Conceptualization and Modelling the Functioning of The Networking Unit in Cyber Physical System for Smart Water Management

Abhishek M B[a], Neelawar Shekar Vittal Shet [b]

[a]Assistant Professor , Department of Electronics and Communication, Dayananda Sagar College of Engineering
[b] Professor Department of Electronics and Communication, National Institute of Technology, Karnataka
[a]abhishek.mb@gmail.com, [b] shet@nitk.ac.in

Article History: Received: 10 January 2021; Revised: 12 February 2021; Accepted: 27 March 2021; Published online: 28 April 2021

Abstract: The paper concentrates on the networking part of Cyber physical system (CPS) perspective for water inflow and outflow details in the storage tanks. The system comprises the communication of customized existing water pipeline infrastructure in the storage tank interfaced with RF modules, Data Transfer Unit and aggregator. Finally in web server, the resulting information collected in the monitoring unit (RF module+ aggregator + Data transfer unit) will be displayed. In this paper, we focus in detail on communication between RF module, aggregator and DTU unit. This helps us to find out when water is most needed

Index Terms: Cyber physical system, RF module, Data transfer Unit, aggregator, water management

1. Introduction

Earth's ecosphere is facing inconsiderate and harsh encounters in terms of water sustainability [1]. Simultaneously, communication and information expertise is swiftly progressing and is also anticipated to seizure and evaluate data at a scale without precedent [2]. With a prospective to mark aquatic environment's remote sensing allover, Cyber-Physical Systems can increase assessment making in lines with several extortions to water security, tenacious water quality glitches and contamination, flood forecasting and response, climate changes prediction and a host of others [3].

Implementing Cyber Physical System's perception in water monitoring and dispersal chains in the undertaking to fund unceasing water 24/7 stockpiled through storing reservoirs to its one-to-one utility [4]. Real time information through monitoring of water flow rates aids in conserving water when required the utmost.

In future, Cyber Physical System will be vitally essential, as on-line mechanism is massive, improvident, involves enormous hard work and tough in sustaining too. In our research study, we are working in view of the networking dominion of CPS to monitor water distribution system in storing reservoirs and converse messaging amongst web server and DTU by means of nominal wireless tools.

CPS is an emergent exploration and research domain.

Some key technologies and roles of the CPS in water management system [6]:

- The distributed sensing. Perception and communication enable the functionality of time critical and time aware.
- The predictive and adaptive control of the hierarchical hybrid achieves synchronized actions and tightly coordinated in water CPS to be intrinsically synchronous, noisy and distributed.
- The prognostic and diagnostic help in predicting, identifying and preventing faults.
- The human interaction facilitates the design-based model of reactive water.
- The verification, certification, and validation ensure system functionality and safety.
- The modularity composability and abstraction enable the element to be reused and combined while retaining security, safety, and reliability.
- The system-based engineering standards and engineering enable the development and design of the reliability system ensuring integration and interoperability with the legacy system.
- The cyber security provides safety by guarding against the malicious attacks.

Application for the sustainability of water for CPS [5]:

- The increase in reliability efficiency public confidence and security increase water systems thus the path towards water sustainability has been set. The sensing of water quality advances in computing and communication in real time for monitoring and interaction. On a continuous basis, the remotely used in-situ data infrastructures are cost-effective to analyze visualize, communicate and store in real-time.

- In the CPS the important application in the water sector is the systematic monitoring of water distribution.

- For the emergency management and advance-warning, the quality monitoring of the source water can be critical. The water supplies need to be a safeguard in order to protect the ecosystem, public health and time-monitoring due to cost limitation.

2. Networking Unit set up

Experimental set up

As shown in the Figure 1, the pictorial representation of monitoring system which includes aggregator, DTU and web server which forms the CPS network system. The monitoring system as shown in Figure 2 serves to develop an automation system that reads each storage tank's water inflow and outflow parameters [7]. The aggregator collects the water inflow and outflow details in each storage tank with the help of RF modules. An aggregator is connected to DTU with the help of RS 232 port as shown in Figure 2. DTU is interfaced with an aggregator for reading the details of water inflow and outflow and transmitting the relevant information to the webserver. Each storage tank is fitted with one DTU, and DTU gathers water flow details from both the inlet and outlet of the storage tank. DTU measures the water pulse count for each inlet and outlet, the total pulse count for each inlet and outlet, the net volume of water contained in the storage tank respectively for every 15 minutes. Eventually, all the information collected by the DTU will be displayed on the ACE web server [8].

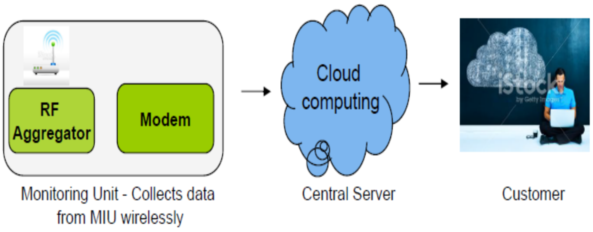

Figure 1: Networking Unit

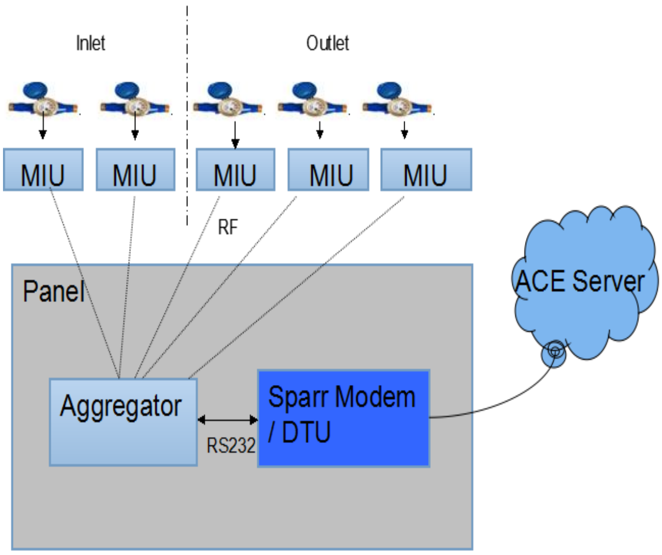

Figure 2 : Communication between MIU, Aggregator, DTU and Web server.

Communication protocol

The water meter which is interfaced with RF module (865-867MHz) is a low power RF module which provides immune condition for wireless communication [9]. The main influence for using this RF module is that, with the help of serial data interface we can add wireless capability to any product [10]. The use of wireless communication on water meter hugely cuts down the cost of maintenance and manual cabling. The gateway is used to communicate with the ACE web server over GPRS and establish HTTP POST connection to send data.

The communication between the DTU and the web server is device initiated communication and hence the DTU has to be pre-programmed with the server domain information. The web application is available for enterprise users through both Intranet and Internet as per the policy.

Communication between RF module and Aggregator

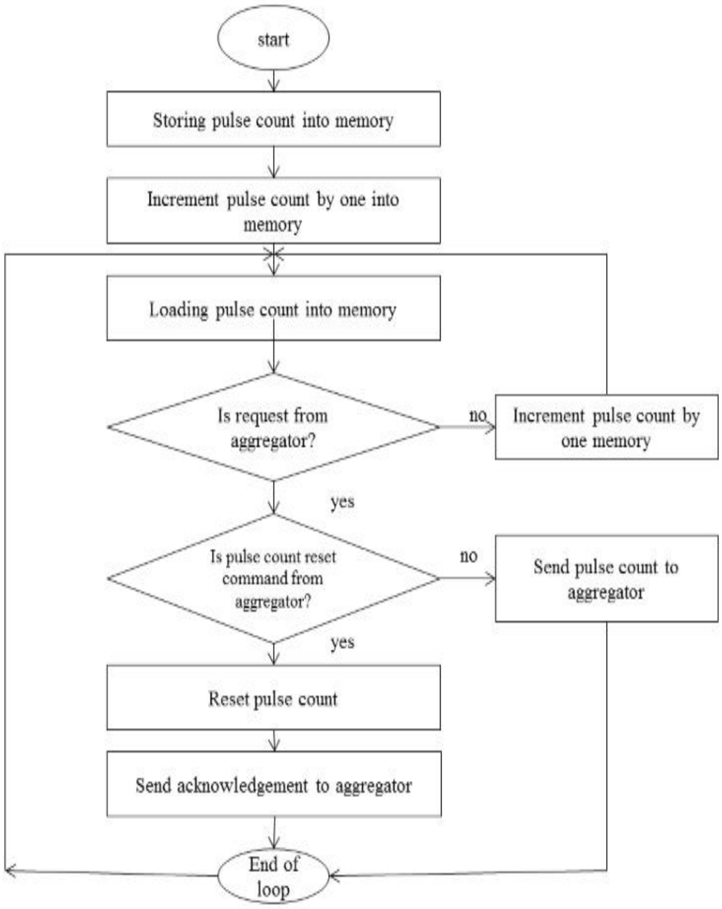

Figure 3: Flowchart for Communication between RF module and Aggregator.

Algorithm for the communication between RF module and aggregator is as shown in Figure 3 and is listed below

- STEP 1: STORING THE PULSE COUNT INTO NON-VOLATILE MEMORY.
- STEP 2: INCREMENT THE COUNTER VALUE BY ONE WHENEVER REED SWITCH DISCHARGES THE RF MODULE AND STORE INTO NON-VOLATILE MEMORY AND GO TO STEP 3.
- STEP 3: LOADING PULSE COUNT INTO NON-VOLATILE MEMORY AND GO TO STEP 4.
- STEP 4: IF AGGREGATOR READ COMMAND IS RECEIVED, GO TO STEP 5, ELSE GO TO STEP 3.
- STEP 5: IF AGGREGATOR PULSE COUNT RESET COMMAND IS RECEIVED, GO TO STEP 6, ELSE SEND PULSE COUNT TO AGGREGATOR.
- STEP 6: RESET THE PULSE COUNT AND GO TO STEP 7.
- STEP 7: SEND ACKNOWLEDGEMENT TO AGGREGATOR AND GO TO STEP 3.

Communication between DTU and Aggregator

Each storage tank will have one DTU, where DTU is used to collect the inlet and outlet water flow details of each pipe in a storage tank from the aggregator with the help of RS232 port through UART configuration. We have designed DTU to request the data from different MIUs for every sampling time period of 15mins [12]. So, DTU after every 15mins will query it through the aggregator.

Then, aggregator communicates with different MIUs and collects the data from MIUs. Once the aggregator receives the information it starts transmitting the information to DTU through RS232 port. When the DTU receives the information based on inlet and outlet details of each tank, it will calculate the total volume of inlet, outlet and finally the net volume in the tank [6] [7].

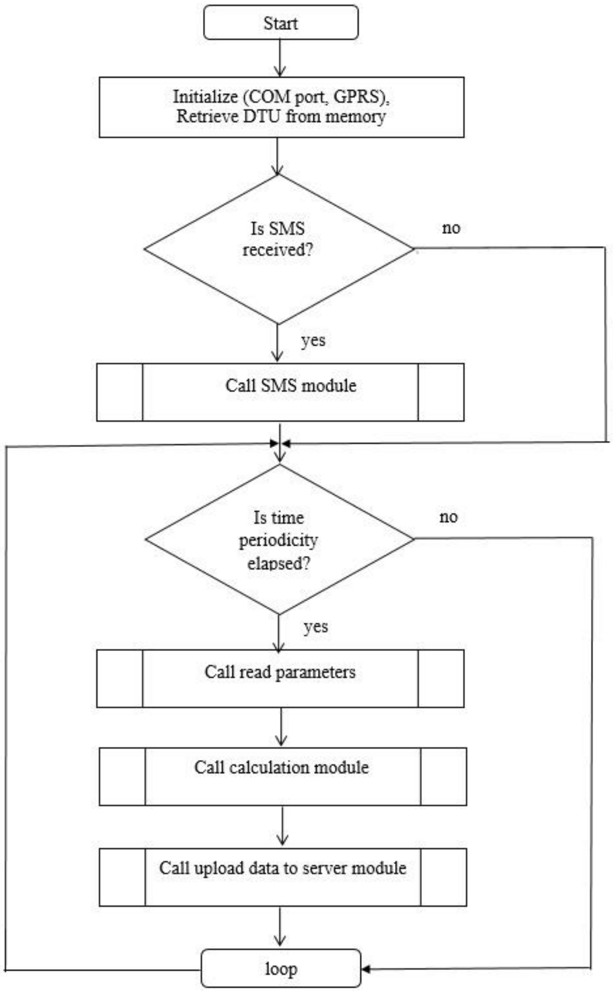

Figure 4: Flow chart for communication between DTU and Aggregator.

Algorithm for the basic steps of the operation for Communication between DTU and aggregator shown in Figure 4 to 7 and is listed below:

- Step 1: Initializes the peripherals and retrieves the settings from memory.
- Step 2: If SMS received, goes to step 3. Else directly goes to Step 4.
- Step 3: Processing the SMS module block by checking device identification information as shown in Figure 5 and go to Step 4.
- Step 4: If web time periodicity is elapsed, then go to Step 5. Else goes back to Step 4 till web time periodicity is elapsed.
- Step 5: Reads the inlet and outlet parameter from each water meter as shown in Figure 6 and go to Step 6.
- Step 6: Calculates the total volume of inlet, outlet and net volume of total water flows in each tank as shown in Figure 7 and go to Step 7.
- Step 7: Sends the received data to server over GPRS and repeat the loop

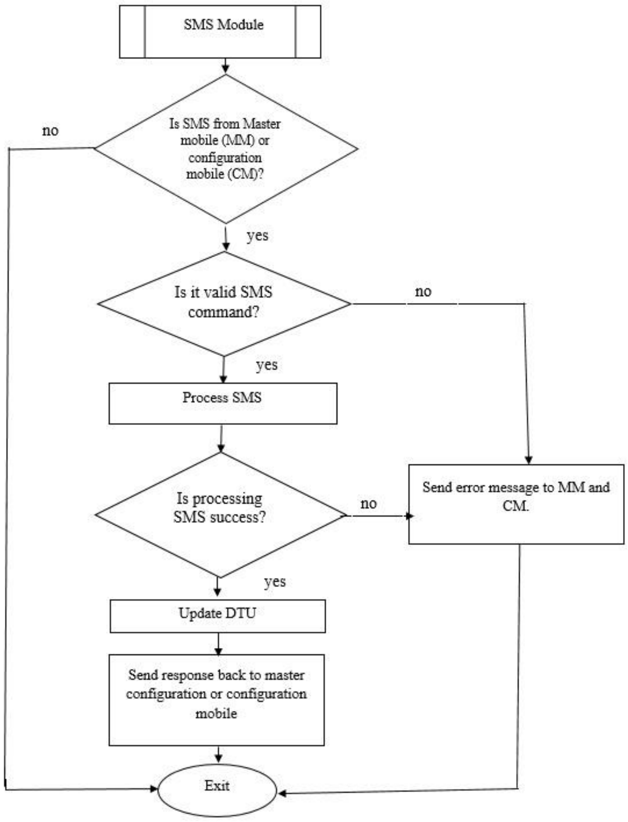

Figure 5: Flow chart for SMS module between mobile and DTU.

Algorithm for SMS module shown in Figure 5 is listed below:

- Step 1: Checking whether SMS received from master or configured mobile. SMS received from non-configured number will be deleted by DTU with out any response and goes to Step 2.
- Step 2: Checks the SMS command. If command is valid goes to next Step 3 otherwise goes to Step 4.
- Step 3: Process the SMS command received as shown in Table 1 and goes to Step 5
- Step 4: In cases of failure in processing an SMS command, the DTU will send the response message with below error codes as shown in Table 2 and goes to exit.
- Step 5: Checks SMS processing ?. If Success goes to Step 6 other wise goes to Step 4.
- Step 6 : Updates DTU. The DTU will send acknowledgment message to the Configured mobile only after fulfilling all the action conditions for that command and goes to next Step.
- Exit: goes to next module

Table 1 :Command is used to get the present reading of water meters

	Format	Example1	Example2
SMS Request	get meterreport	get meterreport	get meterreport
SMS Response	I1: xxxx I2: xxxx O1: xxxx O2: xxxx O3: xxxx Or get meterreport error errorcode	I1: 2421.3 I2: 1234.5 O1: 1256 O2: 1123 O3: 8765	get meterreport error 06

	x: number Ix: Inlet Ox: Outlet		

Table 2: DTU shall send the response message with any of the following error codes.

DTU error code	Description
Success	Sent as response to successful command execution.
Failed	Sent as response if DTU is failed to execute the command.
01	Invalid SMS parameter
02	Invalid SMS Command.
03	Connection to Server Failed.
04	Failed to save in the Database
05	Failed to send data to server even after retries
06	Water meter communication failure
07	Incomplete parameters

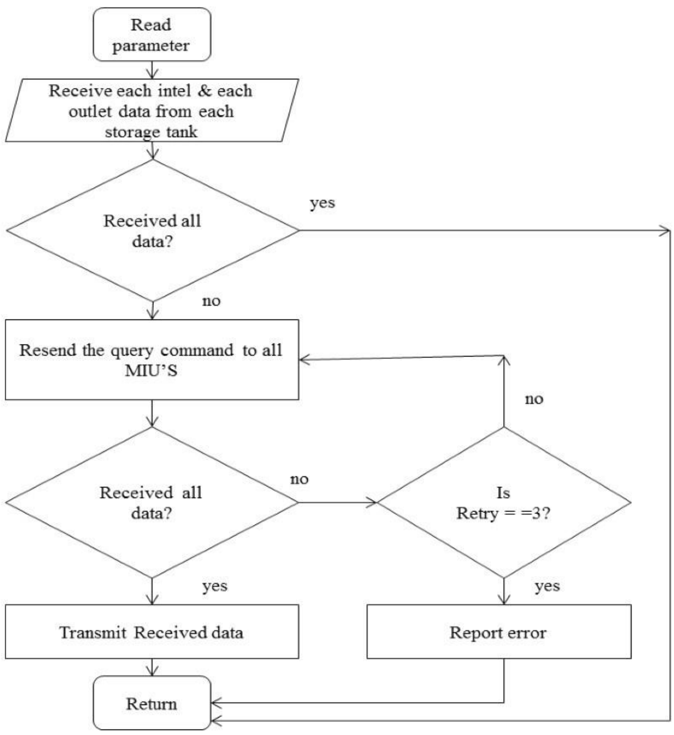

Figure 6: Flow chart for reading commands from MIU to aggregator.

Algorithm for reading commands from MIU to aggregator as shown in Figure 6 is listed below:

- Step 1: MIU consecutively read water meter parameters from both Inlet and Outlet by receiving commands from aggregator as shown in Table ?.

- Step 2: Checks the received data ?. If success goes to Return other wise goes to Step 3.
- Step 3: Resends the command to all MIU's and goes to Step 4.
- Step 4: Checks the received data ?. If success, transmit the data to aggregator and goes to Return otherwise retry 3 times if no response is received from Aggregator and send error report and goes to Return.
- Return: Goes to next module.

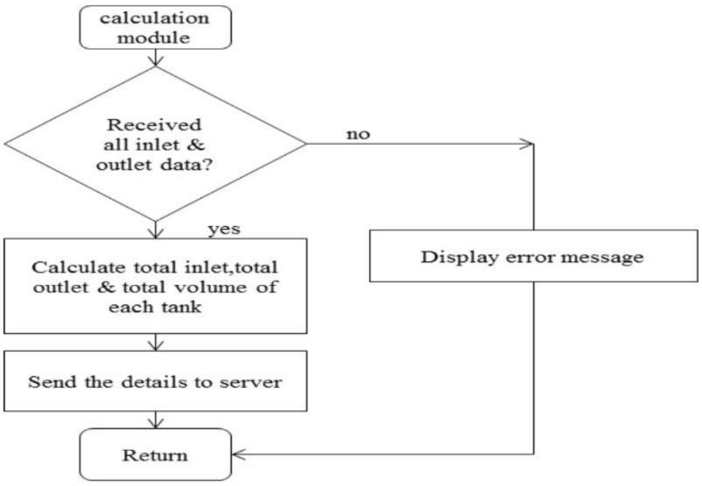

Figure 7: Flow chart for calculation model.

Algorithm for Calculation module as shown in Figure 7 is listed below:

- Step 1: DTU shall store all previous readings in the non-volatile memory and checks whether received all data. If success goes to Step 2 other wise goes to Step 3.
- Step 2: Calculates the total volume of inlet, outlet and net volume of total water flows in each tank and goes to Step 4.
- Step 3: Display the error message and goes to Return.
- Step 4: Send the results to the server and goes to Return.
- Return : Goes to next module

Algorithm for the basic steps of the operation for Communication between DTU and aggregator as shown in Figures 4 to 7 is listed below:

- Step 1: Initializes the peripherals and retrieves the settings from memory.
- Step 2: If SMS received, processing the SMS module block by checking device identification information and goes to step 3. Else directly goes to step 3.
- Step 3: If web time periodicity is elapsed, then it reads the inlet and outlet parameter from each water meter, calculates the total volume of inlet, outlet and net volume of total water flows in each tank. Else goes back to step 2 till web time periodicity is elapsed.

Step 4: Sends the received data to server over GPRS.

Communication between DTU and ACE web server

The DTU will communicate with ACE server over GPRS and establish HTTP POST connection with the server to send data. If GPRS connection is not available, then DTU shall retry three times to connect. If it is not connected, then error connection will be sent. It will send three types of message packets to the web namely,

Device Identification

Device Identification message will be sent to server after successful configuration of the application ID or Device type or DTU ID through SMS command from the configuration mobile. The Meter Interface Unit Address for each storage tank is defined as shown in the Table 3.

Table 3: Pre-defined MIU Address table

MIU	ADDRESS
Inlet 1	0x00000001
Inlet 2	0x00000002
Inlet 3	0x00000003
Inlet 4	0x00000004
Inlet 5	0x00000005
Outlet 1	0x00000006
Outlet 2	0x00000007
Outlet 3	0x00000008
Outlet 4	0x00000009
Outlet 5	0x0000000A

Water meter parameters.

Water meter parameters shall be sent to server on expiration of web reporting period.

- Request Byte Stream Format: 3CA10003000D0B07DC0F05050007371000000000002001C02E01F02000010002000B

000C00150018001B00004321000012340000456300003214000023130000ACFD000A4321xx3E.

Water meter communication failure.

Water communication failure message shall be sent to server when DTU failed to read parameters from Aggregator or received parameter value with error code.

After sending the message, DTU must wait for the server's approval. A SUCCESS or FAILURE notification is sent by the server. The Reply sent by Web server is either Successful or Failed as shown in Table 4 and Table 5 respectively [11].

The Response Byte Stream Format shall be as below

- Success:

Table 4: Success Response Byte Stream Format

Message header	Description	Length (bytes)
3C	Start byte (constant)	1
A100	Message code (constant)	2

0	Status: 0 { Success	1
0	Indicates the total number of responses that shall follow the current message stream	1
A1	FCS (^operation on all message heads excluding the Start and Stop Bytes)	1
3E	Stop byte	1

- Failure:

Table 5: Failure Response Byte Stream Format

Message header	Description	Length (bytes)
3C	Start byte (constant)	1
A100	Message code (constant)	2
02	Status: >0 { Error	1
00	Indicates the total number of responses that shall follow the current message stream	1
A3	FCS (^operation on all message heads excluding the Start and Stop Bytes)	1
3E	Stop byte	1

3. Result And Discussion

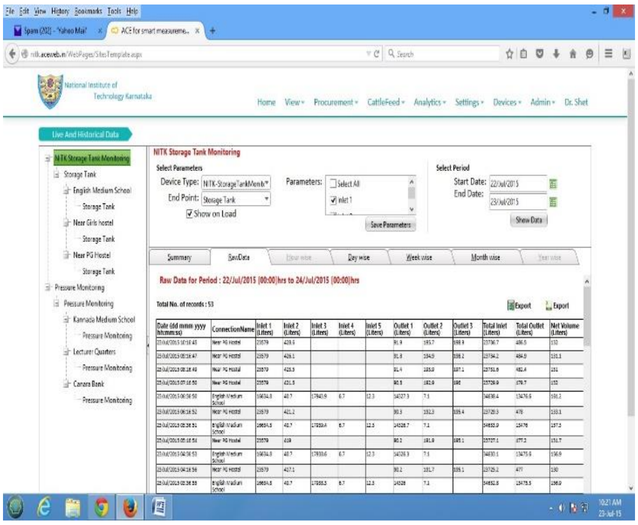

Figure 8: Webserver displaying water inlet and outlet flow information of a Storage tank.

The communication of the networking system in the monitoring unit of CPS in water management is achieved successfully. The DTU, aggregator, and web server connection works as required. RF module, aggregator, DTU, and web server accurately communicates the request and response byte stream format for success and failure messages. At last, we can view inlet and outlet water flow information as well as net storage tank volume in the webserver as shown in the Figure 8. With the available water flow data, we have the following data analytics strategies, as data analytics plays a meaningful role in CPS computing and the actuation system. We hope that these challenges and issues will provide sufficient motivation for future discussions and research interests on CPS..

References

A. Tien Shiao, Tianyi Luo, D.M.E.L.C.C.S.N. The India Water Tool; Technical note in The World Resources Institute and Columbia Water Center, Washington DC, 2016; pp. 1–24. report, T.N.A. The Niti Aayog report, year = 2018, url = http://niti.gov.in/documents/reports, urldate =2019.
B. Ramachandran, M. India’s Urban Confusion: Challenges and Strategies; Copal Publishing Group, 2016.
C. Campisano, A.; D’Amico, G.; Modica, C. Water saving and cost analysis of large-scale implementation of domestic rain water harvesting in minor Mediterranean Islands. Water 2017, 9, 916.
D. Amrutur, B.; Kumar, M.M.; Kumar, K.S.; Patel, L.; Sundaresan, R.; Vaidhiyan, N.K. WaterOpt: a method for checking near-feasibility of continuous water supply. Cyber-physical Systems for Smart Water Networks (CySWater), 2016 International Workshop on. IEEE, 2016, pp. 7–12.
E. Wang, Z.; Song, H.; Watkins, D.W.; Ong, K.G.; Xue, P.; Yang, Q.; Shi, X. Cyber-physical systems for water sustainability: challenges and opportunities. IEEE Communications Magazine 2015, 53, 216–222.
F. Reddy, B. P. and P. Eswaran, Metro overhead tanks monitoring system using zigbee based wsn. In 2013 IEEE Conference on Information & Communication Technologies. IEEE, 2013.
G. Abhishek, M.; Shet, N.S.V. Data Transmission Unit and Web server Interaction to Monitor Water Distribution: A Cyber-Physical System Perspective. International Journal on Advanced Science, Engineering and Information Technology 2018, 8, 1307–1312.
H. Abhishek, M.; Shet, N.S.V. Cyber physical system perspective for smart water management in a campus. Desalination and Water Treatment 2019, 147, 296–307
I. Tarang-Product Manual-Melange System Pvt Ltd. 2010. URL www.melangesystems.com.
J. Suresh, M., U. Manohary, A. G. Ry, R. Stoleru, and M. K. M. Sy, A cyberphysical system for continuous monitoring of water distribution systems. In 2014 IEEE 10th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob). IEEE, 2014
K. Abhishek MB, N. Shekar V. Shet, Wirelessly monitoring of water usage in smart campus: A CPS perspective", International Engineering Symposium, Kumamoto University , Japan, March 2017.
L. Abhishek, M. B., and Neelawar Shekar Vittal Shet. "Data Processing and deploying missing data algorithms to handle missing data in real time data of storage tank: A Cyber Physical Perspective." In 2019 1st International Conference on Electrical, Control and Instrumentation Engineering (ICECIE), pp. 1-6. IEEE, 2019.