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# CODE STRATEGY ALGORITHM FOR ONLINE POWER QUALITY MONITORING OF ELECTRICAL EQUIPMENT USING WSN UNDER TINY-OS ENVIRONMENT

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**ABSTRACT**

Minimization of energy consumption is one of the most vital objective for Wireless Sensor Network (WSN) based applications. The rate of the node's energy consumption is based on the sampling rate of the sensors in wireless sensor networks (WSNs), since most of the energy is used in sampling and transmission. To save the energy in WSNs and thus prolong the network lifetime, this paper presents a novel approach based on Event-Driven Algorithm (EDA) with code-driven strategy. In this algorithm, energy efficient wireless sensor network has been developed and code driven protocol for data forwarding which minimize the transmission power of sensor node has been designed. The proposed algorithm has shown 68% increase of network lifetime in Event-Driven Algorithm (EDA) and 79% increase in Code-Driven Algorithm (CDA) when compared with a continuous monitoring algorithm. The performance of the proposed protocol is analyzed experimentally using Crossbow IRIS motes under TINY OS environment and results are discussed.
**Keywords—***Energy Efficient, Event-Detection, Power Quality Monitoring, Power Control, Smart Grid*

## 1. INTRODUCTION

Traditionally, energy evaluation in industrial power plants is realized through wired systems formed by communication cables and various types of sensors [1]. The installation and maintenance of these cables and sensors are usually much more expensive than the cost of the sensors themselves. Clearly, the elimination of communication cables and the associated installation cost can greatly reduce the overall expense. This naturally presents the opportunity to investigate the use of wireless systems. However, due to the high cost of commissioning legacy wireless systems, this opportunity was not feasible until the appearance of the wireless sensor network (WSN) over the past few years.

Recent advances in sensing, computing and communication have allowed the deployment of cost effective ad hoc sensor networks for various applications, such as military sensing, physical security, traffic surveillance, industrial and manufacturing automation environment monitoring, building and structures monitoring [1], [24] and power grid monitoring and control [13]. This paper addresses one unique problem faced by the power grids, namely the voltage and current transients like Voltage sag, Voltage swell etc. These power quality problems causing major damage of equipment and poor quality of transmission power. This is an increasing demand to monitor such unforeseen and unpredictable events occurring on the large power grid. Because of inherently large geographically spread characteristics of the national power grid, distributed sensing for power delivery systems [3],[4],[7],[8] becomes another potential application of SNs.

The evolution of sensor technology and communication networks has allowed employing intelligent sensors for improving the processing control. In this case, sensors not only collect data but also perform some local processing and later transmitting their results through a wireless channel (i.e., radio transmission); thus, there is no need for a wired communication infrastructure [2]. Some paper discussed Adaptive Power Control with Overhearing Avoidance [15] to reduce the energy consumption.

Emerging advances in wireless communications, integrated electronics, and MEMS technology, new types of wireless networks, such as WSNs, have been developed. The ideal wireless sensor [1] is

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networked and scalable, consumes very little power, smart and software programmable, capable of fast data acquisition, reliable and accurate over the long term. WSN focuses primarily very-low-cost and very low-power-consumption applications. Wireless sensor networking is a form of mesh networking, with self-forming, self-healing properties, because most devices are unplugged, operating for years on a pair of AAA batteries, a WSN solution is much cheaper and faster to deploy. The advantages of WSNs over traditional sensing make them a promising platform for power quality monitoring systems. An overview of the proposed power quality monitoring scheme for SMART grid using WSNs is shown in Figure. 1.

This work extends previous work by the authors [6], [9] in which WSN was applied for continuous monitoring of industrial motor system [5],[6] and Smart Grid applications [9],[16]. The current work focuses power quality monitoring of SMART grid using Energy Efficient Event-Driven ($E^3D$) algorithm of wireless sensor networks and analyses impact on its performance characteristics such as energy level, power consumption… The proposed scheme comes from the fact that the power quality monitoring of SMART Grid is achieved by using energy efficient event-driven Algorithm [10], [18], [23] and TINY-OS Cross-bow IRIS motes.

## 2. WSN

Wireless sensor networks are designed to be application aware and deployed accordingly. Most

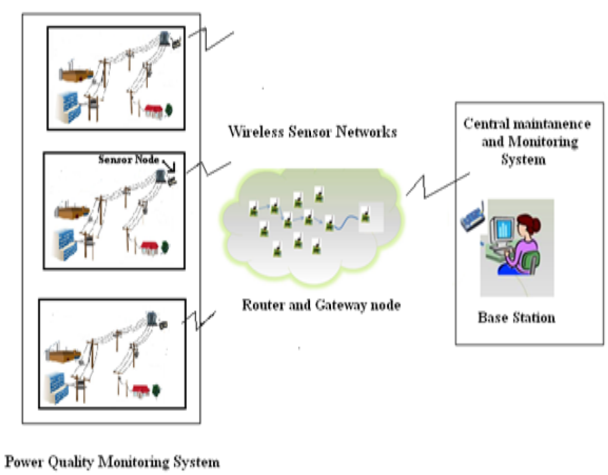


*Figure 1. Power quality monitoring using WSN*

sensor nodes are battery operated and normally they cannot be recharged due to its deployment in remote environment. Therefore, energy efficiency is a very critical issue to increase the network lifetime [2–4]. In this paper, the transmission power control based protocols, which use an event-driven algorithm to save transmission energy. There are four major sources of energy consumption, transmission, reception, listening, packet overhead and idle. In IEEE 802.15.4, the power consumption on transmission is more as compared to the other sources of energy consumption, so transmission is the dominant factor of energy waste. This paper focus on the concept of transmission power control [17-21] (TPL). Event-driven algorithm is discussed in this paper which reduces transmission power consumption and it has been implemented using crossbow IRIS motes under TINY-OS environment. In an effort to reduce power consumption, condition-based maintenance employs many different technologies to monitor the performance of transformers. It is believed that a reduction in transformer failures increases plant efficiency and productivity. Wireless sensors are becoming a much more feasible monitoring option because of their desirable characteristics.

IEEE802.15.4 standard [12] is designed to provide simple wireless communications with short range distances, limited power, relaxed data throughput, low production cost, and small size. These are also the properties of the industrial system health monitoring and maintenance. It is self configured network topology. The IEEE 802.15.4 standard supports two frequency bands: a high band at 2.4GHz and a low band at 868/915 MHz. The 802.15.4 standard shown in the Figure. 2 [12] uses

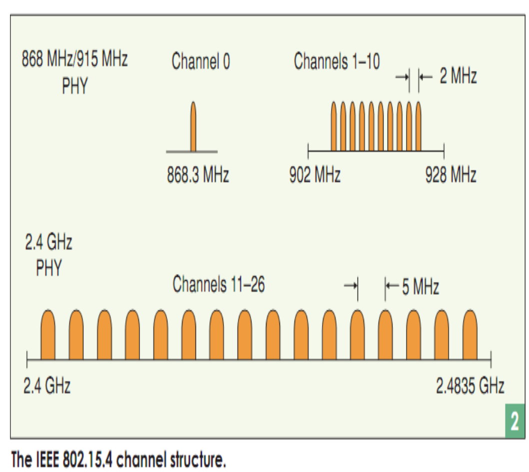


*Figure 2. IEEE 802.15.4 Structure*

a standard packet structure. Each packet contains a

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preamble, a start of packet delimiter, a packet length, and a payload field. The payload length can vary from 2–127 B depending upon specific application demand.

## 3. NETWORK COMMUNICATION MODEL

A typical wireless sensor network consists of various sensor nodes with number of different sensor. In this analysis sink node and all sensor nodes are stationary. A sensor node which is connected to the equipment, monitor the physical quantity of the equipment. If a fault occurs then the local event detection is conducted by the source node and only faulty data is routed to the sink node to take further action.

This paper considers a static event-driven wireless sensor network with 'K' sensor nodes. The network uses a KxK neighborhoods router node matrix $Q_{kxk}$ to indicate the direct communication of node pairs. Assume that the $Q_{kxk}$ is a symmetric matrix, means, both i and j can transmit in both directions. This means the $Q_{i,j} = 1$ if node 'i' can transmit a packet to node 'j'; otherwise $Q_{i,j}=0$. The network model [14], allows bidirectional transmission between a pair of node. Mathematically, let $FN_i$ be the set of nodes that are closer to the sink than the source. $FN_i$ belongs to $K_i$ such that $j \in FN_i$ , if

$$Dist(K_i, K_s) \leq Dist(K_j, K_s) \quad (1)$$

$$Dist(K_i, K_d) \leq Dist(K_j, K_d) \quad (2)$$

Let $BN_i$ be the set of nodes closer to the source than the sink. $BN_i$ belongs to $K_i$ such that $j \in BN_i$ , if

$$Dist(K_i, K_s) \geq Dist(K_j, K_s) \quad (3)$$

$$Dist(K_i, K_d) \leq Dist(K_j, K_d) \quad (4)$$

Where $Dist(K_i, K_j)$ represents the distance between node 'i' and node 'j', 's' and 'd' denote the source and destination node respectively.

Most researchers discussed Shortest Path Routing (SP) algorithm for efficient energy utilization in wsn. But rhis algorithm considers only the distance between the nodes. This paper proposes the efficient shortest path routing algorithm, which consider energy as the one of the parameter to select the path. In the proposed routing algorithm, route computation is based not only on the distance but also on the residual energy in the nodes. The proposed routing algorithm is as follows:

Routing Algorithm

```
N: Network with 'n' node;   (n = 1,2,3,4,5,…,n )
n: node in a network;
Dist: Distance between two nodes;
n_for: formed nodes ;
n_ufor: un formed nodes ;
n_eval: evaluated node;
n_des: destination node

  Initialize
    Dist(initialnode) = 0;
    Dist(othernodes) = infinity;
    n_for = 0;
    n_ufor = n;

For i=1 to n{
  While (n_ufor ≠ 0){
   n_eval = lowest Dist node in n_ufor;
   n_ufor = n_ufor -1;
   n_for = n_ufor+1;
 For each n_des routed via edge from n_eval{
   Dist_edge = Dist(edge(n_eval ,n_des);
   Dist_new =Dist_eval + Dist_edge;
   If ((Dist_des > Dist_new) && (E_res > E_th)) {
         Dist_des = Dist_new;
}}}}
```

An event is defined as a set of predefined records and corresponding outcomes based on the attributes. Mathematically, E can be defined as either composite or atomic event. The composite event is defined with a compound propositional function as expressed in equation (5):

$$E = F(O_1(x), O_2(x), ...., O_n(x)) \quad (5)$$

Where $O_1(x)$ through $O_n(x)$ are outcomes, F is a function of Boolean algebra operators. For example, an event fire can be defined as Fire = $O_1(x)$ U $O_2(x)$ U $O_3(x)$, where $O_1(x)$ denotes the outcome of temperature > 3500, $O_2(x)$ denotes the outcome of smoke > 120mg/L, and $O_3(x)$ denotes the outcome of light > 400cd.

This paper concentrates only on atomic event. An atomic event is a special type of composite event which involve only one observation attributes

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and its corresponding outcome. For example, an event voltage sag in power quality can be defined as a fault = O($V_{sag}$), where O($V_{sag}$) be the phase voltage of the distribution transformer. Similarly, Voltage swell in power quality monitoring is also an atomic event.

## 4. ENERGY MODEL

This paper considers a general energy model [11], the energy consumption of a sensor is dominated by its data transmission and reception. The energy consumption [22] due to sensing and processing is negligible as compared to the energy consumption due to transmission and reception. The energy model has been designed using first order radio model. In the radio model $E_0$ be the initial energy of each sensor, $E_T$ be the energy cost to activate the transmitter and receiver circuitry and $E_A$ is the transmitter amplifier energy cost to communicate. Assume that the maximum transmission energy consumption to transmit 'n' packet to the distance 'd' denoted as $E_{TMAX}(n,d)$ and the energy to receive the same packet is denoted as $E_{RMAX}(n,d)$. The energy consumption model is,

$$E_{TMAX}(n,d) = E_T * n + E_A * n * d^2 \qquad (6)$$

and

$$E_{RMAX}(n,d) = E_T * n \qquad (7)$$

Since, the transmission range of each sensor is $R_T$, equation(6) can be further simplified as ,

$$E_{TMAX}(n,d) = N_T * n \qquad (8)$$

Where $N_T = E_T + E_A * R_T^2$ , since 'd' is replaced with $R_T$, maximum coverage limit. From equation(7) and equation(8), it can be seen that the consumption of energy for transmission and reception is proportional to the number of packets to be transmitted.

## 5. E³D ALGORITHM

The pseudo code of the proposed method is described as Energy Efficient Event-Driven (E³D) Algorithm. The source node connected to the electrical system has senses the electrical data and check for the event. If Event occurs for time 't', the counter starts its count. If the count is 'n', it sends the Route Request packet($R_{req}$) to the coordinator through minimum cost path and wait for the Route Reply packet ($R_{rep}$). If $R_{rep}$ is received, it transmits only faulty (event) data packets to the coordinator.

E³D Algorithm.

```
N- Network
Rreq- Route Request packet
Rrep- Route Reply packet
ACK- Acknowledgement packet
mcp- minimum cost path
RPi- Route path for node 'i'

 If (no Rreq packet is sent before){
   Occurrence of event is found by  using DSP
techniques
    If (Event occurs for  t){
       Counter  counts upto 'n' counts
        If  count is 'n'{
          For (all of this node's  neighbours){
            If (RPi==0){
             Calculate costi for neighbor i;
             Find minimum cost path(mcpi)
             Send Rreq to the sink node for
                   minimum  cost pathi}};
             If (Rrep  is received){
               Transmit data packets
               };
             If (a ACK  is received from sink){
             Continue  data packet transmission
              Over mcpi}}}}
```

The base station which is connected to the CMS receives the $R_{req}$ packet. Upon reception of $R_{req}$. BS sends the $R_{rep}$ packet to the source node and waits for the data/code packet. Depending on the structure of incoming data/code packet, the corresponding action would be taken by CMS.

Algorithm for Sink node

```
 If (the first Rreq packet is received)
   {
     Send Rrep packet in reverse;
    }
     waiting for data packets or code packet
   If  (data packet or code packet is received)
    {
     send the ACK packet to the source node
and
     immediate action to be taken by CMS
     }
```

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## 6. EXPERIMENTAL VALIDATION OF POWER QUALITY MONITORING

A sag or swell is a decrease or increase in the RMS value of the voltage ranging from a half cycle to a few seconds. The voltage sag and voltage swell is shown in Figure 3. The largest cause of problems from the utility side is voltage sags. Sags or swells can occur within a plant at the point of use and may be unrelated to the quality of power at the service entrance. These types of disturbances can lead to loss of production etc and the recorder being used should be able to capture these events. It should be noted that sags/swells can occur and be outside normal operating limits and not cause any problems. It is therefore important to know what levels of abnormal voltage and for how long specific equipment will tolerate it. The proposed algorithm is investigated through a series of laboratory experiments. In this section power quality monitoring concept is demonstrated using cross-bow IRIS motes using shortest distance routing protocol with mesh topology in laboratory.

The experimental setup for power quality monitoring is shown in Figure. 4a and 4b. The secondary output of 230V-18V, transformer is measured by using Hall effect probe sensor whose output is connected to the IRIS source node (sensor node at the source). This node senses the incoming analog voltage from the sensor and check for the event. If event (sag or swell) has continuously occurred for time ‘t’, it transmits the corresponding data packets in EDA algorithm or code packet in CDA algorithm to the base station (sensor node at the destination) otherwise

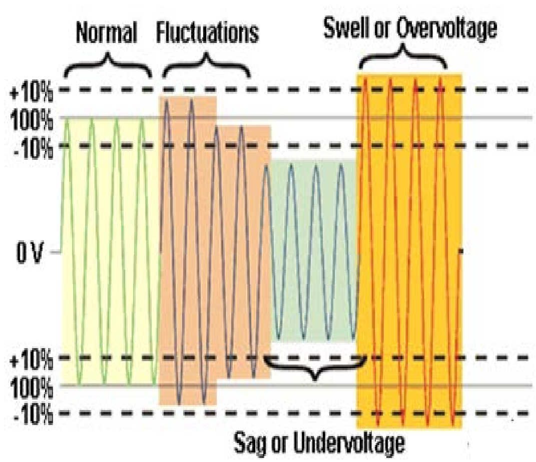


*Figure 3. Voltage sag and Voltage swell*

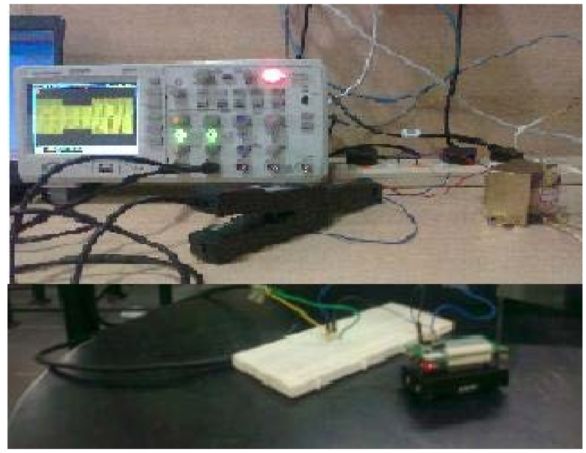

*Figure 4a Experimental prototype test bed at the transmitter*

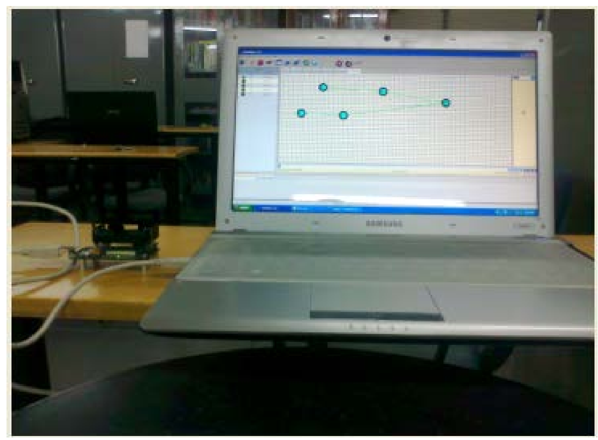

*Figure 4b Experimental prototype at Base station*

it will not transmit any packets. The proposed algorithms transmit packets to the base station only when the event is happened. It uses the IEEE 802.15.4 standard RF230 radio components for transmission

*Table 1 MOTE Packet Format*

| Tiny Os Header | Xmesh Header | XSensor Header | Payload | CRC |
|---|---|---|---|---|
| 5 bytes | 7 bytes | 4 bytes | 9 bytes | 2 bytes |


*Figure 5 IRIS mote*

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The experiments are carried out in Lab Environment. One IRIS mote, which is shown in Figure 5 is configured as Coordinator and another IRIS mote is configured as Source node which senses the data and checks the event. All other nodes are configured as router. When the event occurs, the source node collect the faulty data packets and transmit to the Base station (BS) until it receives acknowledgement packets from Base Station in event-driven algorithm (EDA) through multihop approach. In Code-driven algorithm (CDA), a code packet which corresponds to the fault is transmitted to the BS. Each packet either data packet of code packet has 27 bytes. Each mote packet includes TinyOS header, XMesh header, XSensor header, data payload and CRC. Table 1 shows the mote's packet format.

## 7. RESULT AND DISCUSSION

The performance analyses of various algorithms are shown in Figure 6 through Figure 11. The network life time of the wireless sensor network which is based on the many constraints, is here discussed on the basis of Transmission Power consumption of the nod Most of the paper discusses only continuous monitoring algorithm(CMA) and Data Aggregation Algorithm(DAA) However, these algorithms consume more transmission power because it transmits all the sensed packets or average of the sensed data packets to the BS.

In the proposed technique, the Fault is introduced at 30 minutes and at 120 minutes after switch ON the experimental setup. At 30 minutes EDA transmit only 8 packets and CDA transmit one packet, but DAA and CMA transmit 89 and 1640 packets. Due to the reduction of the number of packets transmitted to the BS, EDA and CDA consume only 0.408W and 0.051W and DAA/CMA consumes 4.5W/83.6W. The transmission power consumption of all the algorithms is shown in Figure 6 and Figure7.

Similar to the power consumption, the energy consumption of the node is also depending on the number of packets transmitted. The energy consumption of the node during the experiment is shown in Figure 8 and Figure 9. From the IRIS mote radio (RF230) specifications, the mote requires 17mA current to transmit a packet. At 30 minutes the calculated transmitted energy consumption for EDA and CDA is 0.204J and 0.026J. This is very less as compared to the DAA/CMA which consumes 2.269J/41.82J for transmission. From the graph it is understood that

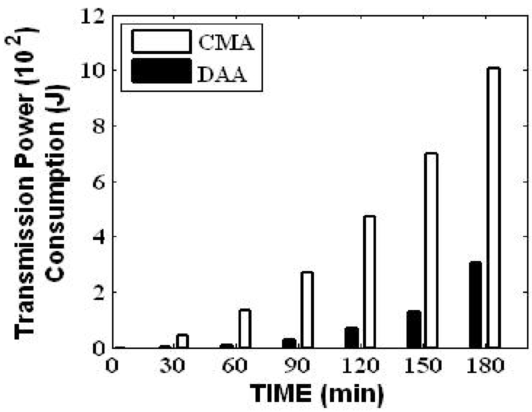


*Figure 6 Transmission power consumption for CMA and DAA*

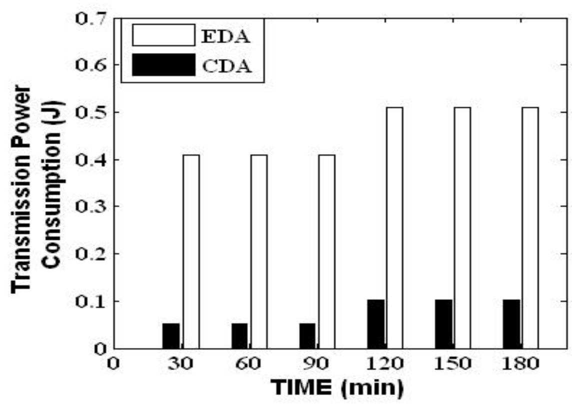


*Figure 7. Transmission power consumption for EDA and CDA*

the proposed algorithms increase the life time of the network. From the analysis, the life time of the network is 28% increased by EDA and 37% increased by CDA as compared to DAA and 68% increased by EDA and 79% increased by CDA as compared to CMA.

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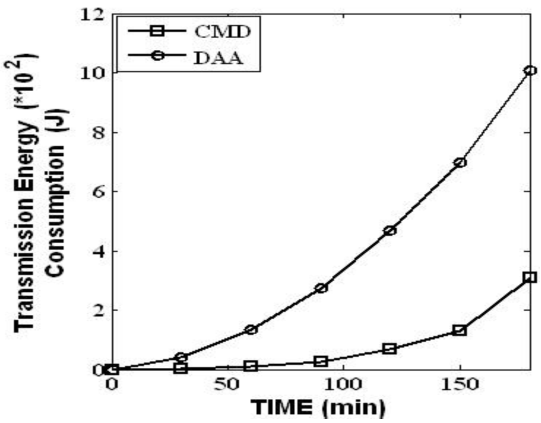


*Figure 8. Transmission energy Consumption for CMD and DAA*

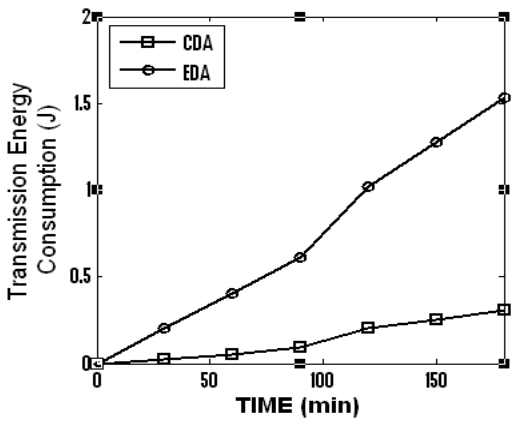


*Figure 9. Transmission energy Consumption for CDA and EDA*

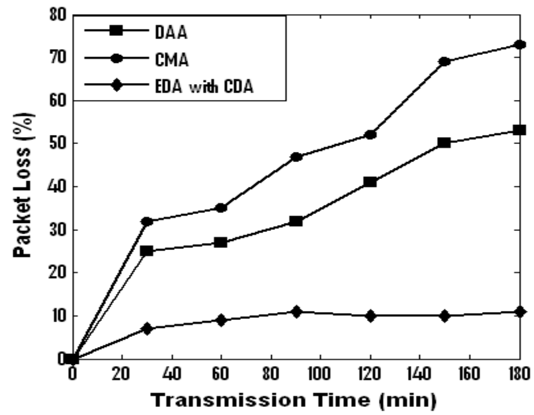


*Figure 10 Packet loss for CDA, DAA and EDA with CDA*

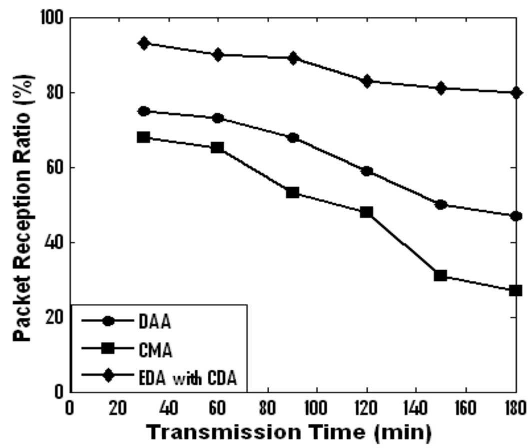


*Figure 11 Packet Reception Ratio*

The continuous set of experiments reveal that the proposed scheme yields a lower packet dropping rate than other schemes. Figure. 10 shows the number of packets dropped in the networks with respect to time. More number of packets are transmitted to the BS in CMA and DAA. So, these scheme drop a significant number of packets during the process of data transmission, whereas fewer packet drops by EDA with CDA scheme are observed from experiments. The proposed scheme transmits the packet only when the event is happened. Thus packet loss has been reduced in the proposed scheme.

Figure 11 shows the Packet reception ratio when the transmission interval of the power quality data is varied from one minute to 180 minutes for DAA, CMA and EDA with CDA. The Packet reception ratio means the average ratio of the number of data packets received by the base station to the total number of data packets sent by source.

The delivery ratio decreases with the increasing transmission time in the network. In the proposed scheme, the E$^3$D algorithm is used to reduce the traffic by restraining the transmission as soon as receiving emergency present message. Thus, the delivery ratio is obviously improved. The EDA with CDA scheme is able to maintain their packet delivery ratio even when transmission time increases.

## 8. CONCLUSION

In this paper a novel Energy Efficient Event-Driven protocol is framed. The proposed algorithm in event-driven wireless sensor networks detects the event and deliver faulty message reliably and timely. It reduces power consumption of sensor nodes and improves data quality received by the sink node. Due to the reduction of power consumption of the node, the life time of the network is increased using proposed algorithm. The proposed algorithm is observed through experiments to consume very less energy for

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transmission and it increases the network life time by 68%. The work is in progress to implement and analyze the effect of algorithm for various other power quality problems in a Smart Grid based on wireless sensor network.

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## REFERENCES

[1] F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wirelesssensor networks: A survey," *Computer Networks*., vol. 38, no. 4, pp. 393–422,Mar. 2002.

[2] Yujin Lim, Hak-Man Kim,Sanggil Kang, "A reliable data delivery mechanism for grid power quality using neural networks in wireless sensor networks", *Sensors Journal Open access*, vol *10*, pp.9349-9358, 2010.

[3] V. C. Gungor and Gerhard P. Hancke, "Industrial wireless sensor networks: challenges, design principles, and technical approaches", *IEEE Transactions On Industrial Electronics*, vol. 56, No. 10, Oct 2009.

[4] T.-K. Ma, C.-C. Liu, M.-S. Tsai, R. Rogers, S. Muchlinski, andJ. Dodge, "Operational experience and maintenance of online expert system for customer restoration and fault testing,", *IEEE Transactions on Power Systems*, vol. 7, no. 2, pp. 835 –842, May 1992.

[5] J. R. McDonald, G. M. Burt, and D. J. Young, "Alarm processing and fault diagnosis using knowledge-based systems for transmission and distribution network control," *IEEE Trans. Power Systems*, vol. 7, no. 3, pp. 1292–1298, Aug. 1992.

[6] Bin Lu, IEEE, and Vehbi C. Gungor, "Online and remote motor energy monitoring and fault diagnostics using wireless sensor networks", *IEEE Transactions On Industrial Electronics*, Vol. 56, pp.4651-4659, Nov 2009.

[7] Z. A. Vale, M. F. Fernandes, C. Rosado, A. Marques, C. Ramos, and L. Faria, "Better kbs for real-time applications in power system control centers: experience from the sparse project", *Computational Intelligence*, vol. 37, pp. 97–111, 1998.

[8] J. A. Hossack, G. M. Burt, J. R. McDonald, T. Cumming, and K. Stokoe, "Progressive power system data interpretation and information dissemination," in *IEEE/PES Transmission and Distribution Conference and Exposition*, Oct. 2001, pp. 907–912.

[9] Vehbi C. Gungor, Bin Lu, and Gerhard P. Hancke, "Opportunities and challenges of wireless sensor networks in smart grid", *IEEE Transactions On Industrial Electronics*, Vol. 57, pp. 3557-3564, Oct 2010.

[10] P. Baroni, G. Lamperti, P. Pogliano, and M. Zanella, "Diagnosis of a class of distributed discrete-event systems," *IEEE Trans. Syst., Man, Cybern. A, Syst. Humans*, vol. 3, no. 6, pp. 731–752, Nov. 2000.

[11] A.A. Somasundara, A. Kansal, D.D. Jea, D. Estrin, and M.B. Srivastava, "Controllably mobile infrastructure for low energy embedded networks," *IEEE Trans. Mobile Computing*, vol. 5, no. 8, pp. 958-973, Aug. 2006.

[12] B. Lu, T. G. Habetler, R. G. Harley, J. A. Gutiérrez, and D. B. Durocher, "Energy evaluation goes wireless: applying wireless sensor network in industrial plant energy evaluation and planning systems," *IEEE Industrial Application Magazine*, vol. 13, no. 2, pp. 17–23, Mar./Apr. 2007.

[13] P. Zhang, F. Li, and N. Bhatt, "Next-generation monitoring, analysis,and control for the future smart control center," *IEEE Trans. Smart Grid*, vol. 1, no. 2, pp. 186–192, 2010.

[14] Lulu Liang, Deyun Gao, Hongke Zhang, and Oliver W. W. Yang, "Efficient Event Detecting Protocol in Event-Driven Wireless Sensor Networks", *IEEE Sensors Journal*, vol. 12, pp.2328-2337, Jun 2012.

[15] M.Ramakrishnan,P.Vanaja Ranjan, "Adaptive power control with overhearing avoidance for wireless sensor networks", *Advances in Electrical and Computer Engineering* vol. 10, no 3, 2010 . pp 84-91.

[16] A. Bose, "Smart transmission grid a]pplications and their supporting infrastructure," *IEEE Trans. Smart Grid*, vol. 1, no. 1, pp. 11–19, Jun 2010.

[17] L. Liang, D. Gao, H. Zhang, and V. Leung, "a novel reliable transmission protocol for urgent information in wireless sensor networks," in *Proceedings GLOBECOM*, , Dec. 2010, pp. 1–6.

[18] A. V. U. P. Kumar, A. M. V. Reddy, and D. Janakiram, "Distributed collaborate on for event detection in wireless sensor networks," in *Proceedings MPAC, Grenoble, France*, Nov. 2005, pp. 1–8.

[19] Weiwei F. Shengxin LI, Xiangmin LIANG, Zhuyi LI, "Cluster-based data gathering in

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

long-strip wireless sensor networks", *Advances in Electrical and Computer Engineering* Volume 12, Number 1, 2012,*pp3-9.*

[20] C. Sergiou, V. Vassiliou, "Energy hole prevention in wireless sensor networks", *Proceedings 9th ACM/IEEE International Conference on Information Processing in Sensor Networks (IPSN), Stockholm, Sweden*, Apr. 2010, pp. 398-399.

[21] D. Son, B. Krishnamachari, and J. Heidemann, "Experimental study of the effects of transmission power control and blacklisting in wireless sensor networks", in *Proceedings of the Annual IEEE Communications Society Conference on Sensor and Adhoc Communications and Networks*, pp: 289-298, 2004.

[22] A. Vijayalakshmi, P. Vanaja Ranjan, "Slot management based energy aware routing (smear) for wireless sensor networks", IEEE *International Conference on Computing, Communications and Applications,Apr 2012.*

[23] F. J. Shang, M. Abolhasan, and T. Wysocki, "Distributed energy efficient unequal clustering algorithm for wireless sensor networks," *Journal on Communications*, vol. 30, no. 10, pp. 34-43, Oct. 2009.

[24] W. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "An application-specific protocol architecture for wireless microsensor networks," *IEEE Trans. Wireless Communication*, vol. 1, no. 4, pp. 660–670, Oct. 2002.

[25] Raj Naidoo, and Pragasen Pillay, "A new method of voltage sag and swell detection", *IEEE Transactions on Power Delivery*, Vol. 22, No. 2, Apr 2007.