Volume 5, Issue 12, December 2015 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

Reliability Enhancement in Wireless Sensor Network using EARQ Protocol

Dr. M. Sughasiny
Assistant Professor, Department of Computer Science, Srimad Andavan Arts & Science College (Autonomous), Bharathidasan University, Thiruchirapalli, Tamil Nadu, India

Abstract— A most challenging invention of Wireless Sensor Network (WSN) is to enhance the network lifetime. The area around the Sink forms a bottleneck zone due to heavy traffic-flow, which will limit the network lifetime in WSN. In this paper we propose the lifetime upper bounds have been estimated with (i) duty cycle, (ii) network coding and (iii) combinations of duty cycle and network coding. It has been observed that there is a reduction in energy consumption in the bottleneck zone with the proposed approach. This in turn will lead to increase in network lifetime. This work tries to improve the energy efficiency of the bottleneck zone which leads to overall advance of the network lifetime by considering a duty cycled WSN. An efficient communication paradigm has been adopted in the bottleneck zone by combining duty cycle and network coding algorithm and EARQ protocol (Energy Aware Routing Protocol) for wireless industrial sensor networks which is a novel routing protocol to achieve capability of energy efficient, real-time, reliable communications. It can send a redundant packet via an alternate path, but only if it is a source of a packet.

Keywords— Energy efficiency, EARQ protocol, Average Latency, Network Lifetime, Packet delay

I. INTRODUCTION

Wireless Sensor Networks (WSNs) consist of self directed sensor nodes that can be deployed for monitoring unattainable areas like glaciers, forest fires, deserts, deep oceans etc. Sensor nodes are generally provided a radio transceiver, a micro controller, a memory unit, and a set of transducers using which they can acquire and process data from the deployed regions.

An Industrial linear position is for measuring displacements of moving parts and it is necessary to consider new QoS requirements such a real-time, reliable communication in wireless sensor network. A sensing data from sensor nodes must be transmitted into the sink, reliably and in time. Delayed or lost data may cause industrial applications to malfunction, because the sensing data is analysed and appropriate commands are sent to the actuator of a machine.

In existing scheme do not provide simultaneous real-time, reliable and energy aware communication. Therefore the aforementioned wireless sensor network require simultaneous real-time, reliable and energy aware communication. Hence, it is necessary to design a routing protocol that can provide a real-time, reliable communication, and energy awareness in WSNs.

In this paper we propose An efficient communication paradigm has been adopted in the bottleneck zone by combining duty cycle and network coding algorithm and EARQ (Energy Aware Routing Protocol) with for wireless industrial sensor networks which is a novel routing protocol.

II. RELATED WORK

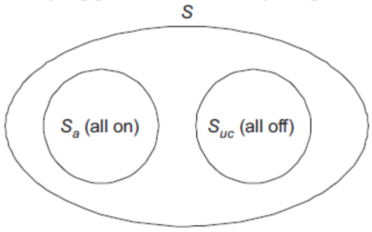
A technologies are develop in a process of gradual scientific change, but the commercial application of technologies is discontinuous. Most of the peoples are interested for technology evolution. These contrasting ideas using a powerful theoretical framework, based on the concept of punctuated equilibrium from evolutionary biology. The framework, which enables the differentiation of the technical evolution from its market purpose, is used in to compare the two standards for wireless sensor networks (WSN) for industrial instrumentation and control: Wireless HART and ISA100.11a.

A resource reservation-based routing can be introduced with signalling algorithm for Ad hoc Qos on-demand routing (AQOR) and it provides an end to end quality of service (QoS) support, in terms of bandwidth and end-to-end delay in mobile ad hoc networks (MANETs). The enhancing use of MANETs for transferring multimedia applications like voice, video and data, leads to the need to provide QoS support.

To perform accurate admission control and resource reservation in AQOR (Ad hoc QoS on-demand routing), a new method developed with detailed computations that allow us to estimate the available bandwidth and end-to-end delay in unsynchronized wireless environment. AQOR (Ad hoc QoS on-demand routing) also includes efficient mechanisms for QoS maintenance which including temporary reservation and destination initiated recovery processed before.

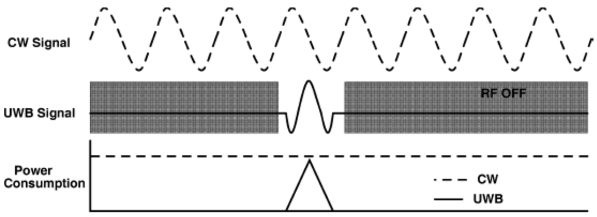
The properties of coverage over time as functions of individual sensor on/off schedules under a random duty cycling assumption. Specifically, the coverage intensity delivered, as defined the probability and distribution of the time

duration in which a target is uncovered. In a semi-Markov processes obtained a mathematical model which allows us to calculate the coverage intensity numerically with very good approximation accuracy.
A lower complexity model with reduced state space with asymptotic version of this measure as the number of sensors tends to infinity. There is a close relationship between coverage intensity and the measure of path availability as defined as the probability distribution of durations in which a path (of a fixed number of nodes) remains available. Thus models obtained the result of coverage intensity readily applies to the study of path availability.



An illustration of relationships among different subsets of the state space of the superposed process.

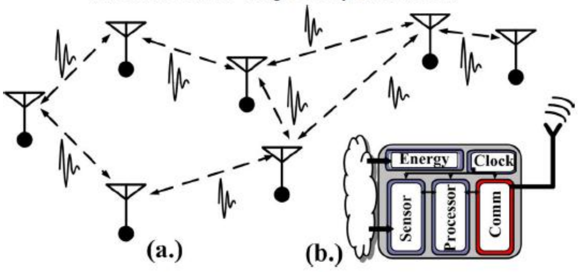
The pulse coupled oscillator (PCO) system of Mirollo and Strogatz has been suggested as a robust, scalable synchronization scheme for impulse radio (IR-UWB) networks. The parameter space for physical implementation of CMOS IR-UWB PCO radios into the traditional PCO mathematical model and express through comprehensive simulation that high-quality synchronization is easily achieved. The most challenging issues in PCOs is the radios and establish systems which is created with extremely low cost and low complexity integrated components with acceptable synchronization performance.



Power savings in IR-UWB systems

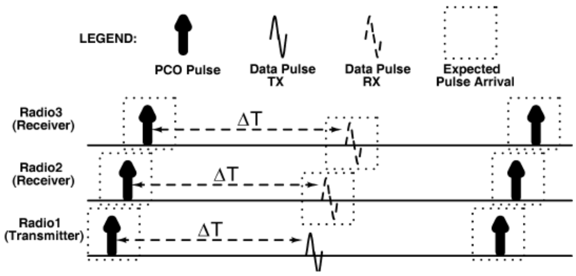
A complete analytical solution becomes totally intractable for the parameter space of arbitrary number of nodes, time delays, coupling strengths, frequency mismatches and network topologies. A periodical solutions, clustered synchronous solutions and bifurcations suddenly changes in the stability of attracting solutions have been observed in various regions of the parameter space.

(a) Radio network using PCO synchronization.



(b) Individual node system block.

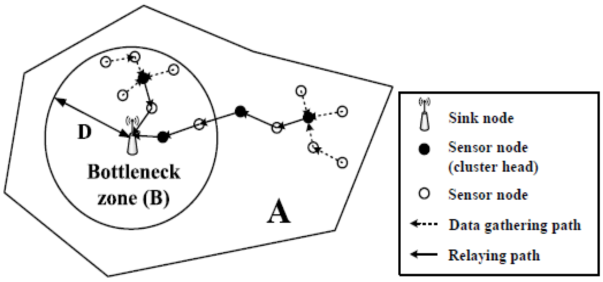
As per an engineering point of view this is an important argument to the feasibility of the PCO system for adoption in scalable distributed sensor networks that has yet to be reasonably investigated in the literature.



Example of impulse radio communications exploiting PCO synchronizations. Data is sent a fixed ΔT from the PCO pulse by a transmitter, where receivers look for the pulse

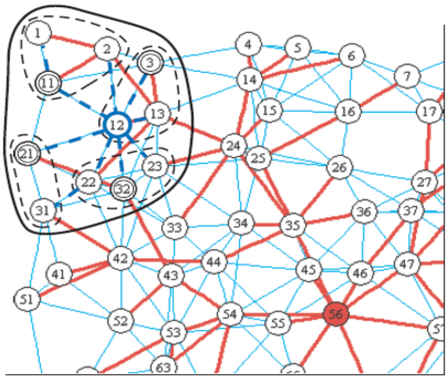
We deploy a new class of problems called network information flow which is inspired by computer network applications. Consider a point to point communication network on which a number of information sources are to be multicast to

certain sets of destinations. Assume that the information sources are mutually independent. These problems are to characterize the admissible coding rate region and model subsumes all previously studied models along the same line.
Further, a distinguish from most classical multi terminal source coding problems in the below modes: there is no rate-distortion consideration, the sources are mutually independent, the network configuration, described by a graph, is arbitrary and the reconstruction requirements are arbitrary.
Majorly the sensor networks, sensing information is transported only to a sink node where the information helpful for users is first collated using the sensing information and then conveyed to users of the applications. Cluster based network topology is considered as a basis for aggregating data in many learning proposes.



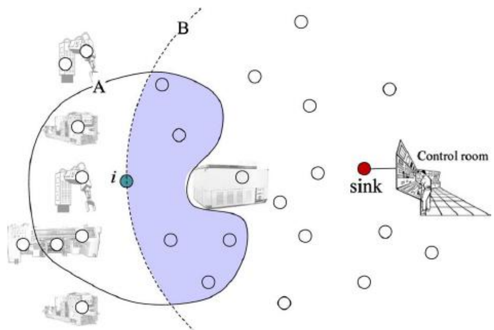
Cluster-based sensor network deployment scenario

In cluster-based networks, nodes transmit sensing information to their cluster heads, and the cluster heads compress the received information. A heavy traffic load is imposed on the cluster heads, so most cluster based networks mitigate the effects of energy imbalance among the nodes by rotating periodically the nodes that function as cluster heads.



Network Architecture

The data collection tree can be easily build in a distributed manner for instance by circulating a tree formation message originated from the base node and making use of a min-hop parent selection policy or similar algorithms used for in-network aggregation. The second layer of the architecture consists of node clusters which partition the sensor network into disjoint regions. Each node in the network suitable for cluster and each cluster elects a node within the cluster to be the cluster head.
There is also a cluster-connection tree with the cluster head as its root node, used to establish the communication between the cluster head and the other nodes in the cluster. TTL value can be used in cluster creation and the nodes that belong to the same cluster cannot be more than a specified number of hops away, thus it is not possible that two nodes from different parts of the network are put within the same cluster just because the values they are sensing are very similar.
The design of reliable, dynamic, fault-tolerant services in wireless sensor networks is a big challenge and a great favour research topic. An optimization method is suggested to tune parameters of the middleware services and applications to provide optimal performance. The optimization method is based on simulation and is capable of handling ‘noisy’ error surfaces. A new spanning-tree formation algorithm is also introduced in which effectively can operate when the links between nodes are not symmetrical.



Neighboring nodes in Routing Table of node i in WISNs for manufacturing machines

It provides real-time and reliable delivery of a packet, when considering energy awareness. A node estimates the energy cost, delay and reliability of a path to the sink node, based only on information from neighbouring nodes in EARQ. It calculates the probability of selecting a path, using the estimates.

Whenever the packet forwarding is required, it is randomly select the next node. A path with lower energy cost is likely to be selected, as reason of the probability is inversely proportional to the energy cost to the sink node. The resultant that EARQ is suitable for industrial applications, due to its capability for energy efficient, real-time, reliable communications. The proposed an end-to-end real-time communication protocol can be ensure a desired delivery speed via a combination of feedback control and nondeterministic geographic forwarding. By this means, it achieved real-time communication.

III. PROPOSED ROUTING PROTOCOL

Upper bounds of network lifetime using Network coding and duty cycle:

The network lifetime has been estimated with a proposed network coding algorithm for a non-duty cycled WSN. Furthermore, network coding and random duty cycle have been combined to estimate the network lifetime in a duty cycled WSN. Here, the lifetime upper bounds have been derived while considering a fraction of total traffic flows through the network coder nodes in the bottleneck zone.

Algorithm1:

ALGORITHM 1: DataPacketProcess(Pi) : DataPacket processing
at a node inside the network coding layer
Require: DataPacket transmission and reception starts, received DataPackets inserted
into the RecvDataQueue()
Ensure: Encoded DataPacket transmitted or discarded
1. Pick a DataPacket Pi from RecvDataQueue(Pi)
2. If DataPacket Pi ∈ ForwardDataPacketSet(Pi) exit;
3. If Node n ∈ EncoderNodeSet() continue;
4. If native(Pi) then
5. CN =ExorEncoding();
6. Node n transmits the coded DataPacket CN to Sink
7. Insert the processed DataPacket Pi to ForwardDataPacketSet();
8. else
9 Discard(Pi);
10 endif
10. else
11. Node n acts as relay and transmits the DataPacket Pi to the Sink;
12. endif
13. endif
14. If (RecvDataQueue() = empty)
15. goto step 1;
16. else exit;
17. endif

Energy consumption in the bottleneck zone to relay the traffic which are received from outside of the bottleneck zone is given by

$$E_{1NC} \geq \sum_{i=1}^{\lfloor N\frac{A-B}{h\cdot A}r_s t\rfloor} \sum_{j=1}^{\lfloor \frac{m+1}{2}\rfloor} E_C(ij) + \sum_{i=1}^{\lfloor N\frac{(A-B)(h-1)}{h\cdot A}r_s t\rfloor} \sum_{j=1}^{\lfloor \frac{m+1}{2}\rfloor} E_R(ij)$$

$$E_{1NC} \geq \left\lfloor \frac{m+1}{2} \right\rfloor N r_s t \alpha_1 \frac{n(A-B)}{A(n-1)} \frac{D}{d_m} \frac{1+k(h-1)}{kh}$$

Inside the zone B, energy consumption is due to sensing inside the zone and relaying the sensed data bits. The sensing energy consumption in time t by the network coder sensor nodes are same as relay sensor nodes. Therefore, total sensing energy consumption in the bottleneck zone is given by,

$$E_{2NC} = N\frac{B}{A} r_s e_s t.$$

Algorithm 2:

ALGORITHM 2: ExorEncoding() : Encoding algorithm
Require: A received queue RecvdataQueue() and a sensed queue SenstheQueue()
is maintained at an encoder node
Ensure: Generation of network coded packet CN
1. If SenstheQueue() is not empty then continue;
2. Pick a packet Pi from head of the RecvdataQueue();
3. Pick a packet Pj from head of the SenstheQueue();
4. CN = Pi ⊕ Pj ;
5. else
6. Pick next packet Pi+1 from the RecvdataQueue();

7. CN = Pi ⊕ Pi+1;
10. endif;
11. return CN

A fraction of the traffic generated inside bottleneck zone may also relayed through the network coder sensor nodes. Assume that the traffic generated inside the bottleneck zone are not encoded and the network coder sensor node functions as a general relay node. So, the energy consumption in the bottleneck zone to relay the data bits generated inside the zone is given by,

$$E_{3NC} = \frac{N}{A} r_s t \int\int_B l(x) dS$$
$$\Rightarrow E_{3NC} \geq \frac{N}{A} r_s t \iint_B \left(\alpha_1 \frac{n}{n-1} \frac{x}{d_m} - \alpha_{12} \right) dS$$

The upper bound of the network lifetime with network coding in WSN is given by,

$$E_{NC} = E_{1NC} + E_{2NC} + E_{3NC} \leq \frac{NB}{A} E_b$$
$$\Rightarrow \left\lfloor \frac{m+1}{2} \right\rfloor \alpha_1 \frac{D}{d_m} \frac{n(A-B)}{A(n-1)} N r_s t \frac{1+k(h-1)}{kh} + N \frac{B}{A} r_s e_s t$$
$$+ \frac{N}{A} r_s t \iint_B \left(\alpha_1 \frac{n}{n-1} \frac{x}{d_m} - \alpha_{12} \right) dS \leq \frac{NB}{A} E_b$$

$$\Rightarrow t \leq \frac{d_m B E_b}{Q_\varphi} = T_{uNC}$$

and the term Qϕ is given by

$$Q_\varphi = r_s \alpha_1 \frac{n}{n-1} \left[\left\lfloor \frac{m+1}{2} \right\rfloor D(A-B) \frac{1+k(h-1)}{kh} + \iint_B x dS \right] + r_s (e_s - \alpha_{12}) d_m B$$

The network lifetime in case of a general network remains constant irrespective of the value of h and it is significantly less than the proposed approach. Furthermore, on increase of the value of m, the network lifetime decreases in both the cases.

EARQ Protocol:

The EARQ protocol is a kind of proactive routing protocol that aims to maintain an ongoing routing table. It constructs and maintains a routing table with information from neighbouring nodes. A beacon message is used to exchange information related to routing among neighbouring nodes. The actual path is decided while transmitting a packet. There are two types of messages are beacon messages and data packets. A beacon message is exchanged among neighbouring nodes to construct and maintain a routing table. Upon receiving a beacon message, a routing table is constructed or updated by calculating expected values of energy cost, delay and reliability.

When a path to the sink node becomes known to a node, the node begins to send a periodic beacon message. The source node sends data packets to the sink after constructing the routing table. Each intermediate node forwards a data packet to a neighbouring node that can deliver the packet in time. A neighbouring node for forwarding a packet is selected based on the expected delay and probability. This probability is inversely proportional to the expected energy cost of neighbouring nodes. Therefore, a path that may expend less energy than other paths is most likely to be selected. To ensure reliable packet delivery, if the expected reliability of the selected node does not satisfy the required reliability, the source node selects an additional neighbouring node to forward the packet.

The beacon message contains C_j, T_j, R_j, and B_j

$$\overline{C}_{i,j} = \overline{C}_j + E_{i,j}$$
$$\overline{T}_{i,j} = \overline{T}_j + H_{i,j}$$
$$\overline{R}_{i,j} = \overline{R}_j \cdot L_{i,j}$$

Where C_j is the expected energy cost of sending a packet from node to the sink node via node j. T_j is the expected time delay of sending a packet from node to the sink node via node j.

For node k in RT—which is the routing table of node i

$$P_{i,k} = \frac{\frac{1}{\overline{C}_{i,k}}}{\sum_{m \in RT} \frac{1}{\overline{C}_{i,m}}}$$

$P_{i,k}$ is the probability that node i selects node k to forward a packet. Therefore, a neighboring node with a lower energy cost is more likely to be selected.

$R_{i,j}$ is the probability that node selects node k to forward a packet. Therefore, a neighbouring node with a lower energy cost is more likely to be selected. Here, the expected values of node can be obtained as follows:

$$\overline{C}_i = \sum_{k \in RT} P_{i,k}\overline{C}_{i,k}$$
$$\overline{T}_i = \sum_{k \in RT} P_{i,k}\overline{T}_{i,k}$$
$$\overline{R}_i = \sum_{k \in RT} P_{i,k}\overline{R}_{i,k}.$$

$H_{i,j}$ is the average time of sending a packet from node to node j directly. This includes the propagation delay, the queuing delay, the retransmission delay, etc. The average strength of the link between node and node . These values can be obtained as follows:

$$E_{i,j} = \frac{(d_{ij}^3)^{\alpha}}{B_j^{\beta}}$$
$$H_{i,j} = \frac{1}{|DT_j|} \sum_{p \in DT_j} Delay_p$$
$$L_{i,j} = \frac{1}{|DT_j|} \sum_{p \in DT_j} ACK_p.$$

To measure the MAC layer a sender time stamps a data packet before the packet enters the network output queue.

$$\mathbb{CTR} = \begin{pmatrix} \overline{C}_{i,k} & \overline{T}_{i,k} & \overline{R}_{i,k} \\ \overline{C}_{i,j} & \overline{T}_{i,j} & \overline{R}_{i,j} \\ \overline{C}_{i,l} & \overline{T}_{i,l} & \overline{R}_{i,l} \\ \overline{C}_{i,m} & \overline{T}_{i,m} & \overline{R}_{i,m} \end{pmatrix}$$

$= \quad - \quad - T_{pack})$

$$= \begin{pmatrix} 35 & 0.5 & 0.95 \\ 41 & 0.44 & 0.99 \\ 45 & 0.51 & 0.99 \\ 47 & 0.45 & 0.98 \end{pmatrix}$$
$$\mathbb{P} = \begin{pmatrix} P_{i,k} & P_{i,j} & P_{i,l} & P_{i,m} \end{pmatrix}$$
$$= \frac{1}{168}\begin{pmatrix} 35 & 41 & 45 & 47 \end{pmatrix}.$$

Here, the i expected values of node are,

$$\begin{pmatrix} \overline{C}_i & \overline{T}_i & \overline{R}_i \end{pmatrix} = \mathbb{P} \times \mathbb{CTR} = \begin{pmatrix} 42.5 & 0.474 & 0.979 \end{pmatrix}$$

When a node finds a path to the sink node, and a data packet is ready, a sensor node begins to send data packets received from other nodes, or its own data packets obtained from sensing. The deadline and reliability of a packet may be predefined by user or determined by nodes at every transmission. The deadline is a relative deadline, which is the tolerable delay of delivering a data packet to the sink node. The reliability included in a packet is the desired reliability, which is between zero and one.

R=0 means that no degree of reliability is required, whereas R=1 means that a high degree of reliability is required. The laxity which indicates the residual time until the deadline, is embedded in a data packet and recalculated at every node along a path to the sink node. EARQ selects the next node to forward a packet, based on the laxity of a packet and the expected values of neighbouring nodes. A path to the sink node is constructed during packet trans- mission. A node including the source node selects the next node, according to the following rules.

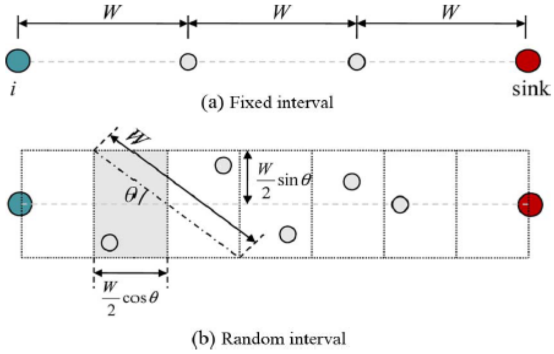
1) Select nodes in the routing table which can deliver a packet within the required deadline

$$RT' = \{j | \overline{T}_{i,j} \leq laxity\_of\_packet \wedge j \in RT\}.$$

2)Calculate the probability $P'_{i,j}$ based on the . For every node j,

$$P'_{i,j} = \frac{\frac{1}{\overline{C}_{i,j}}}{\sum_{k \in RT'} \frac{1}{\overline{C}_{i,k}}}.$$

3) Randomly select the next node by the probability



Deployment of sensor nodes

The selection algorithm based on probability prevents energy loss of nodes on the optimal path with the least energy cost, by distributing the load to other nodes on a non-optimal path. A maximum of two packets are sent to achieve reliability, according to the third rule. This is because the algorithm is simple, and if there was more than two paths this may result in congestion of networks, due to too many redundant packets .

IV. PERFORMANCE EVALUATION

Our simulation work has been carried out using a event driven simulator Known as NS-2.we have taken the performance by varying Duty cycle of the wireless sensor network and verified the parameters like packet delivery ratio, Average Latency, Energy consumed, Network life time . We have consider our simulation parameters as mentioned in Table 1.

Table 1: Simulation Parameters

PARAMETER	VALUE
Number of nodes	50
Routing protocol	DSDV
Mac protocol	802_11
Propagation model	Two Ray ground
Terrain dimensions	500*500
Packet size	512
Initial energy	50 joules

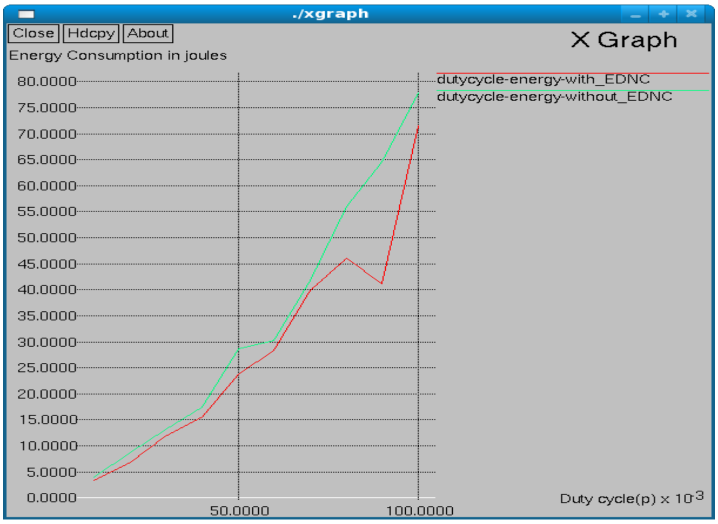


Figure. 1. Average energy consumption with duty cycle

In fig 1 Average Energy consumption has been shown for a duty cycle based WSN with network coding and without network coding. The energy consumption in case of a wireless sensor network with EDNC is Less than a wireless sensor network Without _EDNC.

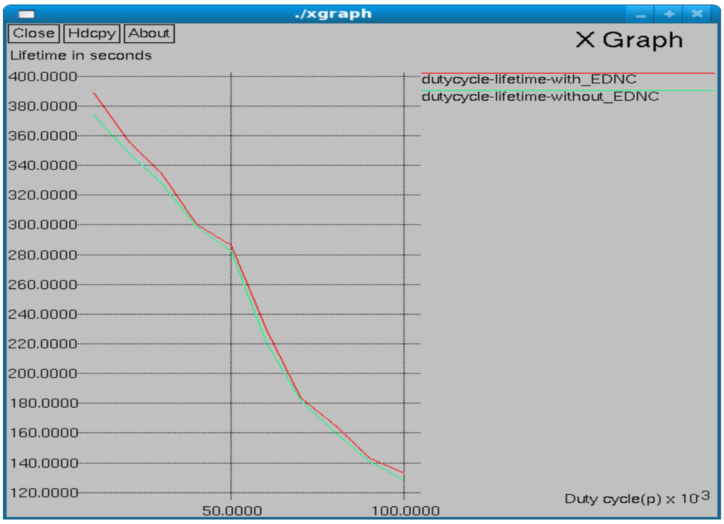


Figure. 2. Average network lifetime with duty cycle

In fig 2 Average Network lifetime has been shown for a duty cycle based WSN with network coding and without network coding.The Network lifetime in case of a wireless sensor network with EDNC is more than a wireless sensor network Without_EDNC.

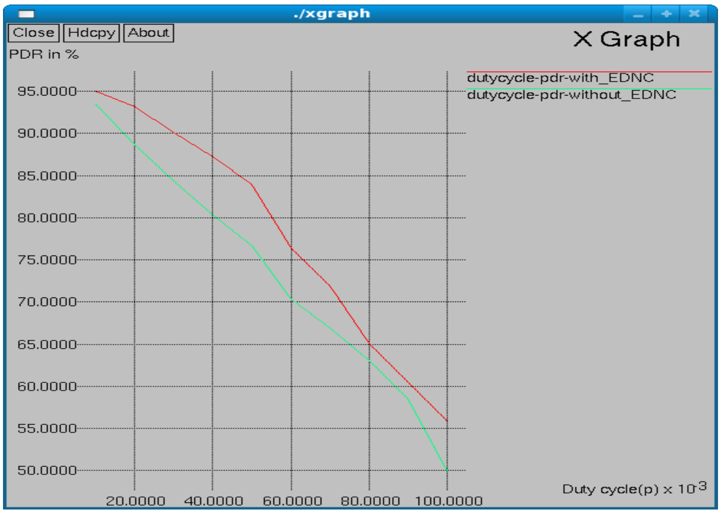


Figure. 3. Average packet delivery ratio with duty cycle

In fig 3 Average PDR has been shown for a duty cycle based WSN with network coding and without network coding.The PDR in case of a wireless sensor network with EDNC is more than a wireless sensor network Without_EDNC.

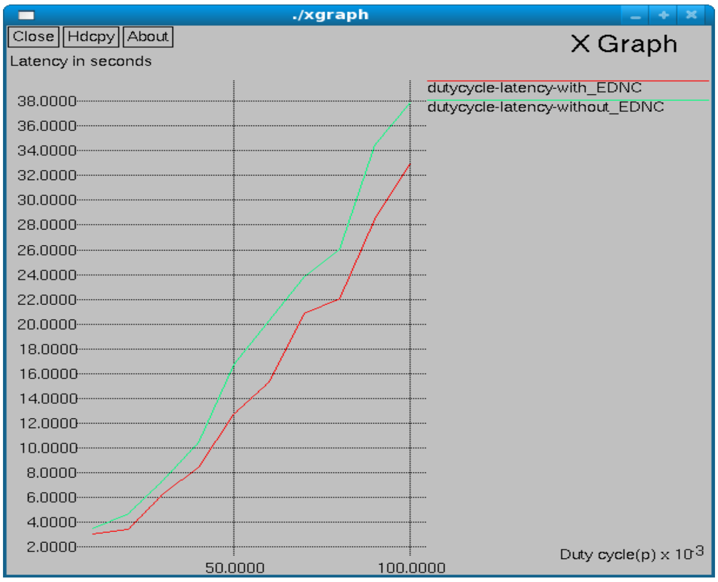


Figure. 4. Average latency with duty cycle

In fig 4 Average latency has been shown for a duty cycle based WSN with network coding and without network coding.The Latency in case of a wireless sensor network with EDNC is Less than a wireless sensor network Without_EDNC.

V. CONCLUSION AND FUTURE WORK

Dynamic and easily maintained industrial control applications can be achieved by applying WISNs to industrial control in manufacturing plants. Industrial control needed a realtime and reliable transmission of sensing data and commands. A new requirements such as real-time, reliable delivery must be considered while designing applications for WISNs controlling data transmission. In this paper we proposed EARQ, an energy aware routing protocol for improving real-time and reliable communication in Wireless sensor network.

EARQ provides real-time communication without flexible the energy awareness of the existing energy aware routing protocol of EAR. As well as, EARQ can provide efficient reliable communication because it only sends a redundant packet via an alternate path if the reliability of a path is less than a predefined value. The deadline in which the maximum tolerable packet delay must be carefully selected. The deadline should be the same as of the minimum network delay. We demonstrated that EARQ performs better than existing QoS routing protocols, in terms of reducing the number of packets that missed deadlines or were lost, while considering energy awareness.

QoS routing for heterogeneous (hybrid) wireless/wired industrial sensor networks will be studied in a future work. As per practical environments, networks can comprise various networks like WLAN, Zigbee, Bluetooth, and wired networks. They may be connected to the Internet and each protocol uses a different MAC layer protocol and has differing characteristics. Hence, a new protocol that ensures a tolerable end-to-end delay for real-time communications in such hybrid networks is necessary.

REFERENCES

[1] G. Simon, P. Volgyesi, M. Maroti, and A. Ledeczi, "Simulation-based optimization of communication protocols for large-scale wireless sensor networks," in Proc. 2003 Aerospace Conference, pp. 1–8.

[2] B. Gedik, L. Liu, and P. S. Yu, "ASAP: an adaptive sampling approach to data collection in sensor networks," IEEE Trans. Parallel Distrib. Syst., vol. 18, no. 12, pp. 1766–1783, 2007.

[3] I. Howitt, W. W. Manges, P. T. Kuruganti, G. Allgood, J. A. Gutierrez, and J. M. Conrad, "Wireless industrial sensor networks: Framework for QoS assessment and QoS management," ISA Trans., vol. 45, no. 3, pp. 347–359, 2006.

[4] C. F. Hsin and M. Liu, "Randomly duty-cycled wireless sensor networks: dynamic of coverage," IEEE Trans. Wireless Commun., vol. 5, no. 11, pp. 3182–3192, 2006.

[5] Q. Xue and A. Ganz, "Ad hoc QoS on-demand routing (aqor) in mobile ad hoc networks," J. Parallel Distrib. Comput., vol. 63, no. 2, pp. 154–165, 2003.

[6] M. Sughasiny and Dr. R. Dhanapal, "Performance Improvisation for Bluetooth Service Discovery Using Single Hop and Multi Hop Methods", European Journal of Scientific Research ISSN 1450-216X Vol.94 Issue 1 January 2013.

[7] X. Y. Wang, R. K. Dokania, and A. Apsel, "PCO-based synchronization for cognitive duty-cycled impulse radio sensor networks," IEEE Sensors J., vol. 11, no. 3, pp. 555–563, 2011.

[8] R. Ahlswede, N. Cai, S. Y. R. Li, and R. Yeung, "Network information flow," IEEE Trans. Inf. Theory, vol. 46, no. 4, pp. 1204–1216, July 2000.

[9] S. Vitturi, I. Carreras, D. Miorandi, L. Schenato, and A. Sona, "Experimental evaluation of an industrial application layer protocol over wireless systems," IEEE Trans. Ind. Informat., vol. 3, no. 4, pp. 275–288, Nov. 2007.

[10] S. Lee and S. H. Lee, "Analysis of network lifetime in cluster-based sensor networks," IEEE Commun. Lett., vol. 14, no. 10, pp. 900–902, 2010.

[11] E. Royer, S.-J. Lee, and C. Perkins, "The effects of MAC protocols on ad hoc network communication," in Proc. IEEE Wireless Communications and Networking Conf. (WCNC), 2000, pp. 543–548.

[12] S. Eberle, "Adaptive internet integration of field bus systems," IEEE Trans. Ind. Informat., vol. 3, no. 1, pp. 12–20, Feb. 2007.

[13] A. R. Lehman, "Network coding," Ph.D. dissertation, Massachusetts Institute of Technology, USA, Feb. 2005.

[14] E. Felemban, C.-G. Lee, and E. Ekici, "MMSPEED: Multipath multispeed protocol for QoS guarantee of reliability and timeliness in wireless sensor networks," IEEE Trans. Mobile Comput., vol. 5, no. 6, pp. 738–754, Jun. 2006.

[15] E. Felemban, C. G. Lee, and E. Ekici, "Mmspeed: multipath multispeed protocol for QoS guarantee of reliability and timeliness in wireless sensor networks," IEEE Trans. Mob. Comput., vol. 5, no. 6, pp. 738–754, 2006.

[16] A. MAHAPATRA, K. ANAND, AND D. P. AGRAWAL, "QOS AND ENERGY AWARE ROUTING FOR REAL-TIME TRAFFIC IN WIRELESS SENSOR NETWORKS," COMPUTER. COMMUNICATION., VOL. 29, NO. 4, PP. 437–445, 2006.