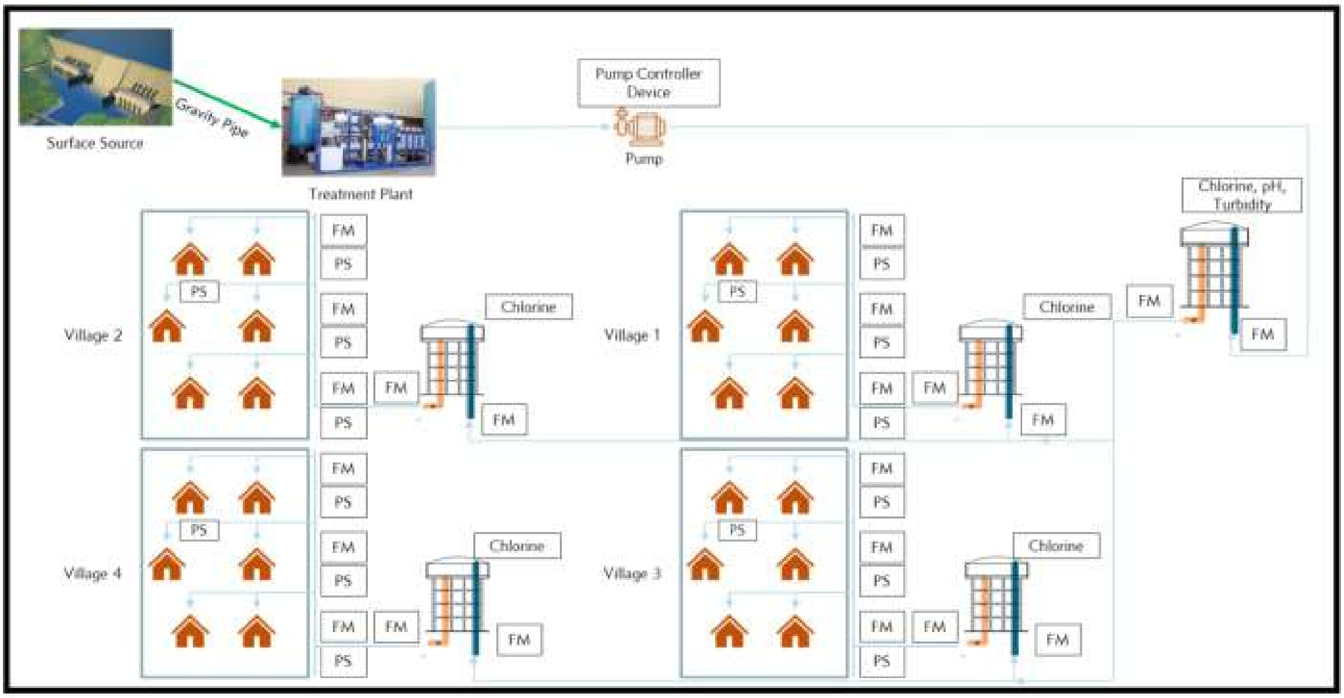


Figure 19 Village MVS with surface source and advanced treatment – gravity based for raw water and pump based for treated water

vi. **Scheme Type – 6) MVS – Pump based for source as well as for transmission of water to other villages/ habitations – with basic (chlorination) or advanced treatment**

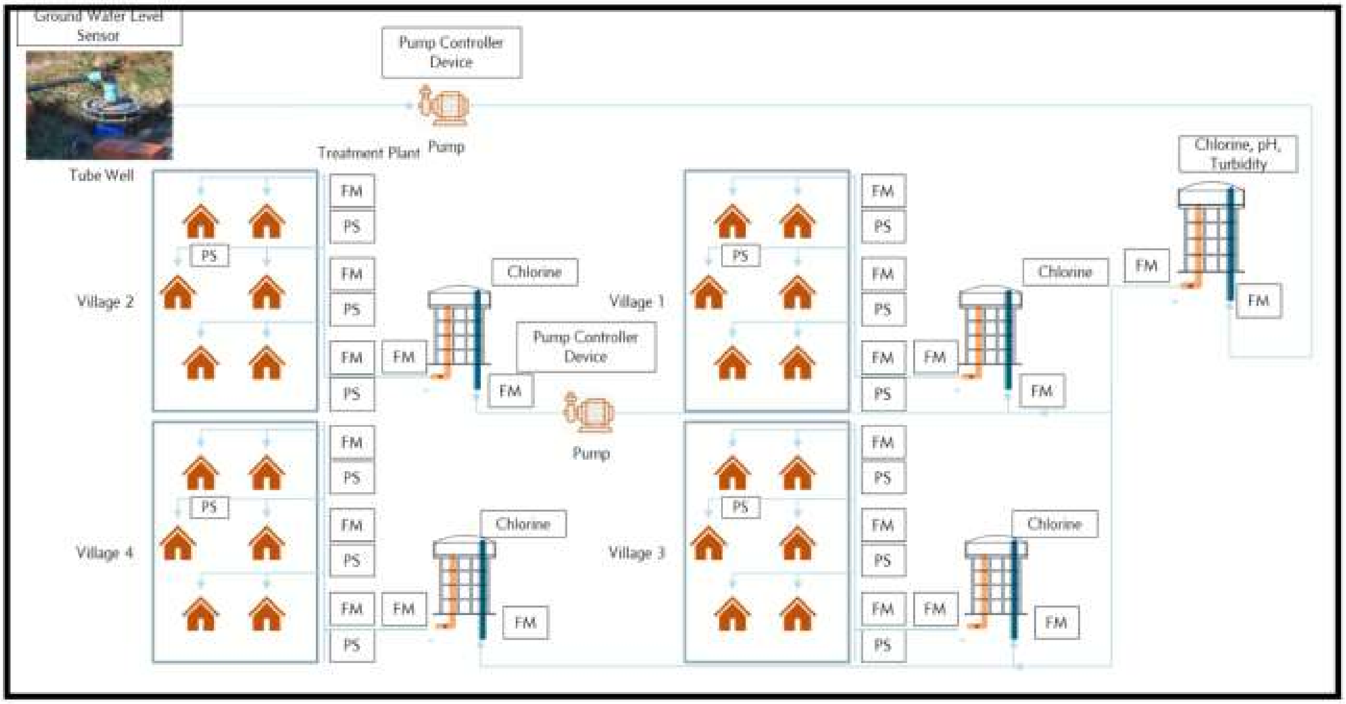


Figure 20 Village MVS with tube well source and basic treatment (chlorination) – pump based for raw water and pump based for treated water

b. Reference hardware specifications

i. Flowmeter (Mechanical)

	Minimum Specifications
Features	Water quantity and flow measurement with remote communication to cloud (server) using in-built / separate RTU
Accuracy	+/-2% or better over typical operating range and temperatures; minimum Class B Multi-jet
Operating Conditions	Temperature -20 to 60°C / Humidity 5 to 95% non-condensing; Working pressure shall 6 / 10 / 16 bar as per local requirement
Output	Pulse output / m-Bus
Body Type	Water Meter: Ip68, Communication Module: IP67 (should support field replacement of batteries if attached with flowmeter)
Calibration & Testing	Calibration certification required at the time of supply (e.g., FCRI)
Certifications	ISO 4064 B / IS:779:1994 / MID (Directive 2004/22/EC) / OIML R 49
Ancillaries	Strainers, Meter boxes / Enclosures etc.

ii. Flowmeter (Ultrasonic type)

	Minimum Specifications
Features	Water quantity and flow measurement with remote communication to cloud (server) using in-built / separate RTU
Accuracy	+/-0.5% or better over typical operating range and temperatures; minimum Class B Multi-jet
Operating Conditions	Temperature -20 to 60°C / Humidity 5 to 95% non-condensing; Working pressure shall 6 / 10 / 16 bar as per local requirement
Output	Analog output: 4 - 20 mA Digital outputs: RS485 (Modbus RTU)
Body Type	Water Meter: Ip68, Communication Module: IP67 (should support field replacement of batteries if attached with flowmeter)
Calibration & Testing	Calibration certification required at the time of supply (e.g., FCRI)
Certifications	ISO 4064 B / IS:779:1994 / MID (Directive 2004/22/EC) / OIML R 49

iii. Flowmeter (Electromagnetic type)

	Minimum Specifications
Features	Water quantity and flow measurement with remote communication to cloud (server) using in-built / separate RTU
Accuracy	±0.2 % of MV inclusive of linearity, repeatability, pressure effects and hysteresis
Operating Conditions	Temperature -20 to 60°C / Humidity 5 to 95% non-condensing; Working pressure shall 6 / 10 / 16 bar as per local requirement
Output	Analog output: 4 - 20 mA Digital outputs: RS485 (Modbus RTU)
Body Type	Water Meter: Ip68, Communication Module: IP67 (should support field replacement of batteries if attached with flowmeter)
Calibration & Testing	Calibration certification required at the time of supply (e.g., FCRI)
Certifications	ISO 4064 B / IS:779:1994 / MID (Directive 2004/22/EC) / OIML R 49
Ancillaries	System: Separate with cable output (minimum 15 meters); End Connection: CS Flanges; Flange Rating: CS, PN10

iv. Ground-water level sensor or DWLR (Digital Water Level Recorder)

	Minimum Specifications
Features	A system for water level measurement for bore wells/ Tube wells (hydrostatic/piezo based); Measuring range: 50 / 100 / 200m (based on bore well depth) Note: Piezometers can be used to observe underground conditions by measuring the pressure level of the ground water at the given depths. Digital Water Level Recorder (DWLR) which can be used in piezometer wells as well as tube wells for measurement of water level data
Accuracy	Pressure accuracy: ±0.05% FS; Pressure resolution: ±0.01% FS
Operating Conditions	Operating temp. range: -20^{o}C to 60^{o}C
Output	Analog output: 4 - 20 mA Digital outputs: RS485 (Modbus RTU)
Body Type	Probe: Ip68, Communication Module: IP67 (should support field replacement of batteries)
Calibration & Testing	Calibration certification required at the time of supply
Ancillaries	Antenna, Cable length – as per requirement (borewell depth); Multi-purpose suspension brackets and adaptor plates for borewell top caps (2 inch or above borewells with or without cutout)

v. **Chlorine sensor**

	Minimum Specifications
Features	Principle: Reagent Free, No Waste-stream Amperometric Chlorine Analyzer; Response time: < 2mins (Electrode: Copper, Platinum, Gold)
Accuracy	Accuracy ±5%, Resolution: 0.05 mg/L Measuring range: 0 to 10.0 mg/l
Operating Conditions	Operating Temperature: -20° C to +60° C
Output	Analog output: 4 - 20 mA Digital outputs: RS485 (Modbus RTU)
Body Type	Probe: IP68, PVC; Shell material - ABS thermoplastic polymer
Calibration & Testing	Calibration certification required at the time of supply

vi. **Pressure sensor**

	Minimum Specifications
Features	Pressure transmitter
Accuracy	Pressure range of 0.1 bar to 60 bar Total Error Band (TEB) as low as 2 %FSS Compensated and operating temperature range of -40°C to 125°C [-40°F to 257°F] Less than 2 ms response time
Operating Conditions	±0.25% full scale accuracy Best Fit Straight Line (BFSL)
Output	Analog output: 4 - 20 mA Digital outputs: RS485 (Modbus RTU)
Body Type	Rated IP67 or better for protection from most harsh environments
Calibration & Testing	Calibration certification required at the time of supply

vii. Communication module (or RTU) for above sensors (inbuilt / attached)

	Minimum Specifications
Power Mechanism	Battery-based or power supply based
Networking	Cellular (GSM/GPRS, 4G/LTE, 5G, NB-IoT), LoRa or other RF technologies, Wi-Fi / Ethernet RF range – 400m – 1000m (for LoRa based RTU)
Communication Protocol	Secured transmission of telemetry via MQTT / AMQP / HTTPS using TLS/DTLS/AES standards
Data Transmission	15 min data transmission for power-supply based RTU / 2-times a day for battery powered RTUs
Data Backup	Should include a memory card for storing data for a minimum of 30 days in case of power failures / loss of connectivity
Body Type	IP67 / Ip68
Configurations	Support remote configuration of data transmission frequency; and OTA firmware updates
Certifications	CE / FCC / CISPER

viii. Gateway device

	Minimum Specifications
Features	32 MHz Ref Clock: TCXO Frequency Band: ISM Tx Out Power: 5 - 22 dBm (Based on Power input) Output: Wi-Fi, Ethernet, and GSM Antenna: 5dB to 22 dBm Hardware support for precise timestamping Hardware-accelerated Data Encryption Standard (DES), 3DES, Advanced Encryption Standard (AES) 128, AES 192, and AES 256 Protective Casing: IP 68
Power Mechanism	Power supply or solar (with batteries)
Networking	RF (e.g., LoRa) / Wi-Fi / or other networking technologies (e.g., Sigfox, Zigbee) for connecting with nodes; Cellular (GSM/GPRS, 4G/LTE, 5G, NB-IoT) or Wi-Fi / Ethernet for connecting to Cloud/server
Communication Protocol	Secured transmission of telemetry via MQTT / AMQP / HTTPS using TLS/DTLS/AES standards
Data Transmission	15 min or continuous data transmission for power-supply based RTU / 4-hour data transmission for solar powered RTUs
Data Backup	Should include a memory card for storing data for a minimum of 2 months in case of power failures
Configurations	Support remote configuration of data transmission frequency; and OTA firmware updates
Certifications	CE / FCC / CISPER

c. Reference data formats

i. Sample Payloads: Device to Cloud Data Transmission

- Flowmeter:
  - o {"gid": "AP_D01_B01_V01", "did": "fm01", “dty”: “fm”, "dt": "2020-11-03T00:00:00",

    "p": {"t": "100.22", "f": "21.5", "b": "99", "e": "00", "p5": “”, "p6": “”}}
  - o Gateway ID (gid) = AP_D01_B01_V01
  - o Device ID (did) = fm01, fm02, fm03, …
  - o Device Type (dty) = fm
  - o Parameter (p) = t, f, b, e
    - ▪ t (Quantity in L)
    - ▪ f (Flowrate in LPM)
    - ▪ b (Battery level 0-100)
    - ▪ e (Error code 00 – no error, 01 – tamper, 02 – other error, 11 – active status at end of day)
- Groundwater level sensor:
  - o {"gid": "AP_D01_B01_V01", "did": "gl01", “dty”: “gl”, "dt": "2020-11-03T00:00:00",

    "p": {"g": "45.53", "b": "99", "e": "00", "p4": "", "p5": “”, "p6": “”}}
  - o Gateway ID (gid) = AP_D01_B01_V01
  - o Device ID (did) = gl01, gl02, gl03, …
  - o Device Type (dty) = gl
  - o Parameter (p) = g, b, e
    - ▪ g (Ground water depth in feet)
    - ▪ b (Battery level – 0-100)
    - ▪ e (Error code 00 – no error, 01 – tamper, 02 – other error, 11 – active status at end of day)
- Service reservoir level sensor:
  - o {"gid": "AP_D01_B01_V01", "did": "sl01", “dty”: “sl”, "dt": "2020-11-03T00:00:00",

    "p": {"lp": 60", "lm": "2.43", "b": "99", "e": "00", "p5": “”, "p6": “”}}
  - o Gateway ID (gid) = AP_D01_B01_V01
  - o Device ID (did) = sl01, sl02, sl03, …
  - o Device Type (dty) = sl
  - o Parameter (p) = l, b, e
    - ▪ lp (Service reservoir water depth in 30% / 60% / 90%)
    - ▪ lm (Service reservoir water depth in metres)
    - ▪ b (Battery level – 0-100)
    - ▪ e (Error code: 00 – no error, 01 – tamper, 02 – other error)
- Chlorine analyser:
  - o {"gid": "AP_D01_B01_V01", "did": "ca01", “dty”: “ca”, "dt": "2020-11-03T00:00:00",

    "p": {"c": "120.22", "b": "99", "e": "00", "p4": "", "p5": “”, "p6": “”}}
  - o Gateway ID (gid) = AP_D01_B01_V01
  - o Device ID (did) = ca01, ca02, ca03, …
  - o Device Type (dty) = ca
  - o Parameter (p) = c, b, e
    - ▪ c (Residual Chlorine in mg/L)
    - ▪ b (Battery level – 0-100)
    - ▪ e (Error code: 00 – no error, 01 – tamper, 02 – other error)

- Turbidity sensor:
  - {"gid": "AP_D01_B01_V01", "did": "tbs01", “dty”: “tbs”, "dt": "2020-11-03T00:00:00",

    "p": {"tb": "120.22", "b": "99", "e": "00", "p4": "", "p5": “”, "p6": “”}}
  - Gateway ID (gid) = AP_D01_B01_V01
  - Device ID (did) = tbs01, tbs02, tbs03, ...
  - Device Type (dty) = tbs
  - Parameter (p) = tb, b, e
    - tb (Turbidity in NTU)
    - b (Battery level – 0-100)
    - e (Error code: 00 – no error, 01 – tamper, 02 – other error)
- pH analyser:
  - {"gid": "AP_D01_B01_V01", "did": "ph01", “dty”: “ph”, "dt": "2020-11-03T00:00:00",

    "p": {"ph": "120.22", "b": "99", "e": "00", "p4": "", "p5": “”, "p6": “”}}
  - Gateway ID (gid) = AP_D01_B01_V01
  - Device ID (did) = ca01, ca02, ca03, ...
  - Device Type (dty) = ph
  - Parameter (p) = ph, b, e
    - ph (pH value)
    - b (Battery level – 0-100)
    - e (Error code: 00 – no error, 01 – tamper, 02 – other error)
- Pressure sensor:
  - {"gid": "AP_D01_B01_V01", "did": "ps01", “dty”: “ps”, "dt": "2020-11-03T00:00:00",

    "p": {"pr": "520.22", "b": "99", "e": "00", "p4": "", "p5": “”, "p6": “”}}
  - Gateway ID (gid) = AP_D01_B01_V01
  - Device ID (did) = ps01, ps02, ps03, ...
  - Device type (dty) = ps
  - Parameter (p) = pr, b, e
    - pr (Pressure in bar)
    - b (Battery level – 0-100)
    - e (Error code: 00 – no error, 01 – tamper, 02 – other error)
- Pump controller:
  - {"gid": "AP_D01_B01_V01", "did": "pc01", “dty”: “pc”, "dt": "2020-11-03T00:00:00",

    "p": {"a": "520.22", "v": "221.22", "s": "1", "vb": "12.1", "e": “00”, "p6": “”}}
  - Gateway ID (gid) = AP_D01_B01_V01
  - Device ID (did) = pc01, pc02, pc03, ...
  - Device type (dty) = pc
  - Parameter (p) = a, v, s, l, vb, e
    - a (Current in Ampere)
    - v (Voltage in Volts)
    - s (Pump status is 1 or 0)
    - vb (Vibration in hertz) - optional
    - e (Error code: 00 – no error, 01 – tamper, 02 – other error)

ii. Metadata for IoT solution deployment

Illustrative metadata to be provided by IoT solution provider:

Data	Description
Device ID	IoT device id that will be sent as part of telemetry (e.g., fm01, fm02, ca01, gl01 etc.)
Device type	Type of IoT device (e.g., flowmeter, pressure sensor, ground water level sensor, chlorine sensor)
Latitude	Latitude of the device post installation (GPS coordinates)
Longitude	Longitude of the device post installation (GPS coordinates)
Altitude	Altitude of the device post installation (GPS coordinates)
Dimensions	Relevant dimension of the IoT device (e.g., line diameter for flowmeter – 15mm, 20mm, 60mm, 100mm etc., Dimensions of the service reservoir (Length, Breadth, Height), Height of level sensor, chlorine sensor in service reservoir etc.
Location ID / Gateway ID	Location id that will be sent as part of telemetry (e.g., AP_D12_B02_V59)
Location description	Describe location of the installed device (e.g., At ESR, At pump-cabin, At FHTC-22, At DMA-5 inlet etc.)
Model	Manufacture name and model of the IoT device
Serial number	Serial number printed on the IoT asset (manufacturer's serial number)
Power mechanism	Power mains, Solar, Battery
Communication module	Type of communication module used (e.g., RF-LoRa, GSM, NB-IoT)
Date of installation	Installation date
Name of installation technician	Vendor technician name who installed the device

Illustrative additional metadata data or properties to be maintained on the application-end to facilitate easy O&M:

Data	Description
Device name (display name)	Application display name of the IoT device (e.g., Bulk Flow Meter at outlet of ESR)
Last maintenance date	Date of last maintenance of asset
Next maintenance date	Date of next maintenance due of asset
Field engineer / technician (IoT solution vendor) - Name	Name of field engineer / technician responsible for maintenance / calibration / repair of device
Field engineer / technician (IoT solution vendor) – Phone Number	Phone number of field engineer / technician responsible for maintenance / calibration / repair of device
Field engineer / technician (PHED /RWS / MVWSS / Private / VWSC) - Name	Name of field engineer / technician from operating agency (PHED / RWS / MVWSS / Private / VWSC) responsible for overall O&M of the water supply scheme

Field engineer / technician (PHED /RWS / MVS / Private) – Phone Number	Phone number of field engineer / technician from operating agency (PHED / RWS / MVS / Private / VWSC) responsible for overall O&M of the water supply scheme
Maintenance notes	Description of maintenance notes, e.g., Fixed wiring between device and RTU, calibrated flowmeter, cleaned chlorine sensor, Replaced RTU for device

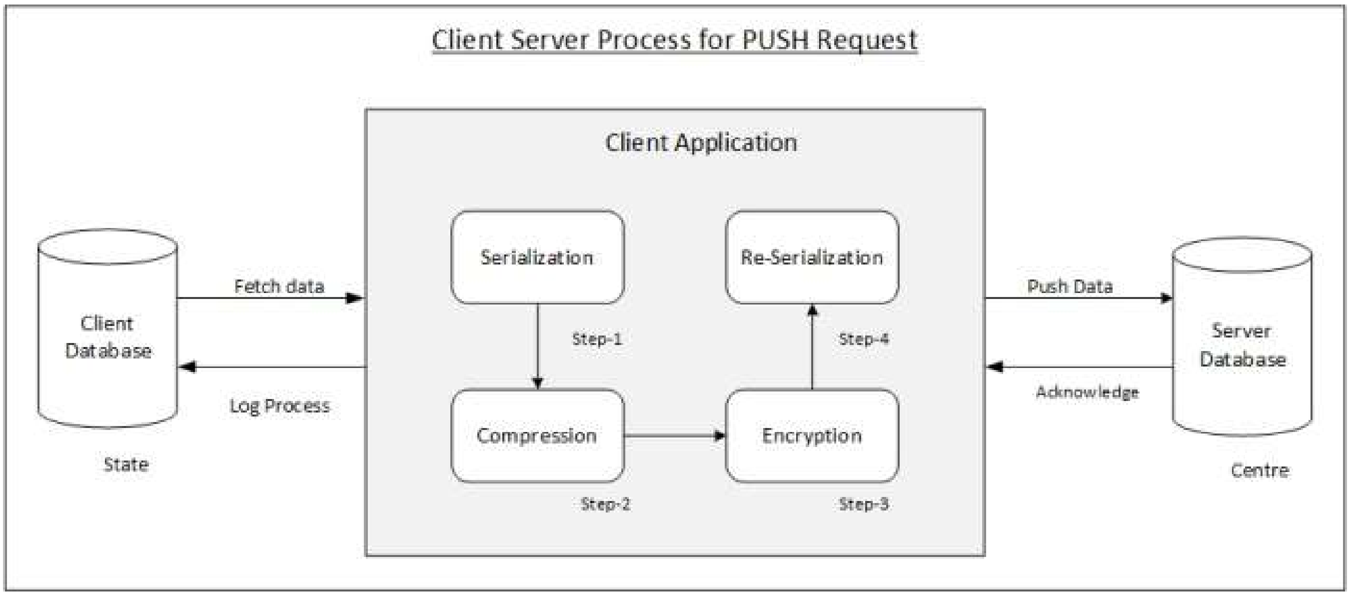
iii. State Cloud to Central Cloud API Format

PUSH data into central cloud through REST API

In this approach proposed data exchange between state servers and central server is done via REST Web API. The diagram below illustrates the data flow communication, for the client server process, for PUSH request.

State may transmit the IoT data, directly, by hitting the predefined Rest WEB API URL to PUSH data into central database using HTTPS (Secure Hypertext transfer protocol).

Each web API URL along with the JSON input parameters can be validated and return response is sent back to the source system, with output parameters such as status code (i.e., 1- Success, 0-Failure) during run time.



Sample Web API Methods and JSON data formats

API URL:
https://xxx.gov.in/IoTData/FlowmeterDataInsert

HTTPS Method: POST

Content – Type: application/JSON

Sample Input parameter JSON String – for Flowmeter


```
{
    "gid": "AP_D01_B01_V01",
    "did": "fm01",
    “dty”: “fm”,
    "dt": "2020-11-03T00:00:00",
    "p":
        {
            "t": "100.22",
            "f": "21.5",
            "b": "99",
            "e": "00",
            "p5": “”,
            "p6": “”
        }
}
```


Description of Sample Input Parameter

- Gateway ID (gid) = AP_D01_B01_V01
- Device ID (did) = fm01, fm02, fm03, ...
- Device Type (dty) = fm
- Parameter (p) = t, f, b, e
    - t (Quantity in L)
    - f (Flowrate in LPM)
    - b (Battery level 0-100)

- e (Error code 00 – no error, 01 – tamper, 02 – other error, 11 – active status at end of day)

API Response Payload:

Content – Type: application/JSON

Sample Output parameter

{
"Status":"1",
"Message":" Data uploaded successfully."
“DeviceID”:”fm01”,
“UploadedOn”:” 2020-11-03T00:00:00”
}

Description of Sample Output

- Name: Status
- Description: Customized Code
- Example:
  - 0- Failure
  - 1- Success
- Name: Message
- Description: Customized Message
- Example: Data uploaded successfully.
- Name: DeviceID
- Description: Device ID
- Example: fm01
- Name: UploadedOn
- Description: Server Response Time
- Example: “2020-11-03T00:00:00”

d. Principles of data and application management

I. Data layer

Recommended Principles	Details
Data Asset	a) Data is an asset that has a specific and measurable value to the Government and is managed accordingly b) Data from IoT device should be directly flow to Government Cloud and should not travel via any other external medium or entity c) Archive and preserve all information exchanged (both in raw and aggregated form), for future reference and if needed, for resolution of disputes. d) The Archival and preservation must be in accordance with the applicable requirements prescribed by the Mission.
Data-sharing	a) Data from IoT water sensors will be shared across the Government and various offices, subject to rights and privileges, so as to prevent creation and maintenance of duplicative sets of data by different agencies. Data Sharing shall be subject to conformance with the principles of Security & Privacy. b) Data availability to concerned users at the required time should be assured
Data Trustee	Each dataset has a trustee accountable for data quality and security.
Data Security	Data is protected from loss, unauthorized use and corruption, through adoption of international standards and best practices, duly protecting the privacy of personal data and confidentiality of sensitive data.
Common Vocabulary and Data Definitions	Data is defined consistently throughout all levels of Government, and the definitions are understandable and available to all users.

ii. Application layer

Recommended Principles	Details
Ease of Use	a) Applications should be easy to use, with the underlying technologies being transparent to the users from Ministry of Jal Shakti, State, District etc. b) All applications as deployed for IoT sensors, must support accessibility for differently abled users and adhere to GIGW Standards c) All OEMs should provide IoT devices with ETL layer in-built to translate or convert the sensor data into meaningful information as per the standards prescribed and provide the same to the designated IP directly.
Change Control	a) There must be a Change Control Board to approve and monitor the changes that are done to the software, if any b) All Change Request documents must be approved before implementation and Unit Testing and System Integration Testing must be done at pre-implementation stage
Sharing and Reusability	All commonly used Applications are abstracted to be built once and deployed across the Whole-of-Government through reuse and sharing. Sharing & Reusability shall be subject to conformance with the principles of Security & Privacy
Technology Independence	a) Application Design to be open standards-based and technology-independent and vendor neutral b) Applications to be secure by design and developed using secure coding standards and practices
Resilience	a) Application must not have any single point of failure. There must be a graceful degradation of services in case of any failure b) The applications must comply by the Recovery Point Objective and Recovery Time Objective as stipulated in the Cloud DC & DR requirements
Scalable	a) The application should be able scale elastically to handle the increase or decrease in workload. b) The Application must support horizontal and vertical scaling of Servers, compute, storage, network, etc. c) The Application must support load balancing and routing d) All applications must be able to handle volume of Y-o-Y growth for the life of the application
Performance Driven	a) The Application must comply by Service Response Time as required by the Application and stipulated in the SLAs b) All Applications must support the Availability SLAs as mentioned for each application. The system must meet the stipulated RTOs and RPOs. c) The applications must be efficient in error handling. It must also provide detailed logs to enable efficient de-bugging and issue resolution. A repository of 'Known Issues' must be made available to the System Administrator

Recommended Principles	Details
Secure	All applications as hosted or deployed for sensors must adhere to Standard Secure Coding Practices as stipulated by GIGW Standards.
Standards and Compliance	a) The applications must comply with ISO 9241-210:2010 Standards (ergonomics of human-system interaction), GIGW Standards and other standards as stipulated by the state government b) The applications must comply by ISO/IEC 25010:2011 Systems and software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) — System and software quality models, GIGW standards and other stipulated standards c) All Software documentation including but not limited to Requirement Gathering, BRS, FRS, Gap Analysis, Design, Testing Use Cases, User Guides, etc. must be maintained with proper Version Control and Access Rights. Software Traceability Matrix must be maintained

iii. Application integration layer

Recommended Principles	Details
Openness and Transparency	Government data is made open, barring exceptions (as per MoJS), so that external parties can build services
Interoperability	Interoperability should be assured through adoption of open standards and open interfaces
Data Portability	Data should be easily transferable and usable across jurisdictions, applications and systems
Primacy of User Experience	All service interactions are designed with citizens at the core, by providing integrated multi-channel
Elimination of Digital Divide	Digital public services are available to citizens and users belonging to all groups, and there are no differences and discrimination based on location (rural versus urban), access to technological infrastructure, and physical abilities
Multilingualism	Services are delivered in language/s that are preferred by the consumer

iv. Technology layer

Recommended Principles	Details
Technology neutral	IoT technology as developed should be in a technology-neutral manner so as to avoid captivity to a specific product or implementation method.
Futuristic Driven	IoT sensors are suitably designed and developed so as to be future proof, not requiring frequent revisions with the advent of every new technology.
Open Standards	Open Standards should be adopted in the design and implementation of all IoT water sensor implementation. Legacy systems are incentivized to migrate to open standards, where required.
Shared Infra	IT Infrastructure for IoT water sensors should be shared to ensure optimal utilization and effective maintenance

Recommended Principles	Details
Cloud Infra	Cloud infrastructure is recommended for deployment of applications and on-site option is resorted to only with strong justification. Mobile First Mobile channels are mandatory for delivery of all services, among all delivery channels.
Availability	The information systems along with the applications for IoT water sensors and services should be made available 24 x 7

v. **Security layer**

Recommended Principles	Details
Data Integrity	Data is correct, consistent and un-tampered.
Data Privacy and Confidentiality	Information is shared on a Need-To-Know basis and is collected/accessed/ modified only by authorized personnel.
Secure by Design	Security has to be built into all stages and all aspects of architecture development. Security concerns extend to all the IT activities of the enterprise, including anti-spoofing measures to be adopted wherever required.
Data Encryption	Data has to be shared in encrypted format only.
Availability	Infra and Application design should incorporate High Availability, Fault Tolerance at all levels
Integrity	Device Hardening, Asset Management, Configuration Assurance, Digital Certificates for securing Device Identity
Confidentiality & Privacy	Network Segmentation should be undertaken. Appropriate security controls should be put in place, where the field network, IT network and control network converge or interface with each other. In case of a security incident/compromise, the affected network should be isolated from the overall architecture. Encryption should be done on data at Rest and Transit. Weak Cipher Suites and Encryption protocols should not be used anywhere in the setup.
Access Control	Role Based Access Control should be adopted for access to the infra, application, service, database and other resources. Multi-Factor Authentication should be used. Principle of Least Privilege Access should be adopted. Administrative Access/ Control should be distributed, and any changes/action executed by Administrators and other users should be logged.
Threat Detection & Mitigation	Firewall, IDS/IPS, Log Analysis and other threat detection + mitigation controls should be used for overall threat visibility.
Risk Assessment	Periodic Audit and Risk Assessment should be done to assess the overall security posture of the setup.

e. IEEE Standards for IoT

IEEE Standards for IoT

Standards	Title
IEEE P1906.1.1	Standard data model for IOT communication systems
IEEE P1912	Standard for private and security architecture for consumer wireless devices
IEEE P1931.1.1	Standard for an architectural framework for real time onsite operations facilitation (ROOF) for IOT
IEEE P1934	Draft standard for adoption of openfog reference architecture for fog computing
IEEE P1935	Standard for Edge/ Fog manageability and orchestration
IEEE P2301	Guide for cloud portability and interoperability profiles (CPIP)
IEEE P2302	Standard for intercloud interoperability and Federation (SIIF)
IEEE P2303	Standard for adaptive management of cloud computing environments
IEEE P2413	Standard for an Architectural Framework for the IOT
IEEE P2557	Standards for Ambient Genetics Framework
IEEE P2558	Standards for Ambient Objects
IEEE P2668	Standard for Maturity Index of IOT : Evaluation, Grading and Ranking
IEEE 2200-2012	IEEE standard protocol for Stream Mgmt. in Media client devices
IEEE – 1856-2017	Standard framework for Prognostics and Health Mgmt. of electronic system
IEEE – 1703-2012	IEEE Standard for LAN / WAN for node communication protocol for end devices
IEEE – 1284-2000	IEEE standards signaling method for bi-directional parallel peripheral interface for personal computers
Device certification	UL, TUV

f. Record of discussions of committee meetings

Virtual meetings of Expert Committee on 'measurement and monitoring of water service delivery system in rural areas' held from 28 August 2020 to 18 November 2020.

Record of discussion of the meetings are as follows:-

1) In the first meeting of Expert committee the team discussed and explained the purpose of the meeting and detailed the need for measurement and monitoring mechanism for the water service delivery in rural areas, describing the problem statement, scope of work for the committee and timelines. It was also discussed that the solution should be affordable, modular, and scalable and should capture data on functionality in an automatic way.

2) In the second meeting challenges to rural water supply, benefits of rural water monitoring, sensors and gauges for surface and ground water, short, medium, long term planning perspective were discussed. 'What, where and how' of the water quantity and quality parameters that need to be monitored should be made.

3) In third meeting IoT based rural water supply system, configuration of the rural water supply system, monitoring components at different institutional level, sensor requirement as per the typology of schemes, minimum automation requirement and communication system was discussed based on the

presentation given by Mr. Rajendra Holani. The affordability could be defined in terms of cost as a percentage of the capex and opex of the scheme.

4) In fourth meeting optimal solution design for measurement and monitoring for proxy sensors was discussed and after a presentation from Mr. S.V. Deshpande on a remote monitoring system for solar-based water supply schemes, team finalized a solution design as per the following:

- Source and Intake level- Groundwater level sensor, pump controller, water quality sensor
- Treatment level- Water quality sensor
- Service reservoir level- bulk flow meter, storage/ESR level sensor, water quality sensor
- Distribution line-level- Bulk flow meter, pressure sensor at the tail end.

5) Fifth meeting was about LoRaWAN communication for IoT applications, cost comparison between LoRa and GSM.

6) In sixth meeting of Expert committee discussed about data parameters along with security of IoT sensors and application, Risk assessment, Threat modelling, vulnerability assessment and penetration testing of any IOT system. The committee based on previous presentation agreed on Network technology, communication, and security protocol it was also considered that a dedicated resource pool may be required across all levels in state to leverage this remote monitoring solution where existing resources could be skilled/trained.

7) In seventh meeting, NIC gave a presentation on rural connectivity, difference between GSM and LPWAN (e.g., LoRa), followed by presentation from Mr. Siddhant Masson on governance structure of smart measurement and monitoring rural water supply system. It was also considered that security protocol and specifications for sensor devices should be given by NJJM.

8) In eighth meeting, Smart Water Supply including measurement and monitoring under Smart City Mission was presented by Mr. Lal Chandama. The second presentation highlighted the security of any IOT Eco system- and what components must be secured in an IOT eco system.

9) In ninth meeting, IoT hardware and security protocol was discussed through CDAC by suggesting different hardware devices for IoT ecosystem. Xylem presented on hardware specifications of Flowmeters and level sensors. Governance framework report structure, roles, and responsibility that various stakeholders at village and district level would play was emphasized by Mr. Siddhant Masson. NIC was asked to prepare an IoT architecture for NJJM rural water supply.

10) In tenth meeting, Mr. Manish Singh from TCS explained reference architecture for IoT implementations as per global standards, he talked about RAMI 4.0 and IIRA frameworks and suggested a cloud native microservices based architecture would be preferred for such an implementation. He further elaborated on several security protocols – TLS / DTLS etc.

11) In eleventh meeting, Department of Telecommunication and Amazon detailed on standards & security of IoT Domain and Cloud services respectively regarding Jal Jeevan Mission. Authentication and identification being important part of IoT domain were discussed briefly along with cloud services storage and post agreement part of cloud services. The Third presentation was given by Ms. Seemantinee about the principles for data and Application management. It was analysed that all these presentations and meetings gave a wide respective on the framework of monitoring and protocol and through them hybrid model for IoT ecosystem can be developed. The team advised to have a super Scada for every scheme.

12) In the twelfth meeting Ericsson presented about IoT domain through 2 case studies and explained how they provided solution to different problem of Mori Pedu village regarding Stinky water, chlorination, and overflow of overhead tank through various sensors. The standardization of sensors was discussed with emphasis on network technology used in the ecosystem. Team analysed that there should be some certain set of standards for specifications of sensors and security protocol for whole IoT ecosystem.

g. Success stories and pilot implementations

i. Tata Smart Rural Water Management (Tata Community Initiatives Trust and Tata Trusts)

1. Village Overview

I.) Single Village Scheme (SVS) in a habitation – Upli Ubariya Fali Habitation of Gharat

ii.) Remote location – hilly terrain (no paved road, dirt road)

iii.) Backward tribal village (ST habitation) with prior instances of unequitable supply to weaker sections

iv.) 24 households with a total of population of 130 people

v.) Solar power based borewell pumping scheme with basic treatment (chlorination) – commissioned in 2017

vi.) Scheme CAPEX of Rs. 6.5 lacs funded 90% by Center for Micro-Finance (CMF) an Associate organization of Tata Trusts and 10% by community

vii.) Scheme supported by CMF; providing implementation support

viii.) VWSC formed; 23 out of 24 members are women

ix.) O&M tarriff of Rs. 50 per household per month

x.) Kitchen gardern for grey water management in every household

xi.) Continuous Contour Trenches (CCT) built for source rejuvenation

xii.) Water testing done frequently using Field Testing Kits (FTKs) and once in 6-12 months from the District lab

xiii.) 100% Functional Household Tap Connection (FHTC) coverage

xiv.) 100% solar power based scheme with no grid-supply

xv.) Two clusters of houses had frequent water outages due to low pressure

2. Pilot Objectives

The objectives of this pilot were as follows:

I.) Monitor the functionality of scheme

ii.) Ensure that adequate quantity of water is being supplied (55 LPCD)

Solar powered pump house for borewell

Women from one of the clusters with water outages (before IoT)

Groundwater level sensor installed at site iii.) Monitor the frequency and periodicity of supply

iv.) Ensure that basic water treatment (chlorination) is being done regularly

v.) Ensure equitable distribution of water across habitations including backward habitations

vi.) Monitor the ground water level and ensure timely intervention (e.g., source augmentation) as and when required

vii.) Enable pump automation thereby reducing repair/ replacement cost and minimizing water wastage

viii.) Minimize Non-Revenue Water (leakage/ unauthorized connections) throughout the network

ix.) Ensure adequate pressure of water in every habitation/ cluster including backward and distant habitations

x.) Monitor household level consumption to allow VWSC to take informed decisions about tariff setting and collections

xi.) Enable effective management of the entire scheme by VWSC using IoT

3. IoT solution design

I.) First of its kind deployment in rural water supply scheme context – completely IoT enabled including consumer level consumption monitoring

ii.) All use-cases enabled – end-to-end monitoring across ground water source level, residual chlorine, ESR tank level, pump controls, bulk flow metering, consumer level metering, and tail-end pressure

iii.) Implemented advanced solution design at a cost of Rs . 8 lacs (Rs. 6 lacs for sensors and devices and Rs. 2 lacs for installation work).


Chlorine sensor installed at site

RTU connected to the flow meter to wirelessly send data to LoRa gateway

Sensor	Source	Service reservoir	Distribution	Connections
Bulk Flow Meter (with RTU)		**2** (1 At inlet of SR i.e., outlet of pump and 1 at outlet of - ESR)	**4** (At entry of **4** cluster)	
Consumer Flow Meter (with RTU)				24+1 (At every household and 1 at cattle trough)
Chlorine sensor		**1** (Submerged probe in ESR)		
Ground water level sensor	**1** (submerged in borewell)			
Pressure sensor (with RTU)				**4** (At tail-end of every cluster)
Pump controller	**1** (In pump cabin)			
Gateway (edge device)		**1** (In pump cabin room)		
Display unit for village Dashboard		**1** (In pump cabin room)		

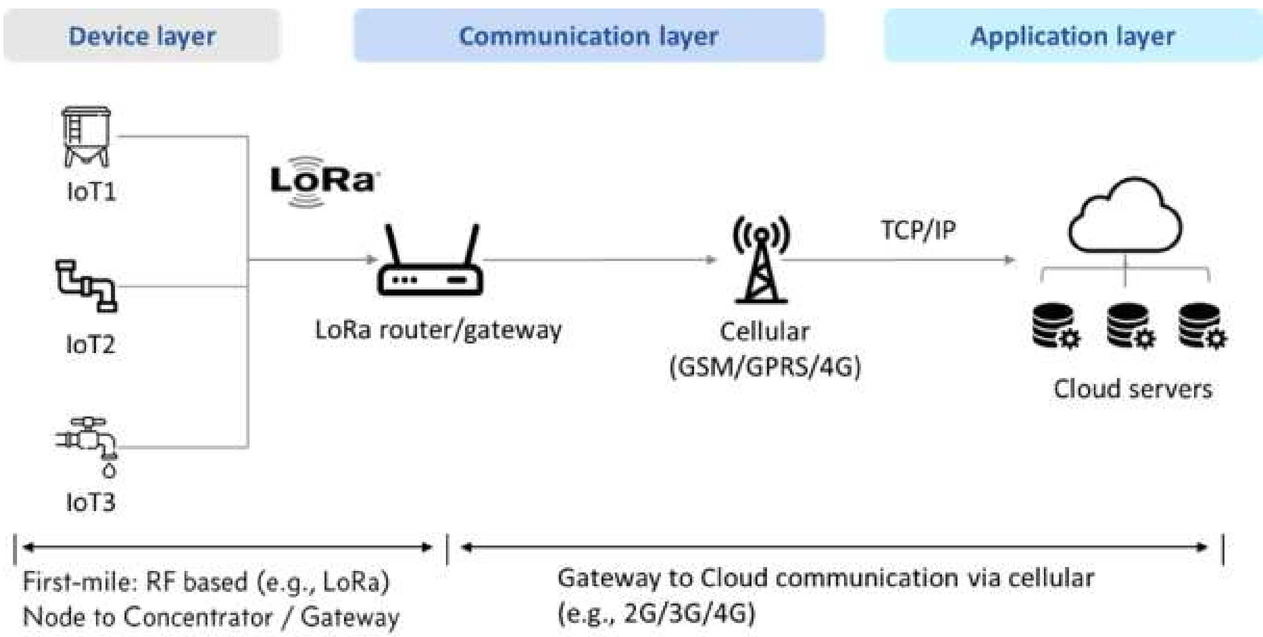
4. **Network Architecture**

I.) Device to gateway and gateway to cloud architecture

ii.) The sensors/ devices are connected to a battery powered Remote Terminal Unit (RTU) with 4-5 years of battery backup which communicates with the gateway wirelessly using LoRa – Long Range unlicensed radio frequency

iii.) The gateway is powered by a battery charged by solar panel. This gateway communicates with the server using a 4G sim card

Figure 21 Network Architecture: LoRa (first-mile) + 4G enabled gateway



5. **Key enablers**

I.) Strong community mobilization – played a key role in gathering enormous support of the community for the deployment including excavation on private property (for consumer flow meters)

ii.) ISA's support (CMF/ Tata Trusts) – the local team of ISA had deep relationship with the village community which contributed in community's willingness to adopt IoT based smart water management

iii.) Local manpower (e.g., plumbers, electricians) – use of local resources provided following key benefits:

a. Skilling/ training of local resources in the field of IoT

b. Creating employment and increasing their earnings

c. Instilling a sense of ownership of the project

d. Reducing the cost of operating and maintaining the system (e.g., minor repairs like loose connection or battery replacement are now done by local resources with minimal remote supervision)

iv.) Training and handholding of VWSC throughout the deployment process meant that at the time of commissioning the VWSC felt like an equal partner, ready to shoulder the responsibility of:

a. Consuming the dashboards to improve their role as 'Utility Operators'

b. Ensuring safety and security of the devices

v.) Instilling a sense of ownership and pride in the community – throughout the deployment process, through regular Information, Education, and Communication (IEC) activities

Local plumber installing flow meters post training

VWSC meeting

Awareness and training for VWSC members

6. **Dashboards and SMS alerts**

I.) **Village dashboard –** created a simple to understand dashboard for the village community which is available on the display screen placed in pump house. It has key high-level metrics in a User Interface (UI) which is visual for easy comprehension by villagers in local vernacular:

a. LPCD

b. Quality of water

c. Pressure

d. Water level in ESR

e. Pump status

f. Ground water level

g. Per household consumption in LPCD

ii.) **Officials' dashboard –** created advanced dashboards for the consumption of officials at NJJM, State Government, District Government levels and PHED engineers. It has several metrics, some of them are listed below:

a. Water pumped and supplied

b. LPCD – overall, cluster, and household level consumption

c. Quality of water (time series)

d. Pressure of water in each cluster (time series)

e. Ground water level (time series)

f. Detailed analysis of pump operations – current, voltage, duration of pump operations

g. Level of water in tank

h. Scheme layout

i. IoT setup - location of IoT sensors, status of sensors, and level of battery

iii.) SMS alerts – creating alerting mechanism for VWSC giving them key action items (if any) and the highlights of service delivery e.g., LPCD, water quality, and pressure

7. **Impact created on the ground (realized benefits)**

I.) **Equitable distribution of water - all clusters now get water supply (adequate quantity and pressure):** visibility of the issue of low pressure in two clusters led to the community installing two gate valves to regulate pressure

VWSC member analyzing the Village Dashboard on TV display in pump house

District official reviewing the Officials' Dashboard ii.) **Regular chlorination process at the service reservoir:** visibility of residual chlorine levels on the TV screen dashboard created awareness and led to the behavior change and regular disinfection by local community operator

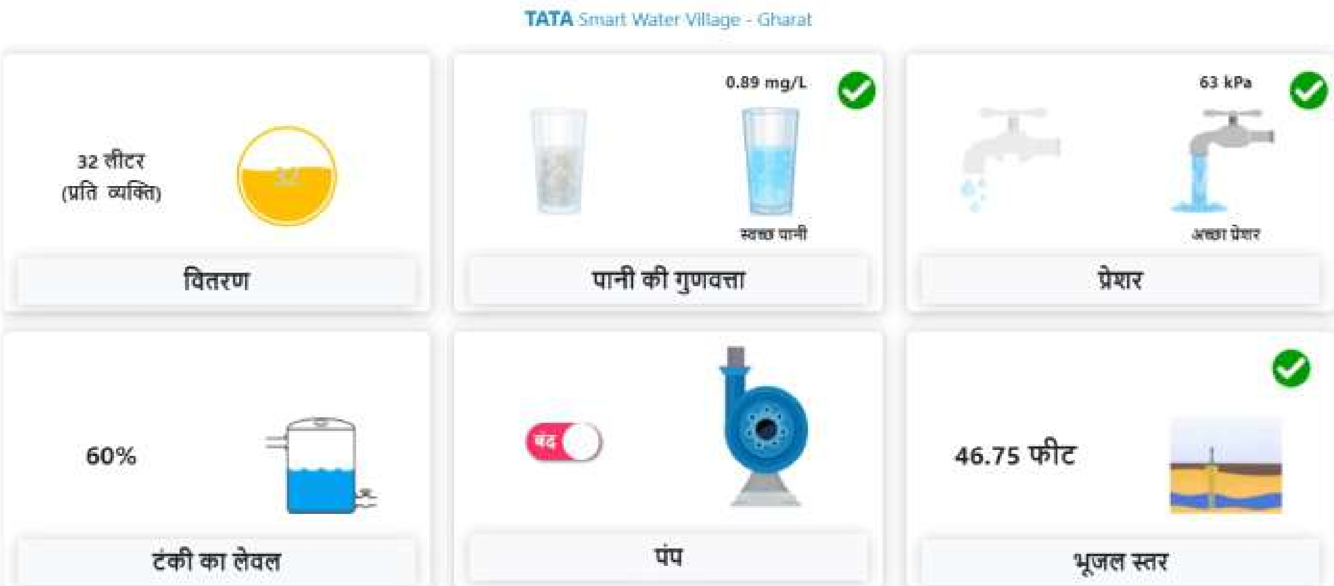
iii.) **Efficient and responsible use of water by end customers by metering the quantity consumed:** VWSC is now monitoring consumption to ensure no one is wasting water or using tap water for agriculture purpose

iv.) **Long term sustainability of water source** through improved source monitoring – community has observed on the TV screen dashboard that ground water has reduced by 0.2 feet over a two week period which has led to the awareness that water is not unlimited and there is a possibility of source drying, if used irresponsibly

v.) **Reduced cost of operations** through data-enabled leak detection, predictive maintenance, and automation

8. Village dashboard (for community in Hindi)

Page 1:



Page 2:

TATA Smart Water Village - Gharat

घर का नल	मीटर आईडी	नाम	कुल सदस्य	कल का उपयोग (प्रति व्यक्ति)	पिछले 30 दिनों का उपयोग (प्रति व्यक्ति)
FHTC1	fm32	मेगी बाई (लक्ष्मण राम)	4	30L	45.62L
FHTC2	fm35	सुरेश कुमार (रावता राम)	2	95L	28.75L
FHTC3	fm25	सोनकी बाई (रता राम)	6	21.66L	32.08L
FHTC4	fm26	शांति बाई (प्रभु राम)	5	14L	18.66L
FHTC5	fm27	लखी बाई (महेंद्र राम)	6	16.66L	8.47L
FHTC6	fm28	हाजरी बाई (कालू राम)	8	30L	20.93L
FHTC7	fm29	ओदी बाई (पिता राम)	8	25L	40.72L
FHTC8	fm30	हंसी बाई (पिता राम)	6	18.33L	19.58L
FHTC9	fm09	शांति बाई (भवरलाल)	3	13.33L	5L
FHTC10	fm31	धापू बाई (नरशा राम)	4	22.5L	30L
FHTC11	fm11	पुरी बाई (रावता राम)	6	20L	10.55L
FHTC12	fm12	सीता बाई (हंसराम)	6	15L	22.08L

Page 3:

TATA Smart Water Village - Gharat

घर का नल	मीटर आईडी	नाम	कुल सदस्य	कल का उपयोग (प्रति व्यक्ति)	पिछले 30 दिनों का उपयोग (प्रति व्यक्ति)
FHTC13	fm13	कुकी बाई (सामता राम)	6	16.66L	10.27L
FHTC14	fm14	राणी बाई (सोवन राम)	4	0	28.3L
FHTC15	fm15	सुगनी बाई (नेति राम)	5	22L	20.5L
FHTC16	fm16	नाजु बाई (मनरूप राम)	7	11.42L	18.45L
FHTC17	fm17	पुष्री बाई (बाबू राम)	6	43.33L	31.94L
FHTC18	fm18	सोनी बाई (धना राम)	6	15L	7.36L
FHTC19	fm33	सुनीता (अमरा राम)	4	35L	12.91L
FHTC20	fm20	रंगी बाई (मेहता राम)	2	15L	30L
FHTC21	fm21	केसी बाई (चतरा राम)	3	26.66L	18.88L
FHTC22	fm22	पेपी बाई (मनसा राम)	10	24L	12.91L
FHTC23	fm23	चुनी बाई (लादू राम)	7	17.14L	11.66L
FHTC24	fm34	बबली बाई (सका राम)	6	0	3.33L

9. Engineer / Officials' dashboard

TATA Smart Water Village - Gharat, Sirohi, Rajasthan

GIS Locations

TATA Smart Water Village - Gharat, Sirohi, Rajasthan

01-12-2020 12-12-2020

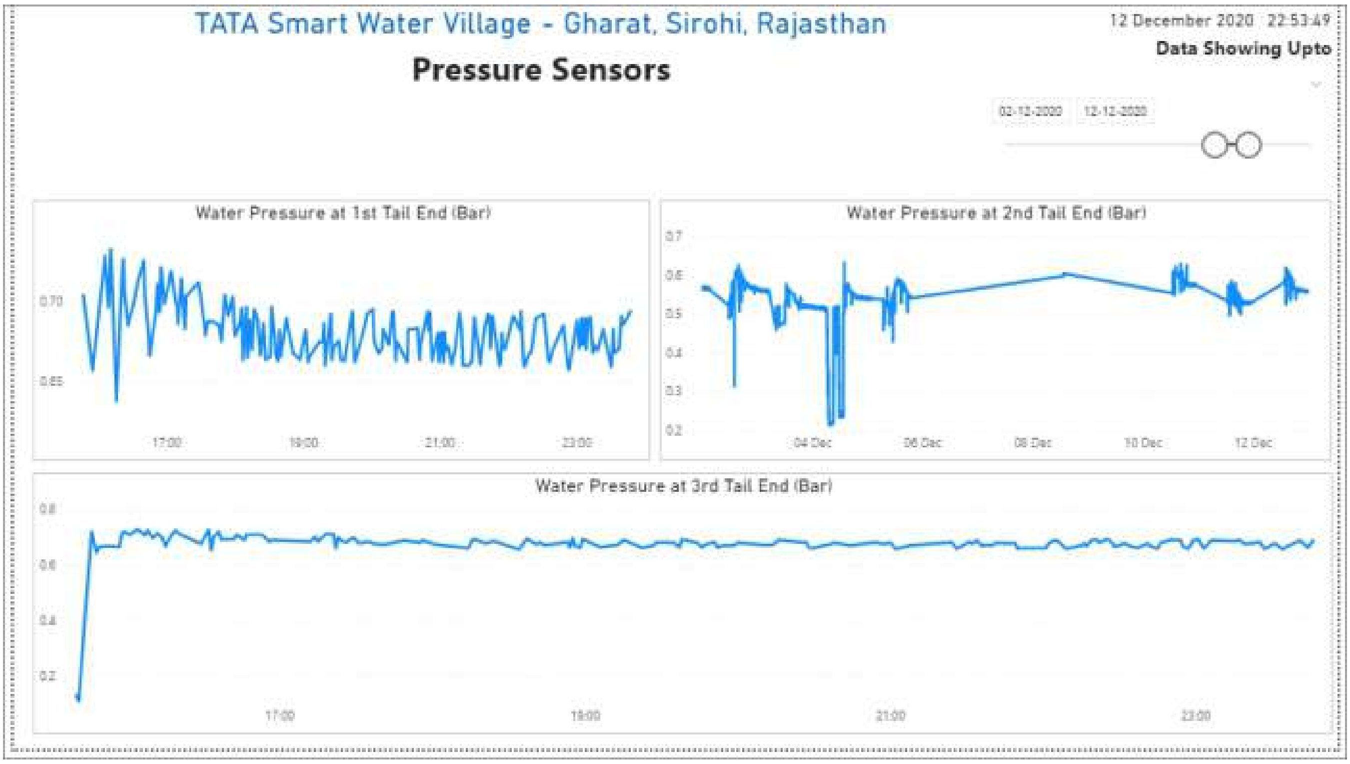
12 December 2020 22:53:49

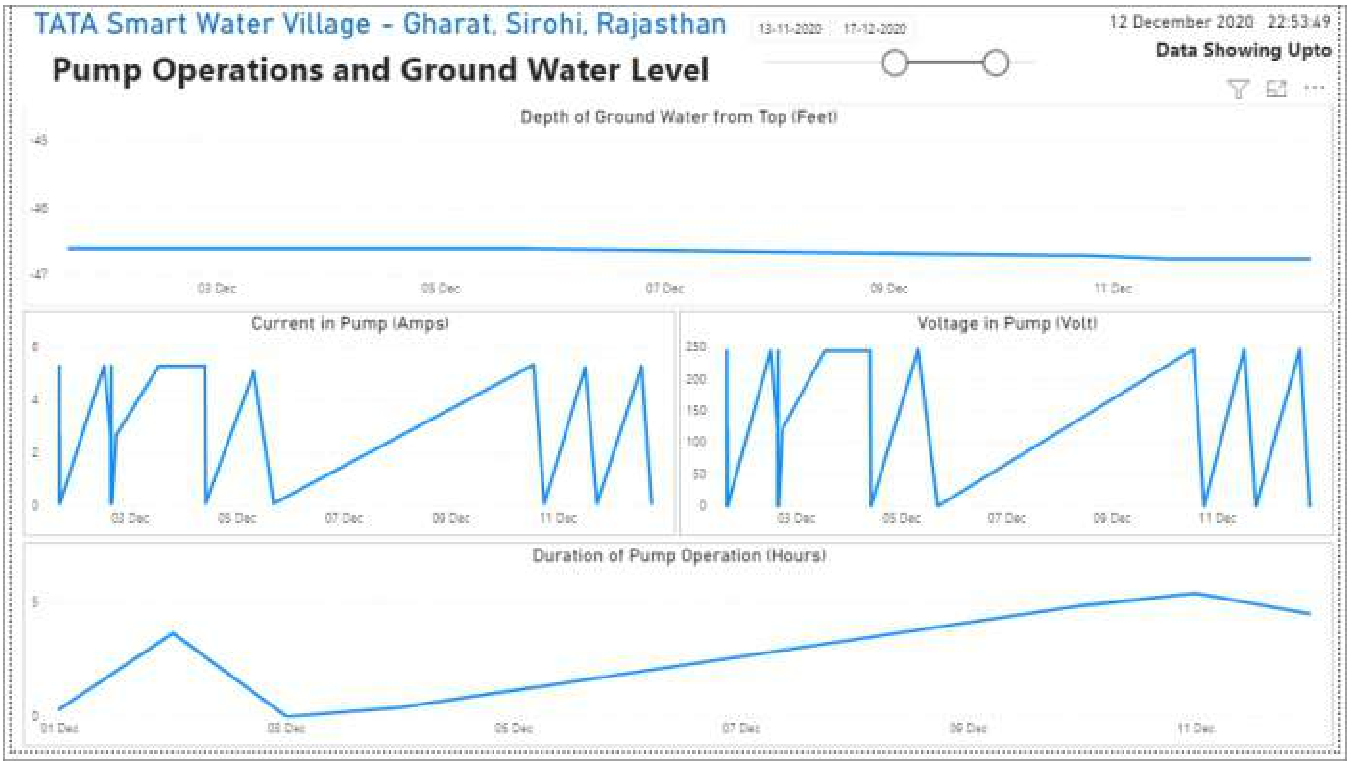
Data Showing Upto

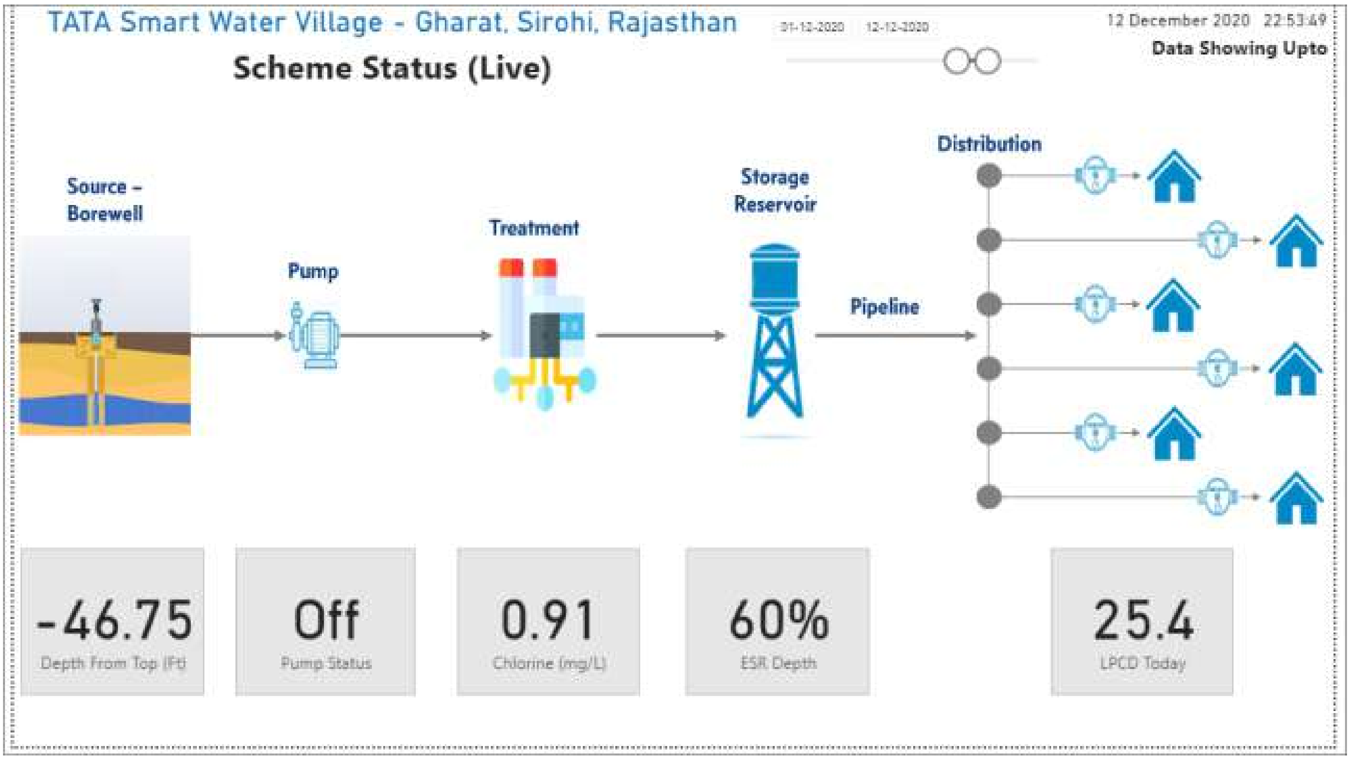
Household Level Monitoring

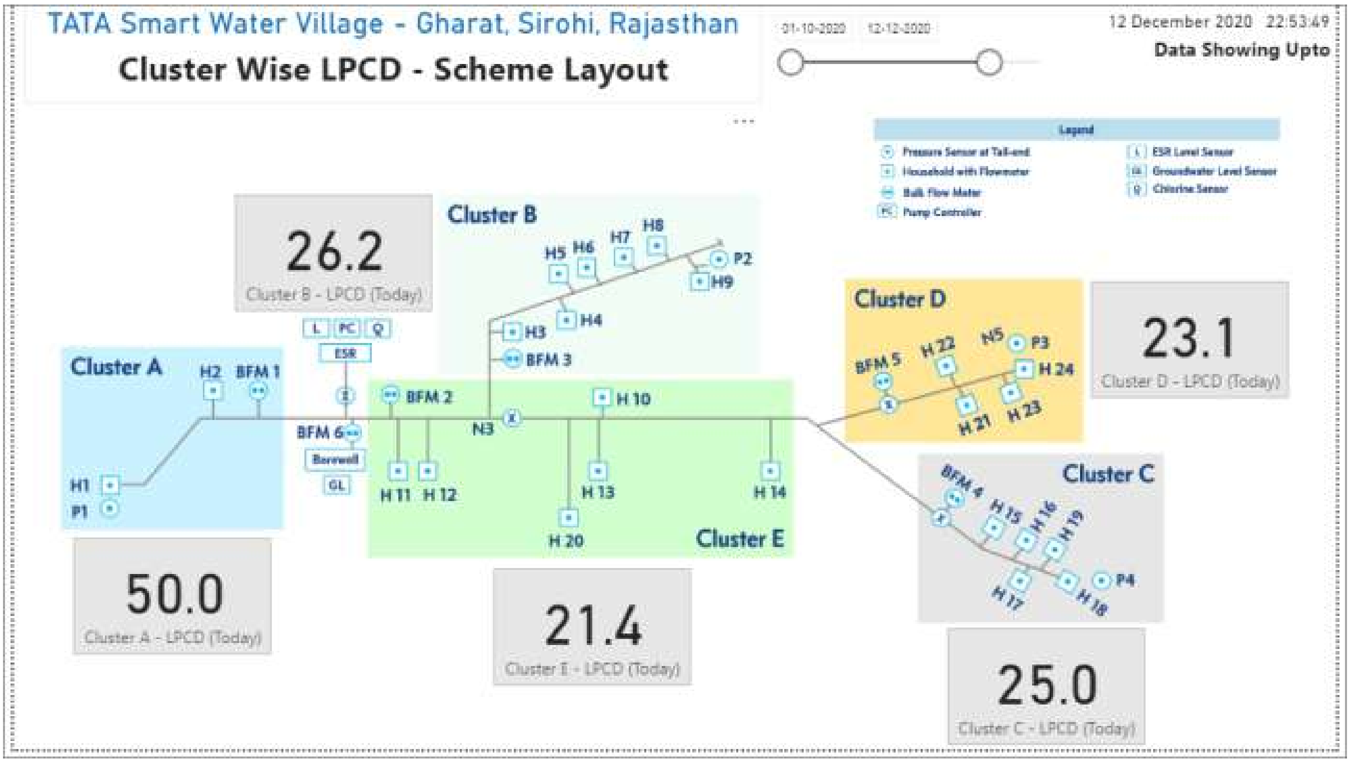
Consumer Wise Consumption

S. No.	FHTC ID	Owners' Name	No. of Members	IoT ID	LPCD Today	Indicator
1	FHTC1	Magi Bai w/o Lakshman Ram	4	fm32	33	
2	FHTC2	Suresh Kumar s/o Ravta Ram	2	fm35	55	
3	FHTC3	Sonki Bai w/o Rata Ram	6	fm25	13	
4	FHTC4	Shanti Bai w/o Prabhu Ram	5	fm26	18	
5	FHTC5	Lashi Bai w/o Mahendra Ram	6	fm27	23	
6	FHTC6	Hajri Bai w/o Kalu Ram	8	fm28	14	
7	FHTC7	Odi Bai w/o Pita Ram	8	fm29	45	
8	FHTC8	Hansi Bai w/o Pita Ram	6	fm30	42	
9	FHTC9	Shanti Bai w/o Bhavar Lal	3	fm09	20	
10	FHTC10	Dhapu Bai w/o Narsha Ram	4	fm31	20	
11	FHTC11	Puri Bai w/o Ravta Ram	6	fm11	20	
12	FHTC12	Sita Bai w/o Hansa Ram	6	fm12	25	
13	FHTC13	Kuki Bai w/o Samata Ram	6	fm13	13	
14	FHTC14	Rani Bai w/o Sovan Ram	4	fm14		
15	FHTC15	Sugani Bai w/o Neti Ram	5	fm15	14	
16	FHTC16	Naju Bai w/o Manroop Ram	7	fm16	23	
17	FHTC17	Chunni Bai w/o Babu Ram	6	fm17	52	
18	FHTC18	Soni Bai w/o Dhana Ram	6	fm18	28	
19	FHTC19	Sunita w/o Amra Ram	4	fm33	5	
20	FHTC20	Rangi Bai w/o Mehta Ram	2	fm20	45	
21	FHTC21	Kesi Bai w/o Chatra Ram	3	fm21	43	


TATA Smart Water Village - Gharat, Sirohi, Rajasthan
Pressure Sensors
12 December 2020 22:53:49
Data Showing Upto
02-12-2020
12-12-2020
Water Pressure at 1st Tail End (Bar)
Water Pressure at 2nd Tail End (Bar)
Water Pressure at 3rd Tail End (Bar)

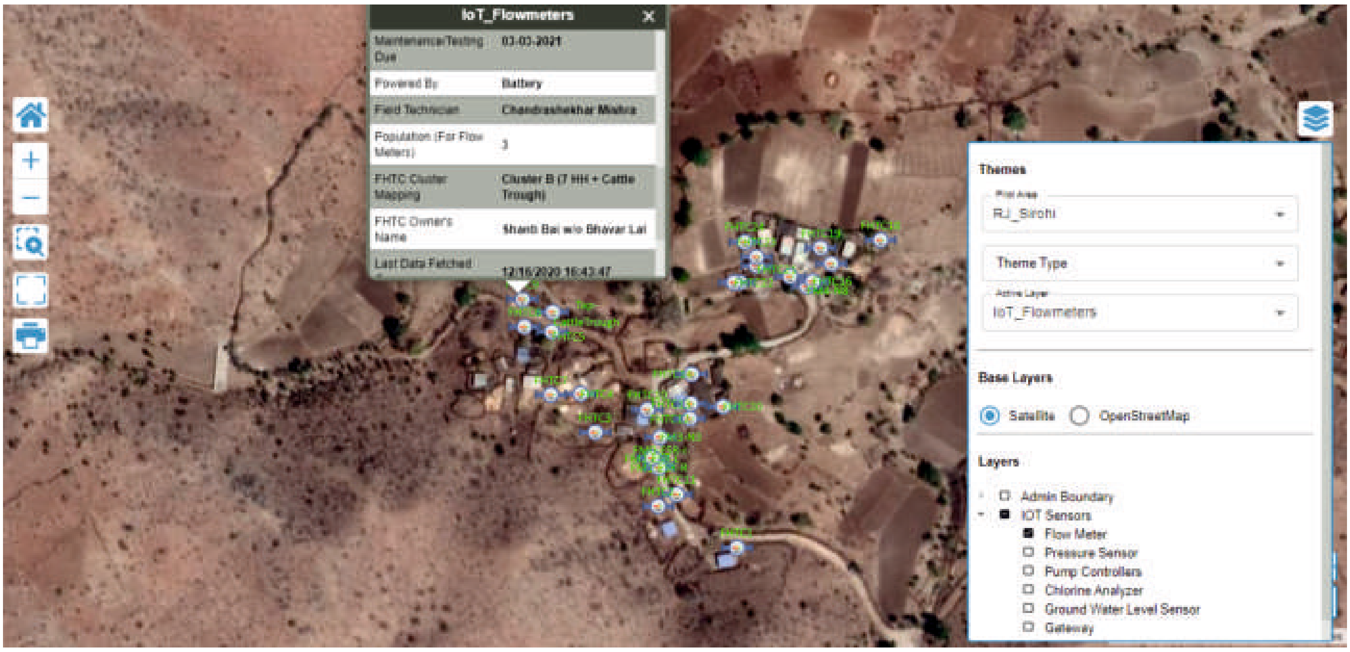

TATA Smart Water Village - Gharat, Sirohi, Rajasthan
Pump Operations and Ground Water Level
13-11-2020
17-12-2020
12 December 2020 22:53:49
Data Showing Upto
Depth of Ground Water from Top (Feet)
Current in Pump (Amps)
Voltage in Pump (Volt)
Duration of Pump Operation (Hours)


TATA Smart Water Village - Gharat, Sirohi, Rajasthan
Scheme Status (Live)
01-12-2020
12-12-2020
12 December 2020 22:53:49
Data Showing Upto
Source - Borewell
Pump
Treatment
Storage Reservoir
Pipeline
Distribution
-46.75
Depth From Top (Ft)
Off
Pump Status
0.91
Chlorine (mg/L)
60%
ESR Depth
25.4
LPCD Today


TATA Smart Water Village - Gharat, Sirohi, Rajasthan
Cluster Wise LPCD - Scheme Layout
01-10-2020
12-12-2020
12 December 2020 22:53:49
Data Showing Upto
Legend
Pressure Sensor at Tail-end
Household with Flowmeter
Bulk Flow Meter
Pump Controller
ESR Level Sensor
Groundwater Level Sensor
Chlorine Sensor
26.2
Cluster B - LPCD (Today)
Cluster B
Cluster A
Cluster D
Cluster C
Cluster E
23.1
Cluster D - LPCD (Today)
50.0
Cluster A - LPCD (Today)
21.4
Cluster E - LPCD (Today)
25.0
Cluster C - LPCD (Today)

TATA Smart Water Village - Gharat, Sirohi, Rajasthan

GIS Location - Village IoT Assets



ii. Ericsson – Smart Water Grid Management Pilot

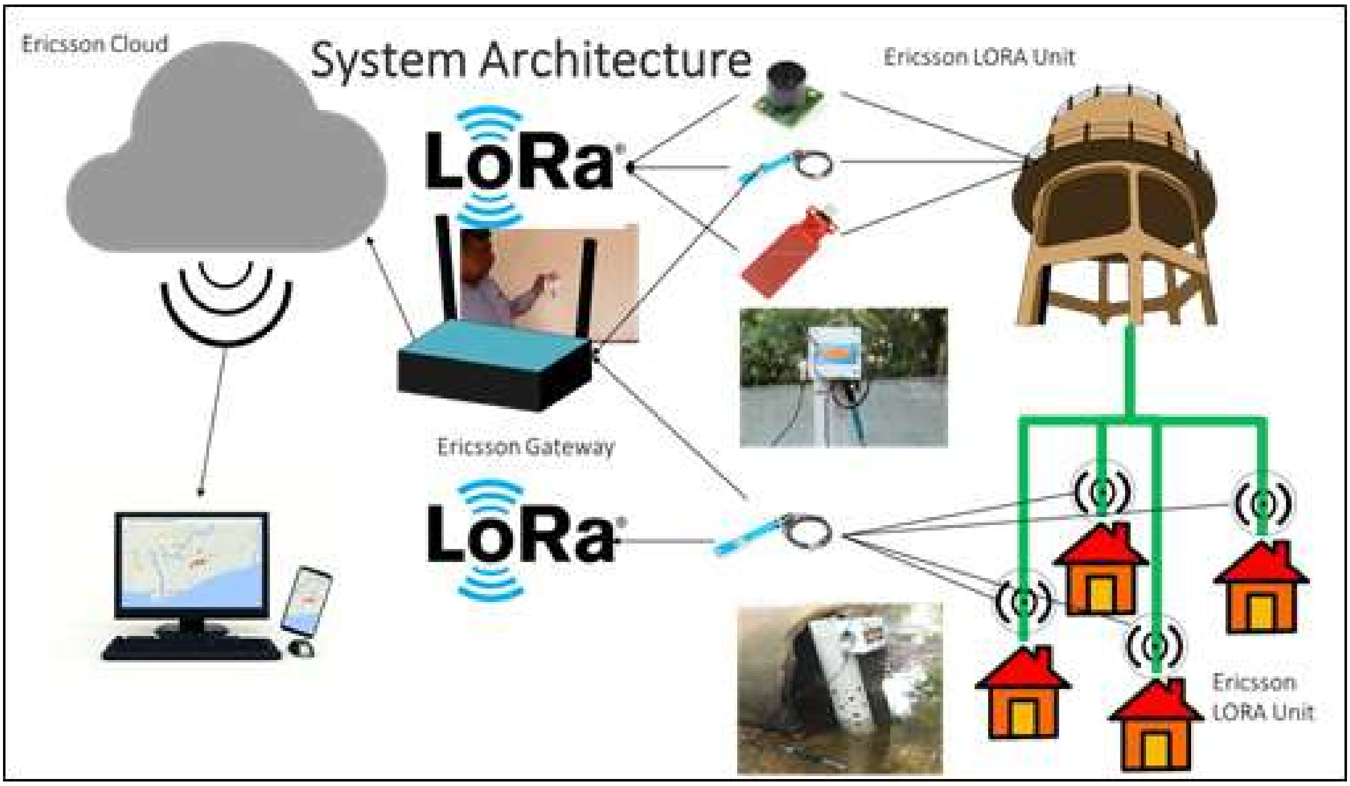
1. Village overview and key issues

- I.) Mori Podu village in Andhra Pradesh;
- ii.) Heavily dependent on river Godavari for irrigation purposes;
- iii.) Manually worked locks employed at the mouths of the distributaries to control the flow of water;
- iv.) Poor quality of water – smelly water and yellow colour;
- v.) Insufficient supply for usage in village;
- vi.) During heavy water flow, the locks are lowered to reduce the flow of water to prevent flooding, it takes more than a day to get a remedy;
- vii.) Back water in salt lake can enter the canals to increase the salinity level;
- viii.) Time taken to employ the locks near the salt lake to control the reverse flow of water;
- ix.) Automatic way of informing these issue was not available.

2. Smart solution by Ericsson

- I.) Automate the checking of quality of water supply;
- ii.) Sensors immediately notify the quality to higher authorities to take immediate action;
- iii.) Periodic mails /SMS will be generated to take action on the quality of water – goes to next hierarchy level;
- iv.) LoRa and 5G enabled architecture;
- v.) Cloud-based solution makes the availability of data on mobile phone;
- vi.) Automated or manually operated lowering and raising of locks;
- vii.) Timely serving of water according to the farmer's needs;
- viii.) Automatic mechanism of implementing the lock based on sensor value.

3. System architecture



4. Outcomes achieved

I.) Water Lock Automation

a) When a lower level of flow is detected, the automated water locks are raised to ensure smooth flow of water;

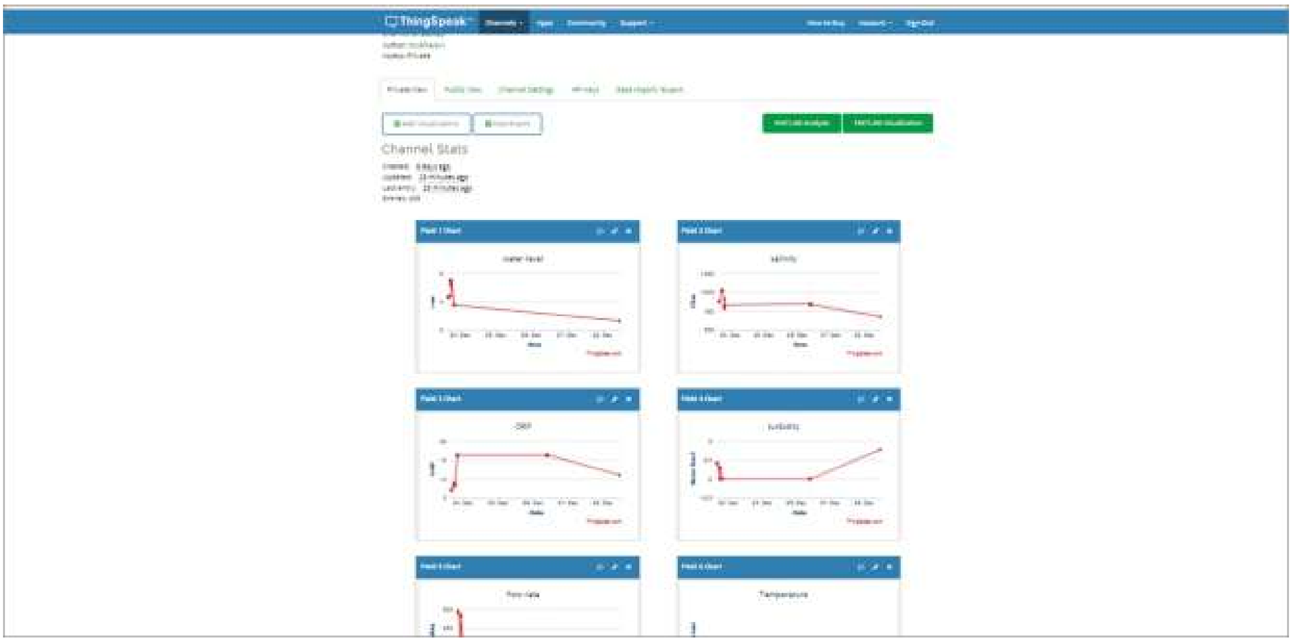
b) Similarly, when the flow of water is too much, the locks are lowered to reduce the flow of water to prevent flooding;

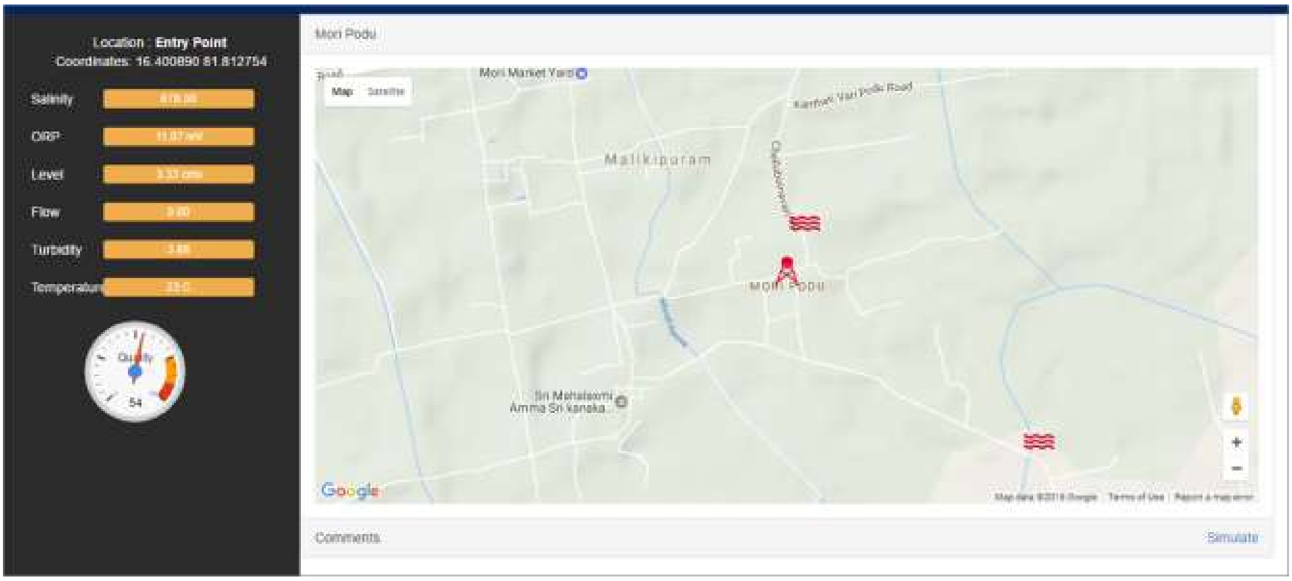
ii.) Controlling Water Salinity

a) Water Salinity checks are performed through sensors fitted in the canals going to the farmlands;

b) The sensors detect abnormal salinity levels and a message is automatically received at the Chief Engineer's office;

c) The Chief Engineer informs the local authorities who remedy the situation through water treatment.





iii. Remote monitoring system for solar based water supply schemes[3]

1. Overview

I.) Remote monitoring System (RMS) of solar water pump system can be used for monitoring running condition of the system, performance of the system and validation of a lot of other data related to analysis of performance of the Scheme.

ii.) Requirements:

a) RMS enabled water pump controller;

b) SIM card – M2M sim cards work better here since they are designed for such applications and are far cheaper than regular sim cards used for voice calls etc;

c) Availability of network – at least 2G.

[3] Shared by Shri SV Deshpande (Ex-Joint Director – Engineering, Groundwater Surveys and Development Agency, Water Supply and Sanitation Department, Government of Maharashtra, Consultant – Renewable Energy and Rainwater Harvesting Solutions, Pune)

2. Architecture

I.) The RMU (Remote Monitoring Unit) captures the data from the motor and the controller and send the data docket to the server using internet connection at the SIM card;

ii.) The data received at server is then shown in readable format to the user through specifically designed software and user interface;

iii.) The data can be seen on any web browser (Firefox, Chrome, Safari, Edge etc) on a laptop, tablet or mobile;

iv.) Depending upon the type of the user, the data that needs to be shown can be configured and relevant data is shown to the respective user;

v.) Remote Monitoring Features: -

a) Network based GEO location of the controller installed;

b) IMEI based unique identification of unit;

c) Live running status;

d) Historical Reports;

e) SD card logging of all above said parameters;

f) Works with input DC voltage range from 5V to 28V;

g) Master Modbus RTU protocol implemented for any slave device;

h) LED indications for user reference;

i) Long range antenna with strong reception and transmission through network signal;

j) Parameters can be sent through TCP/IP, HTTP or to the website link directly;

k) IP address and port number of private TCP can be changed through normal text input message;

l) Incoming call based controlling drive;

m) Temporary NOR flash memory installed for saving Drive parameters when network is not available;

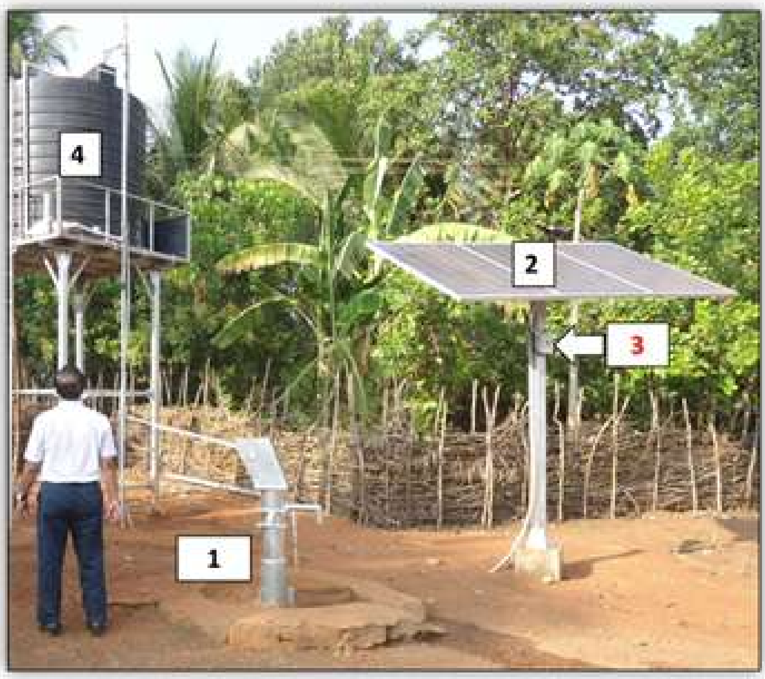
n) Centralised server & database for data storage and security;

o) Control and monitor room for all devices installed over the globe;

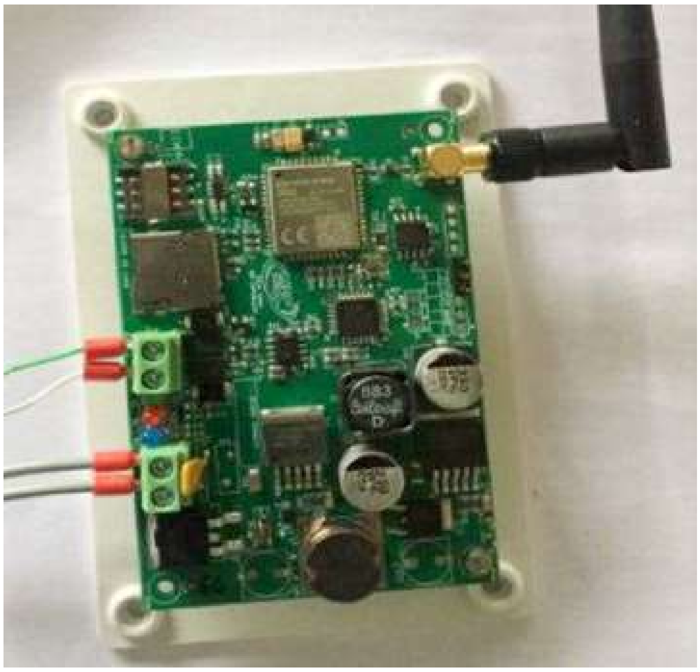
Overall Design

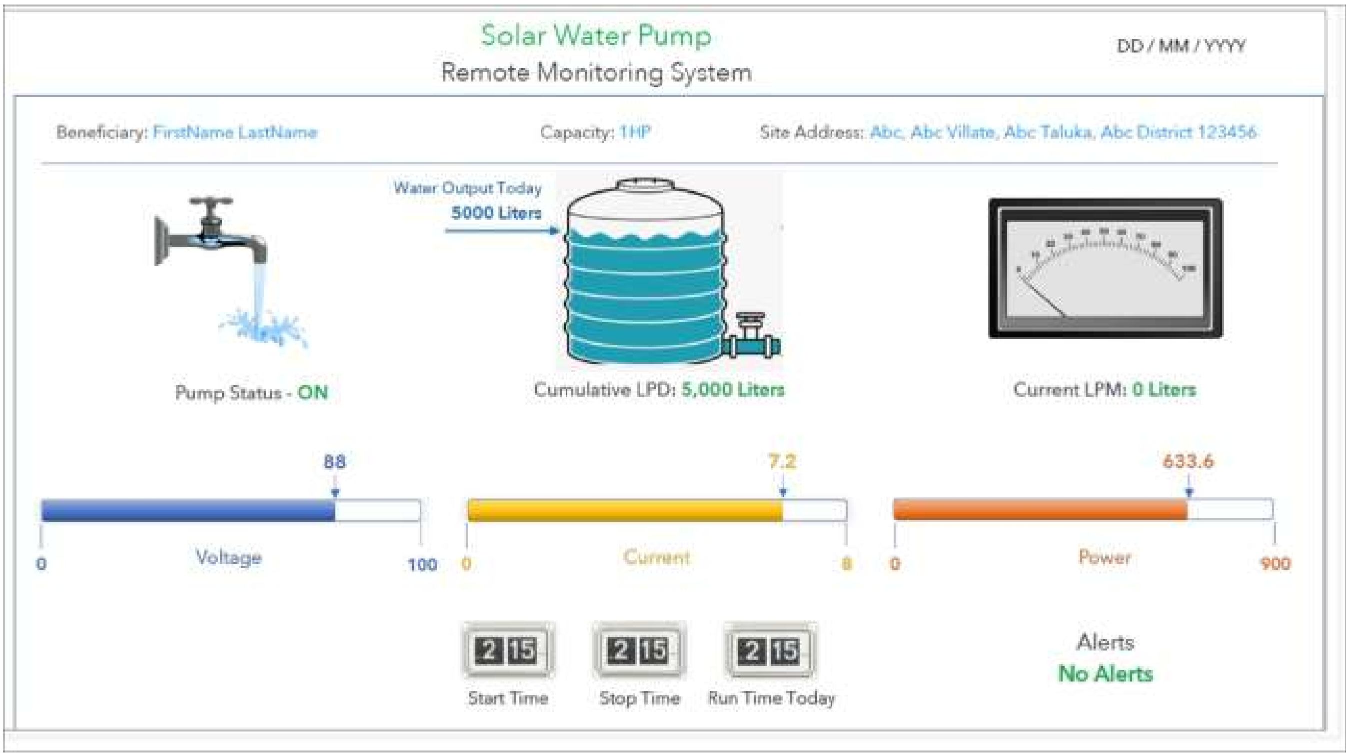
Legends

1. Bore well in which 1 HP Solar submersible pump installed in addition to existing Hand pump with the help of Special Water chamber developed by GSDA
2. Solar Panels
3. Solar Pump Motor Controller with RMS Unit
4. 5000 Liters Capacity HDPE tank fitted with float sensors for controlling switching on the motor when tank gets empty and switch of when tank gets filled

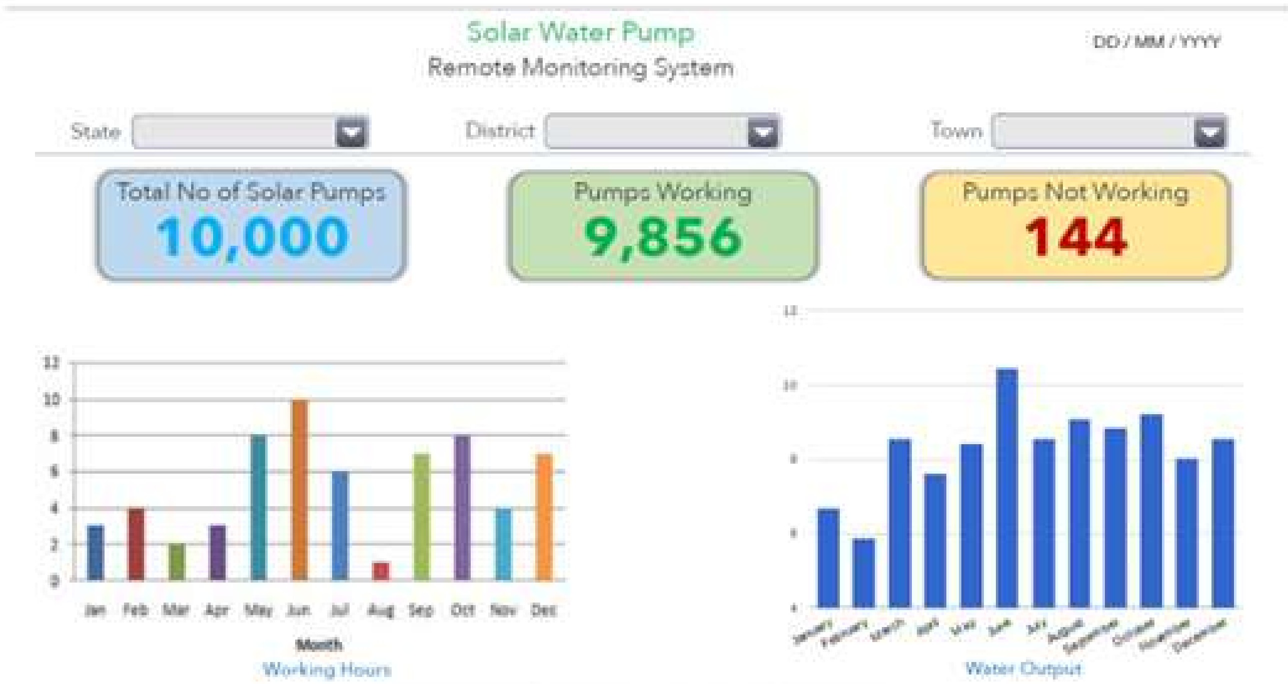


Remote Monitoring System





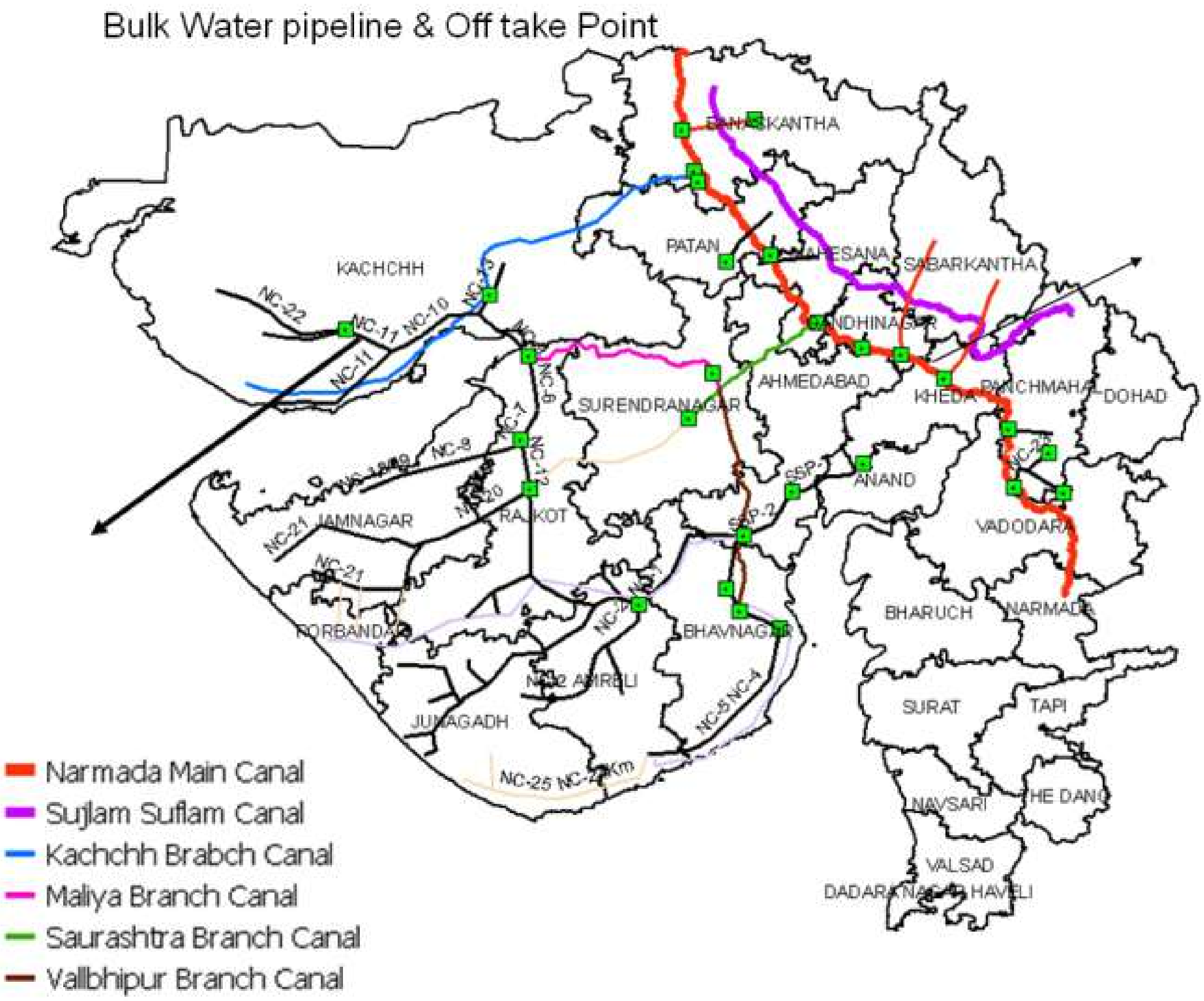
RMS DASHBOARD FOR DIVISION / CIRCLE OFFICE / CE OFFICE /HEAD OFFICE / SECRETARIATE



S V DESHPANE, Retd Joint Director (Engineering) GSDA, WSSD, GoM, Pune

iv. GIS based monitoring of regional water supply in Gujarat[4]

Water Supply Infrastructure (Example)



The structure and components of the database to be created for incorporation in the GIS system will have following structure. Such data bases will have to be created at the various hierarchical levels of the components of the water supply infrastructure.

I. Database Structure:

Source: Maps from local authorities and Local knowledge (Engineers)

I.) Location of water sources

a. Ground Water (Well, Tube well, Hand pump)

b. Surface Water (Reservoir, Canal, Other Water bodies)

ii.) Water Quality, Quantity on day-to-day basis;

iii.) Storage and treatment facility;

iv.) Sourcing network;

v.) Water supply network Attributes (Pipe-Wise);

vi.) Associated authority responsible for Network Segment;

vii.) Functioning / problems (Segment Wise);

viii.) Locality wise Details.

[4] Shared by Shri TP Singh, Director General BISAG-N, Ministry of Electronics and IT, Government of India

II. Mission Management System

I. Administrative Hierarchy/Layer:

a. State

b. District

c. Taluka/Tehsil

d. Tower

e. Panchayat

f. Village

g. Hamlets

II. Executive Hierarchy/Layer:

a. Civil Engineer

b. Service Engineer

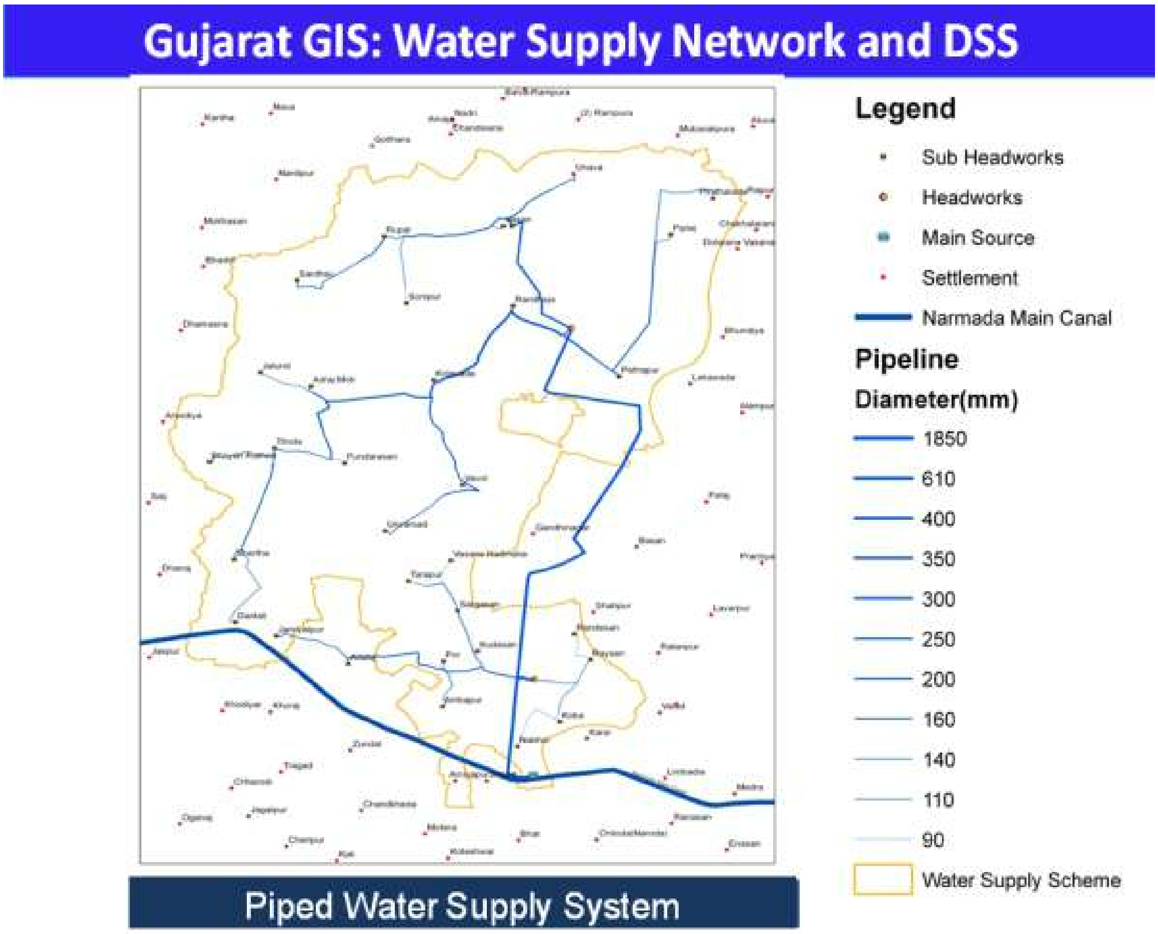
c. Executive Engineer

d. Dy. Executive Engineer

e. Additional Engineer

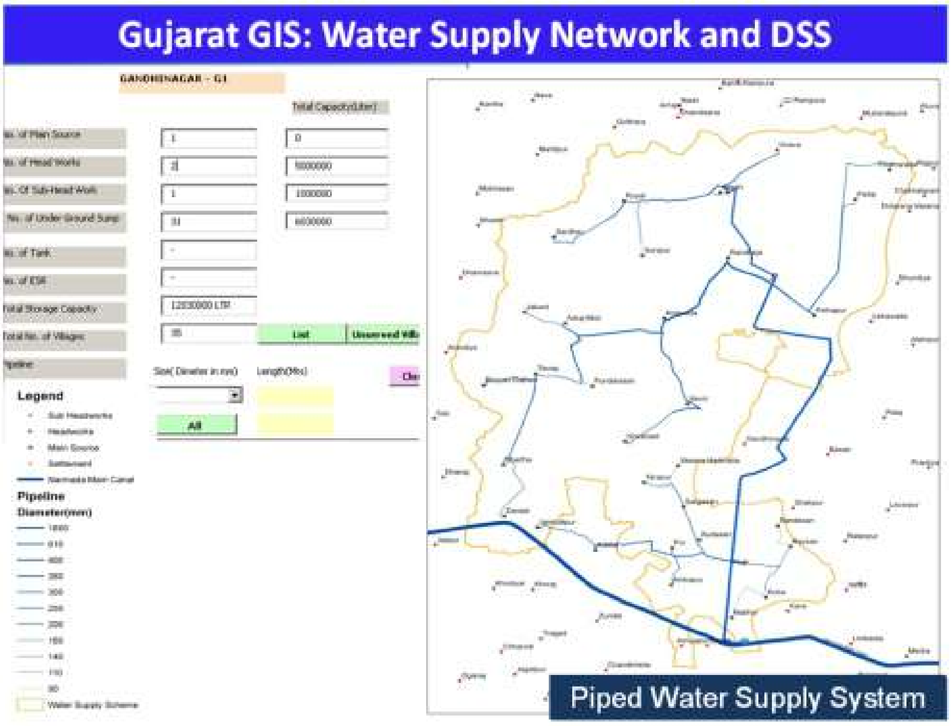
A coding system to be evolved for all segments of the water supply network and components. This **unique coding system** will be used by mobile app as well as across all departments. From the sensor data, the system location shall identify the location of the problem and affected service area, affected households and people and corresponding responsible officials. A provision should exist for partition in case of any decision of bifurcation of district.

I.) Main Layout of Water Supply Network depicting the diameters of the pipes determining water carrying capacity.



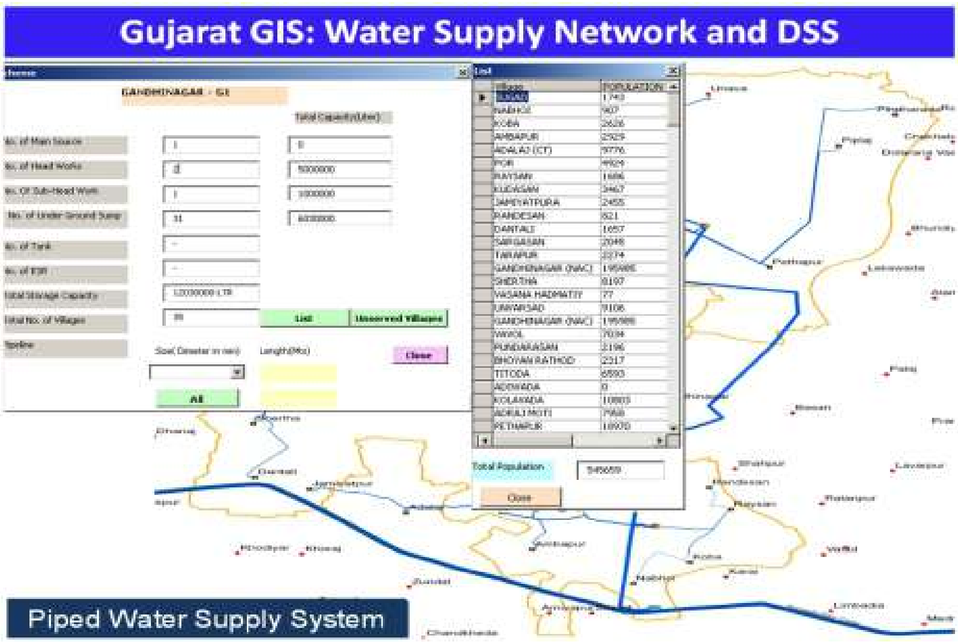
Above figure shows the area of water supply scheme for Gandhinagar, Gujarat, marked by brown boundary. The main source, Narmada Main Canal, head works, sub-head works and settlements are shown. The diameter of pipelines is shown, which determine the water carrying capacity.

ii.) Main Source, number of work head and water carrying capacity of the network.



The above figure shows the details of the network for one main source, two headworks etc along with the water carrying capacity and total number of villages covered under the two subhead works.

iii.) Villages and their population served by the network.



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Jal Jeevan Mission

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