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Energy Efficient Algorithm & Protocol For Wireless Industrial Sensor Network

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Abstract— Wireless sensor networks (WSNs) consists of unattended sensors with limited storage, energy (battery power) and computation and communication capabilities. So, energy efficient mechanism for wireless communication on each sensor node is so crucial for wireless sensor networks. Wireless industrial sensor networks are wireless sensor networks which have been adapted to industrial applications. Most techniques for wireless sensor networks can be applied to wireless industrial sensor networks. A wireless sensor node is often powered by battery which is not easily replaced, so researching how to use its limited energy effectively is the meaningful for wireless sensor networks(WSNs). Energy routing protocol is suitable for industrial applications due to its capability of energy efficient,real-time,reliable comm.& energy efficient algorithm is provided which based on power control.

Keywords—component; Energy aware routing, industrial control, real-time and reliable communication, wireless industrial sensor networks, Energy control , network lifetime
.

I. INTRODUCTION

Wireless Sensor Networks (WSN) have recently been extensively deployed and researched. They are composed of a high number of small and simple nodes where most of them have to function as a router in an ad hoc manner. Because of limited energy sources in sensor network node, routing protocols should save the energy as much as possible. Energy consumption has a direct influence on network lifetime. From the Quality of Service (QoS) point of view, in many applications such as real time one, it is necessary to consider application QoS requirements. In this paper we propose an energy aware routing protocol for real time traffics in wireless sensor networks. The proposed protocol considers both energy and delay metrics to find an optimal path with minimum energy consumption and minimum end to end delay.

Wireless industrial sensor networks (WISNs) are used to collect data from a machine equipped with sensor nodes, and forward data to the sink node.They are generally used for industrial control applications. The sink node is connected to a control system that obtains data via the sink node, and controls actuators in a machine, or alerts users as a result of data analysis. WISNs can provide lower cable costs, and easy setup and maintenance for existing industrial applications. In WISNs, sensing data from sensor nodes must be transmitted to the sink, reliably and in time Delayed or lost data may cause industrial applications to malfunction, because the sensing data is analyzed and appropriate commands are sent to the actuator of a machine. A delayed packet may be useless, and it is difficult to obtain meaningful information from decoding packets if the rate of packet loss exceeds a threshold.

Dominant trends in wireless industry & wireless sensor network offers -

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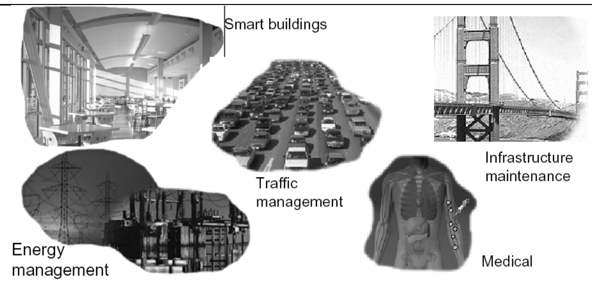

II. Related Work

Past few years, many routing protocols have been developed for wireless sensor networks. As the energy is an important constraint of the WSNs, so the energy aware routing algorithms are too important. In the rest of this section we review some of the general routing protocols proposed for wireless sensor networks. It considers energy consumption in its routing procedure. SPEED is a highly efficient and scalable protocol for sensor networks where the resources of each node are scarce. SPEED can be used in both data link and network layers. It is a flat routing algorithm. By guaranteeing data forwarding rate, it can support real time communications. It acts locally and uses neighbor information for routing. SPEED uses interesting mechanism layer for route maintenance and recovery that uses both data link and network layer.

Routing metric method can reflect router decisions, based on the different routing decisions the node routing table entry will be different. With regard to the limited energy resources at each sensor, many research efforts have been focused on minimizing the energy expenditure for broadcasting either by reducing the number of redundant transmissions due to lack of coordination or by minimizing

the total transmission energy required to maintain full connectivity in the network.

III. Proposed Routing Protocol

In this section, we describe the proposed energy aware routing protocol in details. The proposed protocol uses a flat routing algorithm which is done proactively. This means that the routes are established before traffic transmission. The algorithm is run to find the least cost route between source and sink nodes. The proposed routing algorithm is divided into 3 phases which are: route discovery phase, data transmission phase and route recovery phase. The last phase is only done when the topology has been changed. Each node has a unique identifier (ID) which is determined in the route discovery phase. The nodes also have a routing table which includes 3 fields: ID, signal strength and route cost. There is a record for each neighbor of a node in its routing table. The routing table is created in route discovery phase. This table is used in data transmission phase to send traffic from source to sink. In the following subsections, we describe the functions of each phase in details.

A. *Energy aware routing*

Maximise network lifetime
Communication is the most expensive activity
Possible goals include:

- Shortest-hop (fewest nodes involved)
- Lowest energy route
- Route via highest available energy
- Distribute energy burden evenly
- Lowest routing overhead

Distributed algorithms cost energy
Changing component state costs energy

EAQR, which is a novel routing protocol for wireless industrial sensor networks. It provides real-time, reliable delivery of a packet, while considering energy awareness. EAQR can set the packet reliability. To achieve real-time delivery, only paths that may deliver a packet in time are selected. Redundant packets can be used to prevent packet loss in real-time communications.EAQR estimates the expected values of the energy cost, delay and reliability of a path to the sink node.EAQR selects a path that requires low energy, low delay and provides high reliability

Proactive protocols-

Traditional distributed shortest-path protocols

Maintain routes between every host pair at all times

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Based on periodic updates; High routing overhead

Example: DSDV (destination sequenced distance vector)

Reactive protocols-

Determine route if and when needed

Source initiates route discovery

Example: DSR (dynamic source routing)

Hybrid protocols-

Adaptive; Combination of proactive and reactive

Example : ZRP (zone routing protocol)

B. ***Routing Phases:-***

1.Route Discovery Phase :-

The sink node as the initiator of this phase broadcasts a packet to all its neighbors. This packet is called Route Discover packet. The structure of Route Discover packet is shown in figure 1. As shown in this figure, each Route Discover packet consists of three fields which are: message type, sender ID and best route cost. The message type field determines the type of packet. The sender ID field determines the value of sender's ID. The best route cost field determines the cost of optimal route between sender node and sink.

Message type	Sender ID	Best route cost

Fig. 1. Structure of Route Discover packet

Usually the value of sender ID field in all Route Discover packets which are sent by the sink node is equal to zero. As the cost of optimal route between sink node and itself is always zero, so the value of best route cost field is equal to zero.

2. Data Transmission Phase

When a node detected an event, it should send data related to that event to the sink. As mentioned before, the routes are established in the route discovery phase. All nodes know their least cost route to the sink. So, using the optimal path the node will be able to send its data to the sink. Each node knows its next hop node in its least cost route. When a node detected an event or received any data, it sends them to the sink node via its next hop node.

3. Route Recovery Phase

This phase is executed periodically. The length of time periods depends on the node's mobility. If a node dies, it will never participate in the routing procedure in the next period. Therefore, the dead nodes are not belonging to any established route. If the next hop node is failed, the data are sent using a backup node. All nodes in the network know the cost of forwarding information through their neighbors. When the least cost route is failed then the node forwards data using the second least cost route. As the information about all the possible routes from a node to sink is stored in thenode routing table, so it is easy to find the first and second least cost routes.

B.Beacon Message and Routing Table

Every node exchanges a beacon message to construct and maintain a routing table of a node. A beacon message4 contains expected values such as energy cost , time delay , reliability, and residual energy of a node . is the expected energy cost of sending a packet from node to the sink node. is the expected time of sending a packet from node to the sink node. is the expected reliability of sending a packet from node to the sink node. The reliability is the probability of sending a packet to the sink node without error. , and at the sink node and the expected values of the sink node are constant [22]. The beacon message also contains the position of node . EARQ assumes that every node knows its own position and that of the sink node.the sink node only sends a beacon message while initiating network setup and receiving an empty beacon message. An empty beacon messageis a beacon message that contains nothing.

Whenever a nodereceives an empty beacon message from another node, it respondsto the node with a beacon message. A new node collectsrouting information by broadcasting empty beacon messages toits neighboring nodes. It constructs its own routing table with abeacon message from its neighboring nodes.When a node receives a beacon

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message from a neighboringnode, it only adds the neighboring node to the routing table if theneighboring node is closer to the sink node than it is. If the neigh-boring node is already in the routing table, it only updates the expectedvalues of the neighboring node. Fig.1showsanexampleof neighboring nodes in the routing table of node . Nodes in the area A are neighboring nodes of node .

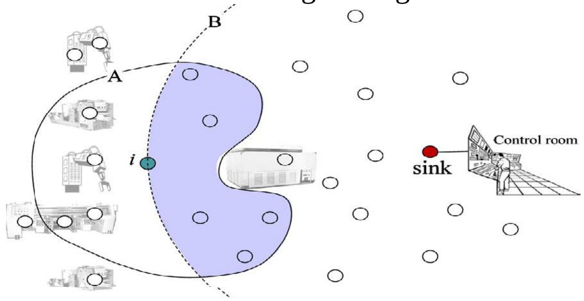

Fig. 1. Neighboring nodes in Routing Table of node in WISNs for manufacturing machines.

C. Node Selection for Forwarding a Packet

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, R, 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, R, included in apacket is the desired reliability, which is between zero and one. R=0 means that no degree of reliability is required, whereas R=0 means that a high degree of reliability is required. The laxity, , which indicates the residual time untilthe 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 theexpected values of neighboring nodes. A path to the sink node is constructed during packet transmission.

A node i—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

2) Calculate the probability P ^ij based on the RT. For every
Nodej in RT,

3) Randomly select the next node by the probability, [22].

If a node is a source node and of the selected node

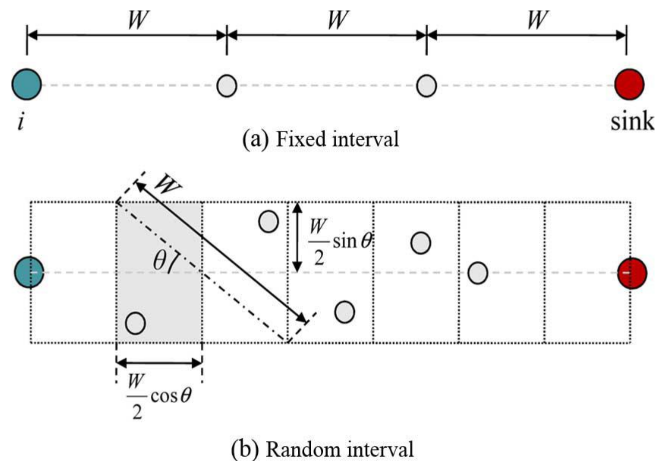

Fig. 3.Deployment of sensor nodes.

D. Considerations for Selecting the Deadline

The packet delay generally depends on the number of hops to the sink node. In other words, the density and size of the network affects the packet delay. A deadline selected at random without considering these network characteristics endangers applications of WISNs. Therefore, the density and size of the network must be considered while selecting a deadline. In this section, we describe the means to select an appropriate deadline, given the density and the size of the network. When sensor nodes are deployed at a fixed interval, as in Fig. 3(a), the expected number of hops to the sink node depends on the radio range, , and the distance to the sink node, . If the distance to the sink node is , the expected number of hops is . However, in most applications, it is difficult to deploy sensor nodes at a fixed interval.

IV. ENERGY EFFICIENT A ROUTING METRIC

Energy is widely recognized as a scarce resource in

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wireless networks and various energy-aware routing and
topology control algorithms were proposed. However, most
of the previous works are based on the simple "Disc Model". In allusion to the problem that actual network
communication exits transitional zone and non-symmetry, In
order to select a relatively reliable routing path, but only
from the packet reception ratio can not determine the actual
communication link situation, In order to induce EEA, this
paper has made the following statement:
[12] analyzed the link for wireless sensor networks to
communicate the underlying lognormal shadow model; the
formula is as follows (in dBm):

$$PL(d) = PL(d_0) + 10\beta \log(\frac{d}{d_0}) + X_\sigma \quad (1)$$

where: $PL(d)$ path loss for a specific location. d_0 for the reference distance, β for the path loss index, σ Standard deviation. X_σ Zero mean Gaussian random variable. In order to evaluate the energy efficiency of different strategies, we use the following metrics:

Delivery Rate (*DR*): percentage of packets sent by the source which reached the sink. Total Number of Transmissions (*TNOT*): total number of packets sent by the network, to attain the delivery rate described above. Energy Efficiency (*Eeff*): number of packets delivered to the sink for each unit of energy spent by the network.

Eeff can be derived from the delivery rate r and the total
number of transmissions t. Let *psrc* be the number of packets
sent by the source, *etx* and *erx* the amount of energy required
by a node to transmit and receive a packet, and ere the
energy used to read only the header of the packet (for early
rejection). Given that we are assuming a random distributed
topology, the expected number of neighbors can be considered as a constant n. Therefore, the total amount of
energy consumed by the network for each transmitted packet
is given by:

$$e_{total} = e_{tx} + e_{rx} + (n-1)e_{re}$$

the delivery ratio r is given by:

$$DR = \prod_{i \in \lambda} prr_i \quad (1)$$

The number of packet transmissions required at each node j that belongs to _ is given by:

$$TNOT_j = p_{src} \prod_{i=0}^{j-1} prr_i$$

Where $PRR_0 = 1$, to accommodate for the number of transmissions required at the source (equal to p_{src}). The total number of transmissions t is the sum of t_j, $\forall j \in \beta$. Therefore t is given by:

$$TNOT = p_{src} \sum_{j \in \lambda} \prod_{i=0}^{j-1} prr_i \quad (2)$$

The number of hops h in the chain topology, defined for the analysis, is given by:

$$h = \frac{d_{src-\sin k}}{d}$$

Given that at each hop the packet traverses a distance d with p_{rr} (d), equations (1) and (2) can be simplified to:

$$DR = (prr_d)^h$$

$$TNOT = p_{src} \sum_{j=0}^{h-1} prr(d)^j$$

So:

$$TNOT = p_{src} \sum_{j \in \lambda} \prod_{i=0}^{j-1} prr_i$$

Which leads to the energy efficiency of :

$$E_{eff} = \frac{p_{src}(prr)^h (prr-1)}{e_{total}(prr^h - 1)} \quad (3)$$

We know that the prr of a link is between [0, 1], $\frac{(prr-1)}{(prr^h-1)} < 1$,and for large number of hops prr decrease dramatically, even for high prr ,Therefore, equation (3)show that for large number of hops, it is recommended to choose links with very high *prr* . Through the above analysis: the link in the end, every note use set the initial power. Firstly, nodes need to calculate the distance between the neighbor nodes. Secondly, using the ETX routing metric to calculate the link quality, and the node use the information about the *prr* , *src p* , *total e* to calculate the eff E , Finally, every node in the link quality, and the node use the information about the *prr* , *src p* , *total e* to calculate the eff E , Finally, every node in the end to end link, need to change the power so as to prolong the life span and improve the transmission reliability..

TABLE I. MAIN PARAMETERS CONFIGURATION IN THE SIMULATION

Parameter	Value
MAC protocol	IEEE 802.15.4
Wireless model	Shadowing
Frequency	2.4GHz
Power for transmission (mWatt)	1.0
Power for idle (mwatt)	1.0
Power for reception(mwatt)	1.0
Power for sleep (mwatt)	0.001

V.CONCLUSION

Energy aware routing is most challenging issue in wireless sensor networks. Current research on routing of sensor data mostly focused on protocols that are energy aware to maximize the lifetime of the network, scalable for large number of sensor nodes and tolerant
to sensor damage and battery exhaustion

In this paper an efficient energy aware routing protocol was proposed. The proposed routing protocol has two major goals which are low power consumption and low end to end delay. We evaluated the performance of the proposed protocol under different scenarios. Simulation results confirmed that the proposed protocol has more efficient energy consumption in comparison with the traditional SPEED protocol.

Furthermore, the proposed routing protocol can find the optimal path with a low end to end delay. We believe that, by using data aggregation techniques the higher performance will be achievable. Also using other cost functions for route selection makes the proposed protocol suitable for other applications.

Generally, nodes of WSN has large scales, complex or even dangerous work environment, restricted energy difficult to supplement, less store space and computing capacity. So, how to design a highly efficient and energy saving WSN routing algorithm to prolong lifetime of networks has become a hot spot of research.

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