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Research Article

# Multi-constraint Fuzzy-based Wireless Sensor Node Communication for Smart Grid

**R. Karpaga Priya[1], S. Venkatanarayanan[2], N. Rajeswari[3], S. M. Kannan[2]**

*[1]Department of Electronics and Communication Engineering, Vaigai College of Engineering, Madurai, Tamil Nadu, India, [2]Department of Electrical and Electronics Engineering, K.L.N. College of Engineering, Sivagangai, Tamil Nadu, India, [3]Department of Electrical and Electronics Engineering, Raaja Raajan College of Engineering and Technology, Karaikudi, Tamil Nadu, India*

## ABSTRACT

Smart grid can be characterized as an advanced electric power network framework for enhanced effectiveness, unwavering quality, and security, with smooth incorporation of renewable and non-renewable sources through computerized control and current correspondences advances. Wireless sensor networks (WSNs) are imagined to be a vital empowering innovation for Smart Lattice because of the minimal effort, simplicity of sending, and adaptability of WSNs. In this work proposes a WSN-based communication system for the monitoring of smart grid, loads and transmission lines in the electrical grid and a controller system for automated control on the grid. We have used a protocol fuzzy-based multi-constraint routing protocol for a wireless sensor node communication. Data communication and relay node selection follow multi-constraint fuzzy membership function implementation results. The routes having minimum fuzzy cost will be considered as optimal path, and the data are to be transmitted over this path from source node to a set of receivers. The simulation has been conducted using network simulation 2 and MATLAB; the results show the effectiveness of the proposed protocol in terms of packet delivery ratio, packet delivery delay, and control overhead.

**Address for correspondence:**
R. Karpaga Priya,
9A, Salaimuthaliyar Street, Narimedu,
Madurai - 625 002,
Tamil Nadu, India.

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## INTRODUCTION

The present electric power appropriation arrange is exceptionally intricate and ill-suited to the necessities of the 21st century. Among the inadequacies are an absence of computerized investigation, poor perceivability, and mechanical switches causing moderate reaction times, absence of situational mindfulness, and so on. These have added to the power outages occurring in the course of recent years. Some extra restraining factors are the developing populace and interest for vitality, the worldwide environmental change, hardware disappointments, vitality stockpiling issues, the limit constraints of power age, one-way correspondence diminish in non-renewable energy sources, and flexibility issues. Likewise, the ozone harming substance emanations on Earth have been a huge risk that is caused by the power and transportation enterprises. Thus, another matrix framework is direly expected to address these difficulties. Due to the land conditions and versatility sustainable power source assets got a more prominent effect in dispersed age. Antiquated electrical framework was not intended to meet out the present day's ability and bidirectional power flow support. To address these issues, smart grid developed. At the point, when the present electrical network winds up plainly more astute by ending up more solid, predictable, and moderate and supports more circulated age will be named as smart grid.

Wireless sensor networks (WSNs) that play a key role in various monitoring applications even in the most robust scenarios will be an ideal candidate. Emerging of such a smarter grid will increase the reliability of the system by taking proactive measures in case of power failure and also in the occurrence of natural calamities. The increased capacity of distribution generation will facilitate the consumers through reducing their dependency on grid added to that emission of greenhouse gases through the burning of fossil fuels will thereby reduce. These advantages were nothing when there is the occurrence of varying faults such as voltage rise and reverse power flow; fortunately, the distributed generation uses electronic converters and inverters, thus can enable islanding mode in case of grid failure or power shutdown to overcome the issues of distributed generation. Sensing and control system has three main phases, namely: Sensing phase, data communication phase, and control phase. The sensing part can be done effectively by the use of wireless sensor nodes (WSNs).

Basically, two types of information infrastructure are needed for data flow in a smart grid system. The first flow is from sensor and electrical appliances to smart meters; the second is between smart meters and the utility's datacenters. The first data flow can be accomplished through power line communication (PLC) or wireless communications such as ZigBee, 6LowPAN, Z-wave, and others. For the second data flow, cellular technologies or the Internet can be used. In any case, there are key restricting components that ought to be considered in the brilliant metering arrangement process, for example, time of organization, operational costs, the accessibility of the innovation and country/urban or indoor/outdoor environment, and so forth.

This paper proposes a WSN-based communication system for the monitoring of distributed generation, loads, and transmission lines in the electrical grid and a controller system for automated control on the electrical grid. We have used a protocol fuzzy-based multi-constraint routing protocol for a wireless sensor node communication. Data communication and relay node selection follow multi-constraint fuzzy membership function. It considers multiple quality of services (QoSs) performance constraints at a time in terms of end-to-end delay, channel bandwidth, and energy.

The rest of the paper is organized as follows: Section 2 presents the related work about the wireless control strategies. Section 3 discusses about the fuzzy logic-based relay node selection. The performance evaluation, analysis, and simulation results are discussed in section 4, and finally, the section 5 provides the conclusions.

## RELATED WORKS

Salvadori *et al*.[1] proposed a digital system for condition monitoring, diagnosis, and supervisory control applied to smart grids. The system is based on hybrid network architecture consisting of a wired infrastructure, a wireless sensor network (WSN), a PLC, and a controller area network.

Sinan *et al*.[2] constructed a detailed link layer model by employing the characteristics of Tmote sky WSN nodes and channel characteristics based on actual measurements of Smart Lattice path loss for various environments. A novel Mixed Integer Programming framework is created using the aforementioned link layer model for WSN lifetime maximization by joint optimization of transmission power level and data packet size.

Benazir *et al*.[3] developed a real-time situational awareness framework for the electrical transmission power grid using WSN. While WSNs are capable of cost-efficient monitoring over vast geographical areas, several technical challenges exist. The low power and low data rate devices cause bandwidth and latency bottlenecks. In this paper, our objective is to design a wireless network capable of real-time delivery of physical measurements for ideal preventive or corrective control action.

Cristina *et al*.[4] proposed an EWS based on WSNs (under the ISA100.11a standard) and reputation for controlling network behavior. The WSNs are organized into clusters where a cluster head (CH) is designated. This CH will contain a reputation manager module. The usability of this approach is also analyzed considering a smart grid scenario.

Vehbi *et al*.[5] started with an overview of the application of WSNs for electric power systems along with their opportunities and challenges and opens up future work in many unexploited research areas in diverse smart grid applications.

Francesco *et al*.[6] presented an IoT software infrastructure that enables energy management and simulation of new control policies in a city district. The proposed platform enables the interoperability and the correlation of (near-) real-time building energy profiles with environmental data from sensors as well as building and grid models.

Falabretti *et al*.[7] described the experimental activities developed in the IoT Lab of Politecnico di Milano, focused on the use of energy storage systems for the primary frequency control. The IoT Lab is a multidepartmental laboratory devoted to design and test experimentally innovative IoT algorithms and thin-layer chromatography techniques for smart user applications.

Anjan *et al*.[8] constructed to build an end-to-end protection system in smart grid application, it is required to have calibration of the security requirements of different subsystems. The paper presents a framework for calibrated security measures for smart grid which could also be the base for other loT applications such as Industrial control systems.

Hamed *et al*.[9] proposed the use of a novel algorithm for smart direct load control and load shedding to minimize the power outage in sudden grid load changes, as well as reduce the peak-to-average ratio (PAR). The algorithm uses forecasting, shedding, and smart direct load control. The algorithm also uses the Internet of Things and stream analytics to provide real-time load control, and generates a daily schedule for customers' equipped with IEDs, based on their demands, comfort, and the forecasted load model.

Mitali *et al*.[10] proposed the main part of article is smart grid meter. When LED in smart meter gives 3200 blinks, this means one unit is consumed. The second feature of this project is one micro switch is fitted in meter. This is to prevent meter tempering. There is one hidden switching circuit in that whenever any person tries to open the meter switch will get popup and controller send the message to owner and consumer. The third feature of project is control meter, if bill is not paid by customer, then owner can cut the meter. Acquiring of data needs human resources, we can save this critical resource using smart grid application.

Nagendra *et al*.[11] developed an advancement in high-speed communication and low-cost sensor coupled with the increased deployment of the advanced provide utilities with better information to manage the grid. It comprises a two-way communication where electricity and information are exchanged by the consumer and utility to maximize efficiency. The control center ensures the smart grid optimize circuit VAR flow and voltages; thereby, power theft location can be monitored with the help of the smart transformers and smart energy meters.

## PROPOSED SYSTEM

The entire framework has been furnished with wireless sensor systems for the obtaining of information from these units. These wireless nodes are fit for forming a network by interfacing together with no other correspondence necessity like base station. The neighboring nodes will be acting as the relay and support multihop communication in the network. The parameters that must be observed are voltage, power harmonics, current at the purchaser side, and atmospheric information of the station. The power quality when affected by the loads of the consumer the information will be recorded and sent to the communication controller in the interest of increasing reliable transmission by maintain the power quality. When there is exceed of rated level of harmonics to be injected, then the connection will be terminated so that the power quality of the overall grid will be maintained.

In this paper, we have tried to control these uncertainties issues to conserve the network resources using fuzzy logic tool. In this mechanism, all the available network metrics of the routes are converted into a single metric, i.e., fuzzy cost (FC) or communication cost. The routes having minimum FC will be considered as optimal path, and the data are to be transmitted over this path from source node to a set of receivers.

## Input fuzzification

Here, three input variables such as delay, bandwidth, and residual energy are fuzzified in fuzzification phase. A linguistic variable is generally decomposed into a set of linguistic terms (value). On the basis of knowledge, base rule of smart grid, the terms low, medium, and high are three linguistic variables to each input variable such as voltage, current, and frequency. For the output variable (FC), the linguistic values are used as very low, low, medium, and high for monitoring the voltage, power harmonics, and the efficiency on consumer side.

## Membership function

Membership functions are used in the fuzzification and defuzzification steps of an FLS, to map the crisp input to fuzzy input and vice versa. In fuzzification step, the crisp input is converted into a fuzzy input set, i.e., (linguistic values), using membership function. The membership function is used to quantify a linguistic term, in the proposed protocol triangular membership function has been used. The membership function for FC is shown in Figure 1.

## Fuzzy knowledge base rule

In an FLS, a rule base is constructed to control the output variable. A fuzzy rule is a simple IF-THEN rule which contains antecedent and consequent statement including either "AND" or "OR" operator. Both operators deal with multiple linguistic statements where "AND" deals whether multiple linguistic statements are valid and "OR" operator deals when at least one of them linguistic statement is valid.

This article proposes a protocol which controls the network metrics uncertainty issues using fuzzy logic system that helps in the selection of optimal multicast routing path to send the data packets from source node to a group of receiver's node at a time. The multicast routing path has been selected based on minimum FC value. The relationship between FC function and the network performance metrics is given in Equation 1.

$$\text{Fuzzy cost (FC)} = F\ (d, b, Er) \tag{1}$$

$$d(R(s,t)) = n\ i = 1\ \text{delay}[ei, e \in R(s,t)] \tag{2}$$

$$b(R(s,t)) = n\ i = 1\ \text{bandwidth}[ei, e \in R(s,t)] \tag{3}$$

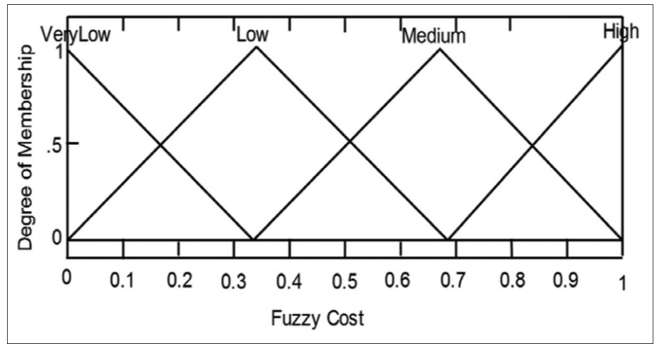


**Figure 1:** Fuzzy cost

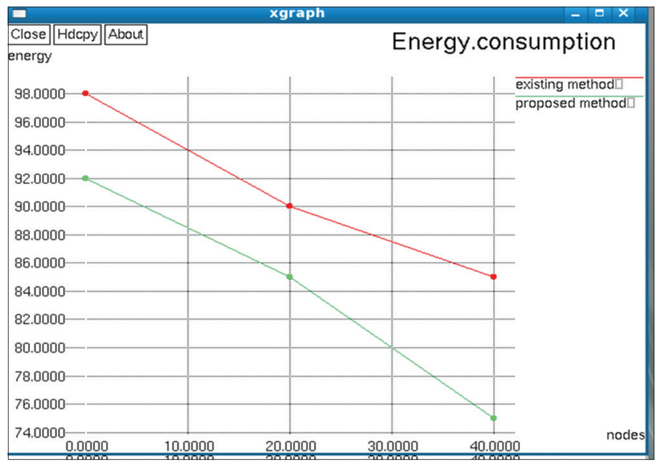


**Figure 2:** Energy analysis

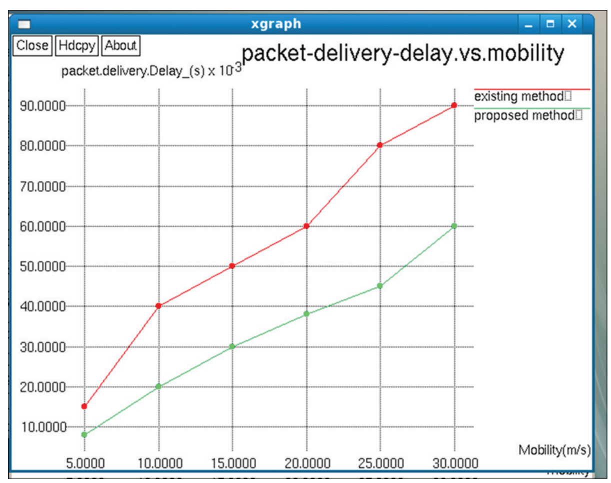


**Figure 3:** Packet-delivery ratio

Where, d is end-to-end delay of the routes, b is channel bandwidth that defines the available slot between two nodes, and Er is the amount of residual energy of the routing path. The delay (d), bandwidth (b), and the residual energy (Er) of the routing path are to be calculated using Equations 2-5, respectively.

$$Er(L(ni,ni+1))=Eint(ni)-[Et(ni)+Er(ni)] \tag{4}$$

$$Er(R(s,t)) = n-1\ i = 1\ Er[L(ni, ni+1)] \tag{5}$$

Where, R is the route from source node s to destination node t, e is transmission channel between two nodes, and n


**Figure 4:** Mobility analysis


**Figure 5:** Overhead analysis

is the number of nodes participating in a particular routing path. The residual energy (Er) from source node (s) to a set of receiver's nodes (t) is calculated using Eq. (4) and dummy TX dummy Equation 5 and is represented by Er. The optimal routing path is to be selected by the source node using the minimum FC value.

## RESULTS AND DISCUSSION

### NS2 Implementation

The proposed protocol has been simulated using network simulation 2 (NS-2) in version 3.5. The performance of the proposed protocol has been evaluated through comparing its QoS metrics with some other existing multicast routing protocols such as MAODV and ODMRP in terms of packet delivery ratio, packet delivery delay, and control overhead [Figures 2-5].

We observe that the packet delivery delay increase gradually as the number of node increases. The reason is that as the number of nodes increases the traffic load also increases that leads to the wastage of time in the selection of multicast routing path.

## CONCLUSION

In this paper, a fuzzy-based route selection communication module and a control strategy for controlling the smart grid substation for islanding of distributed generation, active power control strategy for avoiding voltage rise, and voltage control strategy along with the power quality analysis have been designed implemented and validated. NS2 implementation results show our efficient fuzzy-based multi-constraint routing protocol for a wireless node communication improve packet delivery ratio, packet delivery delay, and control overheads that show better in compare to existing one.

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