International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-07, Issue-10, JAN 2022

Efficient & Adaptive Rate Controlled Real Time Power Quality Monitoring using WSN in Smart Grids

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Abstract: **With rapid urbanization in countries like INDIA, the demand for power increases at a faster rate. Increased demands with old transmission infrastructure become a huge burden for maintaining quality of service. Grids and distribution center carry power from power generation centers to electrical power consumers. Due to various issues in power transmission lines and distribution centers, power quality deteriorates. To manage the power transmission and distribution process in an effective way, wireless sensor networks (WSNs) are used as part of Smart Grid up gradation. Sensors monitor the power quality and send the values via multi hop transmission to centralized monitoring center. Congestion is quite common in WSNs deployed for power grid monitoring because of the higher sampling rate. Due to congestion in network, average latency increases and this affects the core requirement in power grid Real time monitoring. In this work, an adaptive rate-controlled routing is proposed for WSNs deployed to monitor power grid. The adaptive rate-controlled routing along with S-transform, ANN and fuzzy logic are used for obtaining sampling rate instead of checking the power quality at each instance as compared with old techniques. This reduces Delay, Network overhead and improves Packet delivery ratio. The proposed solution was tested on NS2 and results obtained are compared with existing techniques.** Keywords: ***WSNs, S-transform, ANN, Fuzzy*, Power quality, Smart grid**

I. INTRODUCTION

Due to rapid urbanization in INDIA the power requirements grow abruptly from industrial and house hold users. Scheduled/unscheduled load shedding, low voltage, Flickering (Brownouts), High voltage and Transients are the most common problems in power lines of Indian power transmission systems. High voltage fluctuations and transients affect devices used in industries as well as houses which cause serious accidents along with loss to business

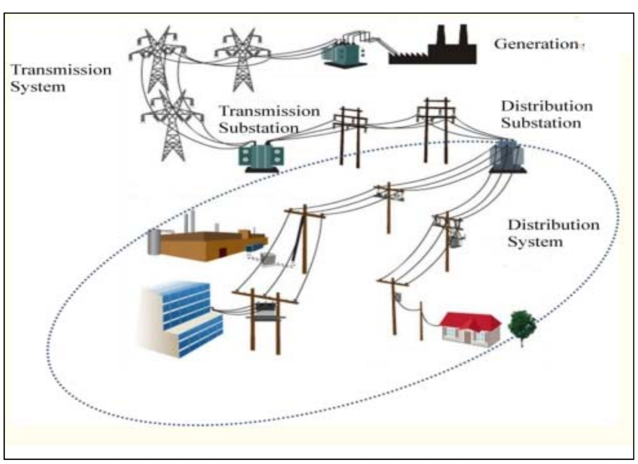

Figure 1 Power Grid Network

Load shedding, both scheduled and unscheduled, is caused by a mismatch between generation and demand. Overloading of transmission/distribution lines or power/distribution transformers, as well as a lack of redundancy in the infrastructure, create this. Due to a sudden decline in generation or technical issues in the local network, unscheduled load shedding is used. Frequent Local outages, which can last anywhere from a few minutes to several hours, occur due to line clears taken by local employees for line/transformer maintenance, tree pruning, system improvement work, and other reasons. As a result of this dilemma, industries and commercial organizations bear some of the obligations and suffer financial losses. Fig [1] depicts the power system grid which includes Generation, Transmission and Distribution of power. In India, transmission and distribution lines are laid for significant distances, environmental (like rain and wind) related damages can harm any time in the year. Due to geographical and environmental factors, power distribution lines are prone to line faults and at sometimes difficult to access for fast repairs. Due to infrastructure faults like loose connections in transformers, voltage fluctuations occur. During overload of distribution lines voltage drops to low value. Due to phase system failure, higher voltage passes and it causes serious damage to power equipment. This necessitates real time power quality monitoring and corrective action.

Wireless Sensor Network is network of sensor nodes. The

 DOI : 10.35291/2454-9150.2022.0013

nodes sense parameters depending on the application and send the parameters to central monitoring server or base station for realization of the application logic. Sensors have short range wireless communication infrastructure and for forwarding packets to base station located far way, multi hop relaying is used. Electrical power grids can be monitored in real time using the WSN infrastructure. The volume of data generated is high and when it is transmitted through WSN, it causes congestion in the network due to which packet delivery ratio drops and the average latency increases. To reduce the network overhead two important objectives must be met

1. Reduce the number of packets in network
2. Reduce the number of hops packets is transmitted in the network

In this work, design of WSN for power grid monitoring is made in consideration to meet the above two objectives. Adaptive sampling depending on spatial temporal correlation and geographic routing-based strategies are adopted in the design of WSN for power grid monitoring. The proposed solution is tested on NS2 test bed with power data generated using Open DSS environment. Performance of the proposed design is measured in terms of packet delivery ratio, average latency and network overhead and compared to existing solutions.

II. RELATED WORK

In this section the previous works on Power quality monitoring and routing is discussed in detail.

In [1] authors proposed a S transform extreme learning machine (ST-ELM) for classifying power quality. The distinctive properties of the PQ (Power Quality) event signals were extracted using an S-Transform-based feature extraction method in this approach. The feature vector obtained from feature extraction was sent into the ELM classifier as input. Ten unique classification procedures were resolved inside the structure of this review to assess the presentation of the ELM classifier on PQ event data. This technique was able to identify power quality and using the power quality values, but propagation of monitored power level to central station is not considered in this work.

In [2] author put forward a hybrid intelligent strategy for the categorizing power quality disturbances. The proposed algorithm is perceived by the way of three approaches: feature extraction, feature selection and feature classification. S-transform (ST) and Wavelet transform (WT), both powerful time-frequency analysis methods, are used to extract the feature vectors. To avoid massive feature vector measurements, three different feature selection methods are used, including Sequential Forward Selection (SFS), Sequential Backward Selection (SBS), and Genetic Algorithm (GA). The most important features are then applied to the Probabilistic Neural Network (PNN) as the classifier core in the following stages. Voltage sag, swell, interruption, harmonics, transient, sag with harmonics, swell with harmonics, and flicker are among the transitory occurrences investigated. Feature selection algorithm mentioned in this work is one important thing which can be used for our proposed solution in this work.

A communication infrastructure with low cost, reliable data delivery has been presented in [3]. The infrastructure includes wired connections between substations and monitoring centers. wireless communication is established between pole transformers and substations. Authors adopt a tree-based data forwarding protocol in order to customize the distribution pattern of the power quality information. Tree based routing has higher probability of nodes being on path, it results in congestion and due to packet drop probability increases.

A fully decentralized power quality monitoring architecture has been proposed in [4] adapting Gossip sensor networks. The implementation of Gossip algorithms is anticipated to be beneficial for power quality monitoring in smart grids as it permits remote sensors to compute a function of the measured data according to a totally distributed paradigm. This characteristic may be used to perform the monitoring computations inside the sensor network so that, in preference to transmitting raw data to a fusion center, only the results of the computation are transmitted to the smart grid operators. This approach is similar to the proposed approach in one way that only the necessary information is transmitted and all unnecessary information will be filtered locally.

Authors of [5] have proposed a smart sensor network that permits inspecting an electrical installation in a nonintrusive way. It achieves standard measurements and also allows examining: PQD events in detail, interactions between lines, identify electrical equipment, correlate events between monitoring points, among others. Furthermore, the presented smart sensor network is used to evaluate an electrical system which has the capacity to detect system faults. All the processing needs to be done at central station which requires large volume of information to be sent to central station. Due to this overhead is high in this approach.

[6] presents a comparison of wavelet transform (WT) and S-transform (ST) for detecting islanding and power quality (PQ) disturbances in hybrid distributed generation (DG) systems using extracted features. The hybrid system described in this paper consists of grid-connected DG resources such as photovoltaic, fuel cell, and wind energy systems. The voltage signal's negative sequence component is utilized to detect the islanding of these resources from the grid. PQ disturbances are detected using a voltage signal retrieved immediately at the point of common connection. The approach can be used for detection of malfunctioning at substations.

 DOI : 10.35291/2454-9150.2022.0013

Authors of [7] have proposed a system model for the development and implementation of a WSN-based communication system for monitoring distributed generation, loads, and transmission lines in the electrical grid, as well as a controller system for automated grid control. The volume of data needs to be transmitted is high between the substation and the central station. Therefore, congestion is high in this approach.

Authors of [8] have proposed a hybrid aggregate scheme for data propagation from node to base station. Due to aggregation volume of packet sent is decreased but still there is no control on what kinds of information must be transmitted. Without this control, the packet overhead and congestion cannot be reduced.

The authors of [9] presented a hybrid hierarchical network design that combines wired, wireless, and cellular technologies to provide low-cost real-time data monitoring. The objective was to minimize the objective of minimizing the installation and operational costs while satisfying the end-to-end latency and bandwidth constraints of the data flows. The solution did not propose methods to reduce the data flow but reducing redundancy and irrelevant information, but by adding additional infrastructure it was able to solve the deficit in data optimization problem.

In [10] authors suggest a new network topology in which sensor/relay nodes can connect with other nodes via a wide area network like the cellular network. Cellular network is used as backhaul for wireless sensor network communication, but this approach is costly. Also, cellular network may not available in all places causing uncertainty in data communication.

Authors of [11] have deliberated on the technique by which the data measured on transmission lines be delivered efficiently to substations. It has been proven that standard data transmission methods are insufficient, and that direct wireless communications should be employed to eliminate information delivery delays. Furthermore, the best location for these direct wireless links is being investigated in order to reduce the time it takes for information to be delivered. Direct wireless links is not feasible for bigger networks. Also, the cost for direct wireless links is huge.

[12] proposes a cost-optimized algorithm for designing real-time data transmission in the smart grid, creating a network architecture, and implementing real-time transmission line monitoring. Authors formulate a three-layer network structure which can deliver data transmission at a low cost by the meantime, the bandwidth, delay, and connectivity constraints can be well met. Furthermore, the optimal placement of the LTE transceiver is with the goal of studying transceivers to maximize bandwidth while decreasing information delivery latency. The work did not consider reducing the data transfer rate from nodes, so there is an increased load on LTE transceivers and it can result in congestion.

The broadband over power lines-enhanced network model (BPLeNM) is introduced by the author in [13], and it is suited for efficiently transmitting the generated data of wireless sensor networks (WSNs) of overhead high-voltage (HV) power grids to substations. The approach addressed ways to reduce the delay but it still under higher data transmission rate, the latency will not be stable and will increase for bigger networks.

The authors of [14] offer a framework for efficient wireless sensor networks that includes a clustering method for network management and energy balance, as well as a hybrid media access control (MAC) (H-MAC) protocol to address traffic fluctuation. The framework takes advantage of network architecture and traffic pattern aspects to improve protocol performance in terms of real-time and energy efficiency. Though network topology for real time data transmission is addressed, the approach will fail due to congestion at node as the data transmission control is not considered in this work.

A cost-effective, flexible, and sustainable Neighborhood Area Network design has been recommended by authors of [15] by employing wireless technologies such as IEEE 802.11s, IEEE 802.16 and renewable energy like solar power. The work considers only two hop transmission and not suitable for transmission of grids value to substations.

In [16] author proposes a sequential control scheme, which achieves higher weighted average energy efficiency by increasing signal-to-interference-plus-noise ratio in wireless sensor network. This work compromises delay at cost of energy efficiency. But in power monitoring applications, energy is not a problem so this work is not practical for power monitoring environment.

III. PROBLEM DEFINITION

Power from generation station is made available to consumers located at far way through transmission and distribution systems. The quality of power at each transmission towers has to be monitored to maintain Quality of Service to customers as well as to lower the losses. The power quality is monitored in terms of voltage distortion. To monitor the power quality at each transmission tower and report to central station, Wireless Sensor Network is deployed. At each transmission tower a sensor node is deployed which monitors voltage distortion and communicates it via packets using multi hop routing to the sink node at central station. The sensor network must transmit this packet with reduced latency and highest packet delivery ratio. To ensure reduced latency and highest packet delivery ratio, the network must have reduced overhead and the relay nodes must be congestion free. This work is designed to solve the problem of reducing the network overhead and congestion while ensuring the reduced latency and increased packet success ratio.

 DOI : 10.35291/2454-9150.2022.0013

ISSN : 2454-9150 Vol-07, Issue-10, JAN 2022

IV. MATERIALS AND METHODOLOGY

Power distortion will be detected at each transmission tower by sensor nodes. These nodes use adaptive sampling technique to detect the distortion. In the proposed solution adaptive Rate Controlled Geographic Congestion Free Routing is employed

A. ADAPTIVE RATE CONTROLLED GEOGRAPHIC CONGESTION FREE ROUTING

The proposed solution for power quality monitoring consist of three sub parts

1. Power Distortion Detection
2. Adaptive Sampling at Node
3. Routing of packet from Substation Node using Geographic congestion free routing.

Figure 2 depicts the suggested solution's architecture. It consists of Substation Node at each transmission towers which communicates wirelessly the data to Central monitoring station. Node basically has Power quality sensor and distortion detector which acts according to the adaptive fuzzy algorithm written.

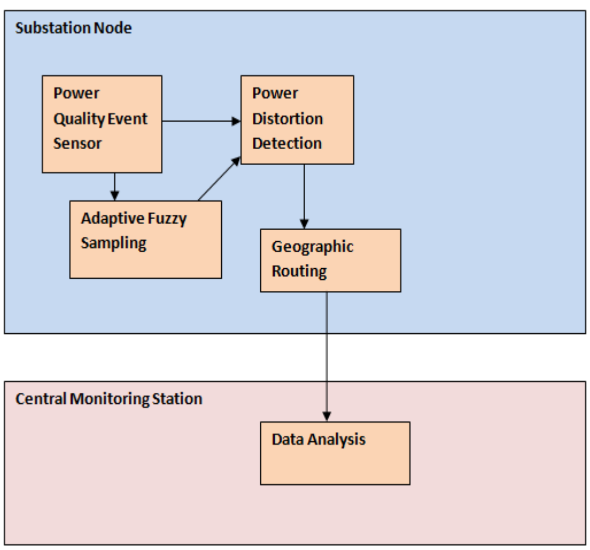

Figure 2 Proposed Architecture

Sensors at each Transmission Tower must be able to detect following events from the Power quality signals.

Voltage deviation (VD)

Voltage deviation is the difference between the voltage at given moment at a point in the system and a reference voltage similar as nominal voltage. voltage and reactive power are nearly linked. In general, the grid user is an R/ L/ C compound load that generates reactive power in the grid, rather than a pure resistive load. When the reactive power is higher, voltage bias occurs. High voltage is produced by capacitive reactance, while low voltage is produced by inductive reactance.

Voltage Fluctuations (VF)

Load impact causes rapid load impedance changes, resulting in reactive power swings. As a result, the amplitude of the voltage will shift. Voltage flicker is caused by voltage fluctuations that are less than 30 Hz, particularly 8.8 Hz.

Three- phase voltage unbalance (VU)

Unbalanced three-phase load generates negative sequence current in the grid, resulting in three-phase voltage imbalance. The power system common connection point's normal voltage imbalance allowable value is 2, and it cannot exceed 4 in the short term.

To detect the events from the power quality signals S-Transform (ST) with Neural Network Classifier is used. S-Transform is a phase correction of continuous wavelet transform (CWT). It has information both in spectrum phase and amplitude.
The CWT, W(τ,d) of the function h(t) is defined in Eq. (1)

$$w(\tau(d) = \int_{-\infty}^{\infty} h(t)w(t-\tau,d)dt \qquad (1)$$

S-Transform is obtained by multiplying the function h(t) with phase factor as shown in Eq. (2)

$$S(\tau(f) = e^{i2\Pi 2\Pi} w(d,\tau) \qquad (2)$$

In the equation (2) the expansion factor d is the inverse of frequency f.
The final form of S-Transform is represented as shown in Eq. (3)

$$S(\tau,f) = \int_{-\infty}^{\infty} h(t)\left(\frac{|f|}{\sqrt{2\Pi}}\right) e^{\left(-\frac{(\tau-t)^2 f^2}{2}\right)} e^{-i2\Pi ft}\, dt \qquad (3)$$

S-Transform is linear process on h(t). h(kT) with k=0,1...N-1 can be used to represent Power Quality event signals in h(t). The sampling interval is T, and the total number of samples is N. Eq. 4 gives the S-Transform of a discrete time series h(kT)

$$S\left(jT, \frac{n}{NT}\right) = \sum_{m=0}^{N-1} H\left[\frac{m+n}{NT}\right] G(m,\ n) e^{-i2\Pi mj/N}, n \neq 0 \qquad (4)$$

where

$$G(m,n) = e^{-(2\Pi^2 m^2/n^2)}$$

Using the efficiency of the Fast Fourier Transform and the convolution theorem, the Discret S-Transform may be calculated quickly. The S-Transform on Power quality event signal produces a complex matrix called S-matrix. Each column in this matrix relates to a specific time, while each row corresponds to a specific frequency. Complex amplitude values make up S-matrix elements. From this S-matrix following statistical features are extracted.

 DOI : 10.35291/2454-9150.2022.0013

ISSN : 2454-9150 Vol-07, Issue-10, JAN 2022

1. Mean
2. SD
3. RMS
4. Skewness
5. Kurtosis
6. Energy

The formula for calculating the features are listed in Table 1

Table1: Formulae to calculate Statistical features

Features	Formulae
Mean	$\bar{x} = \frac{1}{N}\sum_{K=0}^{N-1} S(K)$
SD	$\sigma_{SD} = \sqrt{\frac{1}{N}\sum_{k=0}^{N-1}[s(k)-\bar{x}]^2}$
RMS	$\sigma_{RMS} = \sqrt{\frac{1}{N}\sum_{k=0}^{N-1} s^2(k)}$
Skewness	$\sigma_{Skewness} = \frac{1}{(N-1)\sigma_{SD}^3}\sum_{K=0}^{N-1}[S(k)-\bar{x}]^3$
Kurtosis	$\sigma_{Kurtosis} = \frac{1}{(N-1)\sigma_{SD}^4}\sum_{K=0}^{N-1}[S(k)-\bar{x}]^4$
Energy	$\sigma_{Energy} = \sum_{K=0}^{N-1} S^2(K)$

For each of VD, VF, VU and Normal power quality signals above 6 features are extracted and a three-layer feed forward Artificial Neural Network (ANN) is trained to classify the Power quality signal to above three types. A 3-layer neural network is as shown in Fig3.It basically consists of input and output layer along with the hidden layer. ANN is a supervised machine learning technique. It uses a set of neurons interconnected in layers in its core to remember the training pattern.

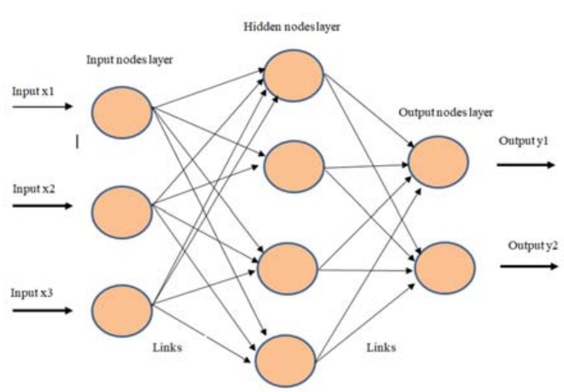

Figure 3 Neural Network

A 3-layer neural network is designed with parameters as shown in Table 2

Table2: Parameters used in Neural Network

Number of input Neurons	6
Number of Hidden Layer Neurons	13
Number of output neuron	4
Transfer Function used	tanh

The power quality signals from the line are subjected to S-Transform to get the S-Matrix. From S-Matrix statistical features (6 features) are extracted and neural network is used to identify voltage deviation (VD), Voltage fluctuation and flicker (VF) along with three phase voltage unbalance (VU). This is fed to the Fuzzy logic to find the sampling rate.

B. Adaptive Sampling at Node

In most of existing solutions, the sampling is time based i.e., data is collected at fixed time interval and sent to central station. This creates many packets in the network and due to this network overhead, packet success ratio is reduced and delay is increased. This necessitates an adaptive sampling strategy at sensor nodes.

In this work, Fuzzy Adaptive Sampling is proposed.

The Sampling rate (R) is dependent on following three variables

1. Max deviation percentage of Power Quality(M)
2. No of times deviation above average Power Quality (NA)
3. No of times deviation below average Power Quality (NB)

Each of three variables are fuzzified to three ranges of Low (L), Medium (M) and High (H) as below

The max deviation percentage of Power Quality (M) is fuzzified as shown in Figure 4. Fuzzy adaptive sampling algorithm checks the power quality data and decides whether it falls under Low, medium or high range of Max deviation.

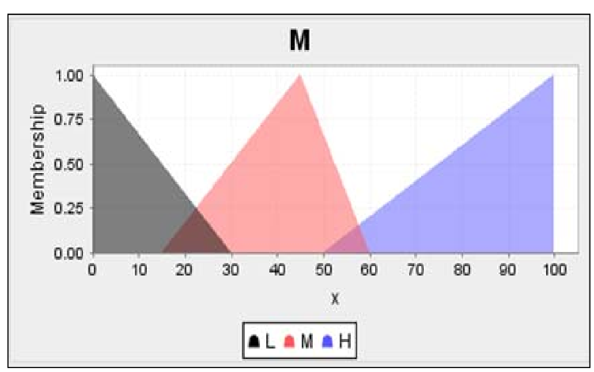

Figure 4 Transfer function for M

DOI : 10.35291/2454-9150.2022.0013

The number of time deviation above average Power Quality (NA) is fuzzified as shown in Figure 5. Fuzzy adaptive sampling algorithm checks the power quality data and calculates the number of times deviation occurred when it goes beyond the above average, which is further categorized under three ranges namely Low, medium and high.

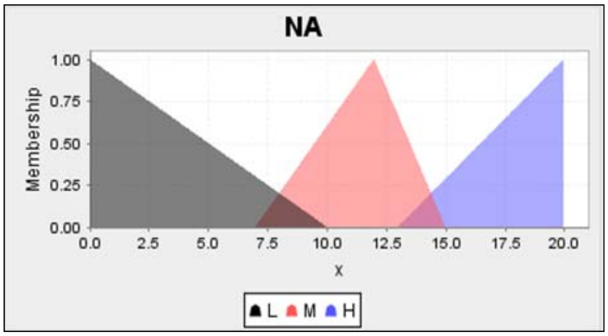

Figure 5 Transfer function for NA

The number of times deviation below average Power Quality (NB) is fuzzified shown in Figure 6. Fuzzy adaptive sampling algorithm checks the power quality data and calculates the number of times deviation occurred when it goes beyond the below average, which is further categorized under three ranges namely Low, medium and high.

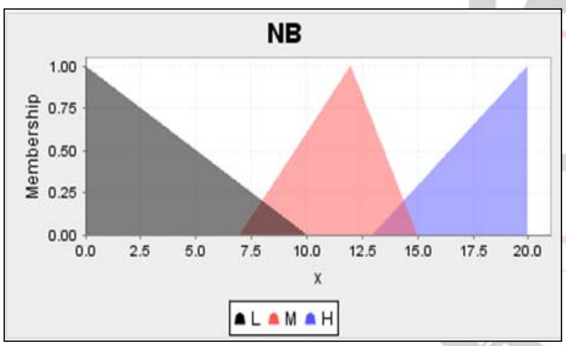

Figure 6 Transfer function for NB

The output variable sampling rate (R) is fuzzified as shown in Figure 7. The Sampling rate (R) will be low, medium or high based on the values of M, NB, NA.

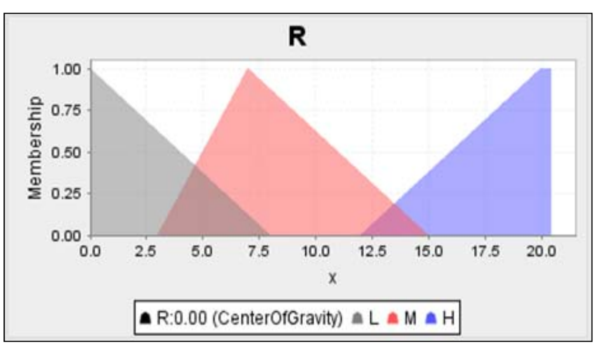

Figure 7 Transfer function for R

The fuzzy rules for mapping the input variables (M, NA and NB) to output variable R is given in Table 3

Table 3: Fuzzy Rules

Rule	M	NB	NA	R
1	L	L	L	L
2	L	L	M	L
3	L	L	H	M
4	L	M	L	L
5	L	M	M	L
6	L	M	H	M
7	L	H	L	M
8	L	H	M	M
9	L	H	H	M
10	M	L	L	M
11	M	L	M	M
12	M	L	H	M
13	M	M	L	M
14	M	M	M	M
15	M	M	H	H
16	M	H	L	M
17	M	H	M	H
18	M	H	H	H
19	H	L	L	M
20	H	L	M	M
21	H	L	H	H
22	H	M	L	M
23	H	M	M	H
24	H	M	H	H
25	H	H	L	H
26	H	H	M	H
27	H	H	H	H

At each substation sensor node, adaptive fuzzy logic is invoked to decide the sampling rate. The sensor samples the power quality event signals at the sampling rate(R) given by fuzzy logic. The sampled power quality signals are passed to S-Transform and Neural Network to get the voltage status. The voltage status is then sent via multi hop routing to the central station.

C. Routing of packet from substation node

The packets must be routed from substation node to central station located far off using multi hop routing. The path decided for route impacts the latency and congestion in the network. For each node, a relay score is calculated based on how many different paths are passing through that node. This relay score is communicated frequently to its one hop neighbor nodes.

A source node that wants to send a packet chooses the next hop node that is on the shortest geographical path to the base station and sends the message there. When a packet is forwarded, it is received by all nodes in the next hop node's

 DOI : 10.35291/2454-9150.2022.0013

deployment area, and the node with the lowest relay score relays it to the next hop node with the shortest geographical path to the base station. The message is not forwarded to any additional nodes in the deployment area with a lower relay score. Until the packet reaches the base station, this cycle is repeated.

Each node's response to receiving the data packet is described by Input: Packet

```
If Packet.dest == self id
    // packet reached destination
    processApp(Packet)
Else
        Mindis=99999
     Mindisnode=-1;
     For all neighbours J
        If distosink(J) – distosink(mindisnode)<20
            If relayscore(J) < relayscore(mindisnode)
                Mindis= distosink(J);
                Mindisnode = J;
            End
        End
     End
     Forward Packet to J.
End
```

From the pseudo code it can be seen that the geographic routing protocol decides the next hop based on choosing nodes closest to base station and selecting the node among them with lowest relay score.

V. NOVELTY IN PROPOSED SOLUTION

Following are the novelty in the proposed solution

1. Due to adaptive sampling the number of packets in the network is reduced. Adaptive sampling increases or decreases the sampling based on the power quality deviation. For a substation with higher deviation sampling rate is higher and for a substation with lower deviation, the sampling rate is lower
2. With S-Transform features and neural network classification, power quality distortions are found accurately. Both time and frequency domain characteristics of the power quality signal are captured using the S-Transform, so distortions can be detected accurately in the proposed solution.
3. Due to Geographic congestion free routing, the number of hops for packet traversal to central station is reduced and this result is lower latency.

VI. RESULTS

The proposed solution was implemented in NS2. For generating of power quality signals OpenDSS tool is used. OpenDSS is a tool to model any power distribution network and generate power quality values at each substation. Using OpenDSS power quality event signals are generated for each substation. In NS2 environment, wireless sensor network is realized with each node as the substation and one central base station. The proposed algorithms for adaptive fuzzy sampling and routing are realized at each node. The simulation is conducted with power quality values for each substation imported from the OpenDSS tool.

OpenDSS scripts are developed to model the substation behavior and collect power quality values. A snippet of open dss environment is shown in fig 8

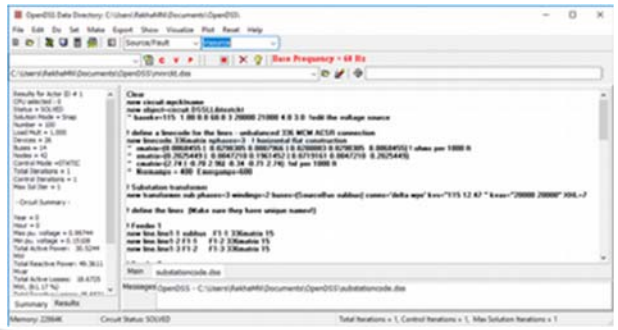

Figure 8 OpenDSS Environment

The simulation is conducted with following NS2 configuration.

Table 4 Simulation Parameters

Parameters	**Values**
Number of Nodes (substations)	100 to 300
Communication range	100m
Area of simulation	1000m*1000m
Node Deployment Topology	Random
Simulation time	30 minutes
Interface Queue Length	50
MAC	802.11
Number of Base stations	1
Location of Base station	Upper right

The proposed solution is compared with [14].

Following performance metrics are used for comparing the solutions.

1. Packet Delivery Ratio
2. Average End to End Delay
3. Network Overhead

The packet delivery ratio is derived by dividing the number of packets successfully received at the base station by the total number of packets transmitted from all nodes.

 DOI : 10.35291/2454-9150.2022.0013

ISSN : 2454-9150 Vol-07, Issue-10, JAN 2022

Average End to End Delay is measured the average of total delay of all packets from nodes to base station.

Network overhead is measured in terms of number of packets handled by the network.

The number of substations is varied from 100 to 300 and packet delivery ratio is measured using proposed solution and existing solution ([14]).

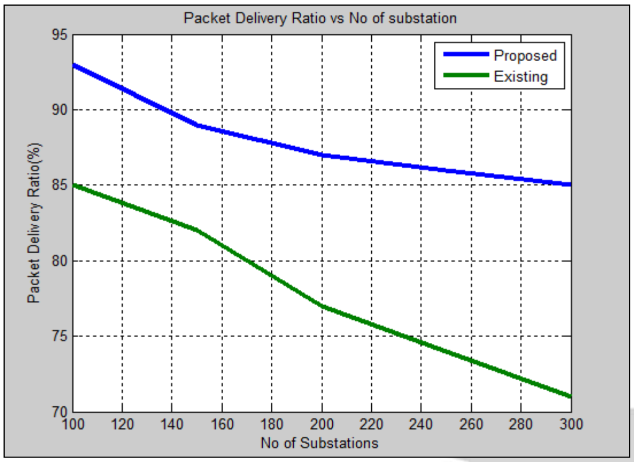

Figure 9 Packet Delivery Ratio

From the result, it can be seen that the packet delivery ratio is higher in the proposed solution compared to existing solution. Due to adaptive sampling the number of packets in the network is reduced and congestion dropped. Since there is no congestion, the packet success ratio is higher in the proposed solution.

The number of substations is varied from 100 to 300 and average end to end delay is measured using proposed solution and existing solution ([14]).

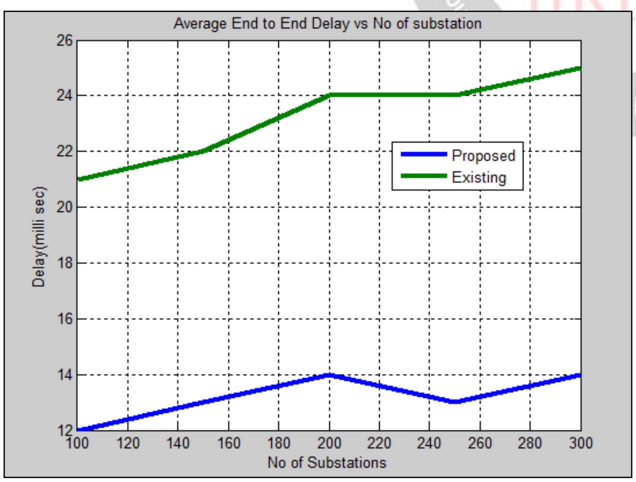

Figure 10 Average Delay

From the result, it can be seen that the delay in proposed solution is less compared to existing solution. Due to reduced number of packets and the geographic shortest path with congestion free routing, the number of hops for packet traversal is reduced. This reduction has reduced the packet delay in the proposed solution.

The number of substations is varied from 100 to 300 and network overhead is measured using proposed solution and existing solution ([14]).

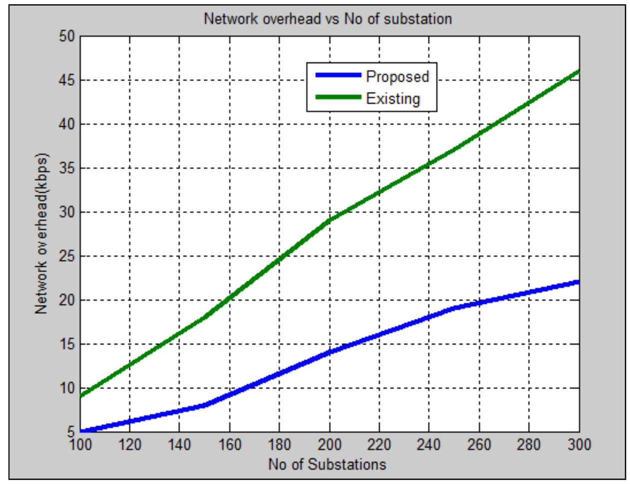

Figure 11 Network Overhead

From the result, it can be seen that the network overhead is reduced in the proposed solution when compared to existing solution. The reason for reduction being adaptive sampling and geographical shortest path routing. Due to adaptive sampling the number of packets from each node is reduced and due to geographical shortest path routing the number of hops for packet traversal is reduced. Due to both of this factor, the total number of packets handled in the network is reduced.

VII. CONCLUSION

In this work, an adaptive sampling with geographic congestion free routing is proposed to improve the performance of wireless sensors for power quality monitoring. The solution used adaptive sampling to adapt the rate of monitoring the power quality signals. From the power quality signals, S-Transform based statistical features are extracted and from the features the power quality distortions are classified. The classified result is sent as packet using geographic congestion free routing from substation to central station. The proposed solution was tested in NS2 test bed and OpenDSS scripts are developed to model the substation behavior to collect power quality values. From the simulations conducted, the proposed solution was found to have higher packet delivery ratio, reduced latency and network overhead. The future work will be on further reduction of network overhead and finding faults using even more efficient classifier.

REFERENCES

[1] Eristi H., Yildirim Ö., Eristi B., Demir Y. Automatic recognition system of underlying causes of power quality disturbances based on S-Transform and Extreme Learning

 DOI : 10.35291/2454-9150.2022.0013

Machine, International Journal of Electrical Power and Energy Systems, 61, pp. 553-562, 2014

[2] Abdoos A. A., Moravej Z., Pazoki M. A hybrid method based on time frequency analysis and artificial intelligence for classification of power quality events, Journal of Intelligent and Fuzzy Systems, 28(3), pp. 1183-1193, 2015.

[3] Yujin Lim, Hak-Man Kim, and Sanggil Kang "A Design of Wireless Sensor Networks for a Power Quality Monitoring System" Sensors (Basel). 2010; 10(11): 9712–9725.

[4] S. L. Ullo, A. Vaccaro "Gossip Sensor Networks for Power Quality Monitoring in Smart Grids" International Conference on Renewable Energies and Power Quality March 2012.

[5] LuisMorales-Velazquez,Rene de JesusRomero-Troncoso "Smart sensor network for power quality monitoring in electrical installations" ELSEVIER June 2017..

[6] Prakash, K.R.; Nand, K.; Soumya, R.M. Islanding and power quality disturbance detection in grid connected hybrid power system using wavelet and S-transform. IEEE Trans. Smart Grid 2012, 3, 1082-1094, doi: 10.1109/TSG.2012.2197642.

[7] Kovendan, A.K.P. and Sridharan, D. (2016) Wireless Sensor Networks Based Control Strategies for the Enhancement of Reliability in Smart Grids. Circuits and Systems, 7, 2499-2506.

[8] R. RajkamalP. Vanaja Ranjan "A Hybrid Aggregation Technique for Continuous-Monitoring in Wireless Sensor Networks" International Conference on Advances in Communication, Network, and Computing, Springer 2011.

[9] Benazir Fateh, Student Member, IEEE, Manimaran Govindarasu, Senior Member, IEEE, and Venkataramana Ajjarapu, Fellow, IEEE, " Wireless Network Design for Transmission Line Monitoring in Smart Grid ", IEEE Transactions On Smart Grid, vol. 4 no. 2, pp. 1076-1086, June 2013.

[10] K. S. Hung W. K. Lee V. O. K. Li K. S. Lui P. W. T. Pong K. K. Y. Wong G. H. Yang J. Zhong "On wireless sensors communication for overhead transmission line monitoring in power delivery systems" Proc. 1st IEEE Int. Conf. Smart Grid Commun. (SmartGridComm.) pp. 309-314 2010-Oct.-46.

[11] Y. C. Wu L. F. Cheung K. S. Lui P. W. T. Pong "Efficient communication of sensors monitoring overhead transmission lines" IEEE Trans. Smart Grid vol. 3 no. 3 pp. 1130-1136 Sep. 2012. .

[12] Yan ZHEN "Transmission Line Monitoring Network Design in Smart Grid " 2016 International Conference on Applied Mechanics, Mechanical and Materials Engineering (AMMME 2016)

[13] Lazaropoulos, A.G. Wireless Sensor Network Design for Transmission Line Monitoring, Metering, and Controlling: Introducing Broadband over power lines-enhanced network model (BPLeNM). ISRN Power Eng. 2014.

[14] Junru Lin "Monitoring power transmission lines using a wireless sensor network" WIRELESS COMMUNICATIONS AND MOBILE COMPUTING 2015

[15] Ye F, Qian Y, Hu R. Energy efficient self-sustaining wireless neighborhood area network design for smart grid. IEEE Transactions on Smart Grid 2015; Volume 6 Issue 1: pp.220-229.

[16] Guo Z, Ye F, Guo J, Liang Y, Xu G, Zhang X, Qian Y. A wireless sensor network for monitoring smart grid transmission lines. In In 2014 23rd International Conference on Computer Communication and Networks ICCCN, Shanghai, China, 2014; pp.1-6.

[17] Patrick R. Casey,& Nabih Jaber "Design And Implementation Of Cross-Platform Sensor Network For Smart Grid Transmission Line Monitoring""ieee2011

[18] Zhai Zi-Nan And Gui Wei-Feng, "Research On Monitoring Power System Faults By Wireless Sensor Network", Research On Monitoring Power System Faults By Wireless Sensor Network, 2010

[19] Hartmann, T. Generating realistic Smart Grid communication topologies based on real-data. In Proceedings of the IEEE International Conference on Smart Grid Communications (SmartGridComm), Venice, Italy, 3–6 November 2014; pp. 428–433.

 DOI : 10.35291/2454-9150.2022.0013