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IMPACT OF ENERGY AND LINK QUALITY INDICATOR WITH LINK QUALITY ESTIMATORS IN WIRELESS SENSOR NETWORKS

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ABSTRACT

The Link Quality Indicator (LQI) and Residual Energy have a fundamental impact on the network performance in Wireless Sensor Networks (WSNs) and affects as well in the life time of nodes. This paper will provide a comparative of Link Quality Estimator, the Link Quality Estimator with Link Quality Indicator and Link Quality Estimator with Residual Energy. In this paper we develop a Collect Tree Protocol (CTP) and compare the performance of LQI and Residual Energy, and show their effect on the packet delivery ratio and throughput, covering the characteristics of low-power links, and their performance to the best of our knowledge, we believe that our efforts would have implementations on embedded application.

KEYWORDS

Link Quality Estimation (LQE), Collection Tree Protocol (CTP), Packet Receive Rate (PRR), the Window Mean with Exponentially Weighted Moving Average (WMEWMA).

1. INTRODUCTION

In Wireless Sensor Network communication various problems appear with Self-organization nodes. To ensure the best performance of network it is necessary to try to solve the problems of unreliability of links. This paper has provided a comparative of Link Quality Estimator, the Link Quality Estimator with Link Quality Indicator and the latter with Residual Energy. It has been attracting a vast array of research works. The route can be built by selecting the highest quality of link, the goal of this selecting is to maximize the lifetime of the sensor network. Avoiding successive retransmission of packet in order to reduce the energy consumption at each node to its task of routing in other words minimizing the route failed re-selection. Consequently, the evaluation specifies the quality of link, minimize the errors and make the interchangeability between nodes more effective to solve the problems imposed by the unreliability of links [1] [3].

This article opens with related work carried out on link quality estimation which shall be introduced in Section 2. Next section will present the most required parameter. Then, in section 4 an overview of the most Link Quality Estimator along with our implementations will be given. While Section 5 includes an overview of the proposed method, Section 6 shall discuss links performance. Last section concludes the paper.

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2. RELATED WORK

Many protocols are proposed in the literature for wireless sensor networks based energy but very few of them tackle real time applications.

There are some of WSN nodes available in market. The following paragraphs give the review of some routing protocols, which are based on the link quality and the energy for the real application and real world of WSN nodes.

1. RLQ: Resource Aware and Link Quality Based Routing Metric

The RLQ routing is based on the quality of the link and energy. The routing based on the link cost and the energy cost which is the sum of normalized energy cost of transmission and reception [12]. If the residual energy and link quality parameters are zero the routing based on the minimum hop counts. If one of them is not zero, the routing based on one of them. For example the minimum total energy path is the shortest path.

2. SHRP (Simple Hierarchical Routing Protocol)

The SHRP protocol is it the proactive protocol. Its route is selected based on the energy battery and the link quality. The parent node selection is based on the information from the link layer. The SHRP protocol eliminates the node which the value of RSSI and LQI is lower than the fixed threshold or when the node is out of battery from the neighbor table.

The protocol chooses the route to the sink that has the maximum energy and the minimum hop possible [7].

3. LQER (Link Quality Estimation based Routing Protocol)

The LQER protocol is a routing protocol which makes the path selection based on the historical states of the link quality after the minimum hop field is established. A dynamic window concept (m; k) is used to record the link historical information. The m is the number of successful transmission of k preview transmission [2].

The LQER protocol is based on the minimum hop field establishment algorithm to find the minimum hop neighbors and then each node will have the list of forwarding neighbors.

3. REQUIREMENTS AND OVERVIEW OF LINK QUALITY ESTIMATION

In this section, we briefly review the literature related to link quality estimators in WSNs, as well as their Overview evaluation. The most respected parameter in our test is the energy efficiency and the stability.

Energy efficiency: since energy has an important concern in sensor networks, LQE is an important factor to the management of low consumption and communication. The active monitoring as well as the expenses of the beacon will be avoided.

Stability: it is necessary to tolerate the small variations to have a better LQE, the long-term evaluation of quality of bond was carried out by the means of the filter (Exponentially Weighted Moving Average) of EWMA with a great soft factor ($\alpha = 0.6$). Also it can evaluate at an early stage based on the last EWMA, a stable LQE leads to stable topology, if one regards the PRR as LQE and one will frequently calculate the PRR we obtain a reactive LQE during the dynamic capture of the bond, this reliability will be at the cost of stability because the PRR will consider a certain transitory fluctuation of quality of bond which could be unaware of.

- Link Quality Metrics

Link quality metrics in wireless sensor networks can roughly be classified in two categories: physical and logical indicators.

The former are provided by the radio hardware and are based on the signal strength of a received packet, such as Received Signal Strength Indicator (RSSI), the Link Quality Indicator (LQI) and Signal to Noise Ratio (SNR) [3]. The logical indicators estimate the link quality by keeping track of message losses classified on three categories as follows. The first is PRR-based which includes Packet Received Rate (PRR) and Window Mean with Exponentially Weighted Moving Average (WMEWMA) the second is RNP-based which contains Required Number of Packet (RNP) [1], Expected Transmission Count (ETX) and Four-Bit.

1. PRR-based

- Packet Receive Rate (PRR)

The PRR is approximated as the probability of successfully receiving a packet between two neighbor nodes. If PRR is high that means the link quality is high and vice versa (1).

$$PRR = \frac{Number\ of\ Received\ Packet}{Number\ of\ Sent\ Packet}$$

- The Window Mean with Exponentially Weighted Moving Average (WMEWMA)

The WMEWMA is used to compute the last rate also this gives a good method to approximate the reception rate of the link at the time [4]. To measure the quality of the path taken by the packet, the product of the instantaneous reception rate was saved. The number of transmissions required for sending a packet through along the mentioned path equals the sum of all the send attempts per hop

$$WMEWMA = \alpha * WMEWMA + (1-\alpha) * PRR \qquad (2)$$

2. RNP-based

- Required Number of Packet (RNP)

The goal of RNP is to explain the distribution of the packet dropped of a link by estimating the quality of link. Studies have shown that among links with the similar rates of the delivery, a link will decrease dropped packets can deliver more packets of data with the same number of send attempts along with consecutive losses during the same period.

The goal of RNP is to analyze all the transmission figures required in an automatic repeat request (ARQ) where the underlying distribution of dropped packet is known [4].

$$RNP = \frac{Number\ of\ transmitted\ and\ retransmitted\ packets}{number\ of\ successfully\ received\ packets} - 1 \quad (3)$$

- Expected Transmission Count (ETX)

The ETX reduces at least the number of data packet and estimates the number of transmission required to send a unicast packet by measuring the packet reception ratio.

The ETX metric calculated as, $\frac{1}{PRR_f * PRR_r}$, where there are forwarded and reverse delivery which rate for link.

When calculating PRR_f and PRR_r, beacon packets are broadcasted by each node periodically. Every beacon packet contains the reception rates of beacons received from each of its neighbors [3]. From the beacon packets, the delivery rate from itself to its neighbors node can be read, and the reverse delivery rate can be computed by counting the number of lost beacons from its neighboring nodes (4).

$$ETX = \frac{1}{PRR_{forward} * PRR_{background}} \quad (4)$$

- Four Bit Interface

The Four-Bit estimator uses the physical link and network layer information to build its estimations [5]. This estimator can indicate if a link is or will be used for routing or not (5).

$$Fourbit = \alpha * Fourbit + (1 - \alpha) * ETX \quad (5)$$

4. EXPERIMENTAL SETUP

Contiki is an open-source operating system for embedded systems and wireless sensor networks which is being developed at Swedish Institute of Computer Science led by soft-ware engineer Adam Dunkels. It provides both full IP (Internet Protocol) networking and low-power radio communication mechanisms. Contiki is written in C [6].

Table I: Simulation Parameters

Parameter	Value	Unit
No of Node	12	Nodes
Dimension of Space	250*250	Meters
Simulation Time	30	Minute
Deployment	uniform	-
Update Interval	3	Seconds

The routing algorithm for enhanced CTP

```
if(Packet=DataPacket)
    rtmetric<-ETX
    sendAck(recievedPacket)
    forwardPacket(parentNode)
end if
if(Packet=AckPacket)
    for NeighborTable[i]
          if(NeighborTable[i].nodeId= SenderAckNodeId)
          UpdateNeighborTable[i].rtmetric<-rtmetric
          end if
    end for
    for NeighborTable[i]
          if(maxRtmetric<NeighborTable[i].rtmetric)
                    maxRtmetric<-NeighborTable[i].rtmetric
                    parentNode<-NeighborTable[i].nodeId
          end if
    end for
end if
```

5. OVERVIEW OF PROPOSED METHOD

We proposed two methods of routing based on Link Quality Estimator and Energy, Energy Link Quality Routing (ELQR) and Quality Link Quality Routing (QLQR).

1. The Energy Consumption with Link Quality Estimator

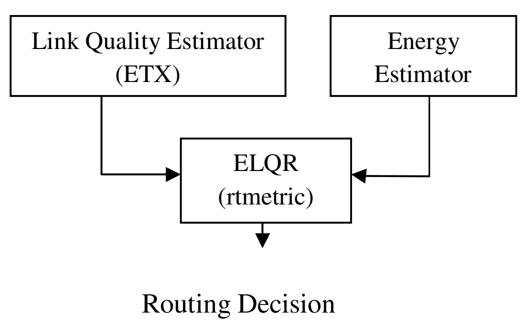

Figure 1: Architecture of ELQR

This method is based on residual energy of node and its estimators, each node makes the table nodes for storing the link and energy of their neighbors. When the node arrives to send or forward the packet it selects the maximum value of ELQR returned by neighbor table. When acknowledgment has been received, it contains the value of ELQR.

2. The Link Quality Indicator with Link Quality Estimator

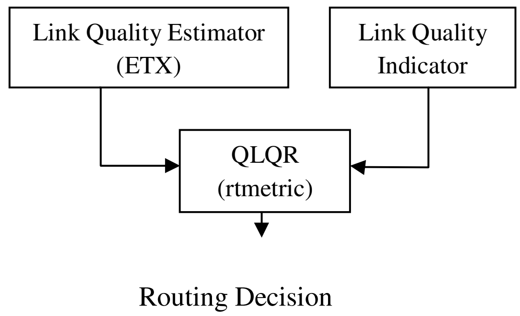

Figure 2: Architecture of QLQR

This method is based on the quality of node and its estimators, each node makes the table nodes for storing the link and energy of their neighbors. When the node arrives to send or forward the packet it selects the maximum value of QLQR returned by neighbor table. When acknowledgment has been received, it contains the value of QLQR.

6. Simulation Results

1. Throughput

The first experiment considers 12 nodes distributed around one coordinator. The aim is to study the throughput when different estimators are set up. The throughput is calculated from the ratio of total packets received divided by total time of simulation multiplied by the nodes number (6).

$$S = \frac{total\_received\_packet}{simulation\_time * number\_nodes} \quad (6)$$

In this section, we investigate the impact of energy residual and Quality Link Indicator on the throughput. We compute the sum of Packet Receive Rate and the residual energy to make the ELQR routing, then we compute the sum of the Packet Receive Rate and the Link Quality Indicator to make the QLQR routing Figure 3.

We remark, in the upper curve, that the route decisions taken with ELQR and QLQR are better than those which are taken with simple PRR, the possibility of route with energy residual and quality indicator can make the route more flexible.

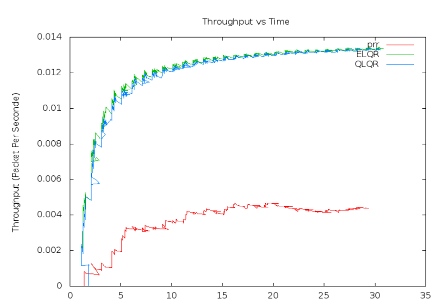

Figure 3: Throughput of PRR, ELQR and QLQR

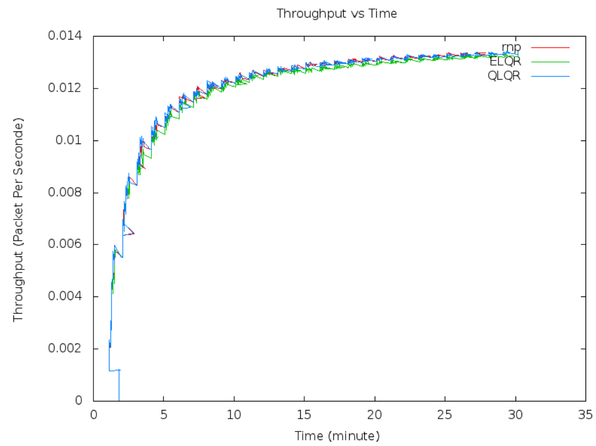

Figure 4: Throughput of RNP, ELQR and QLQR

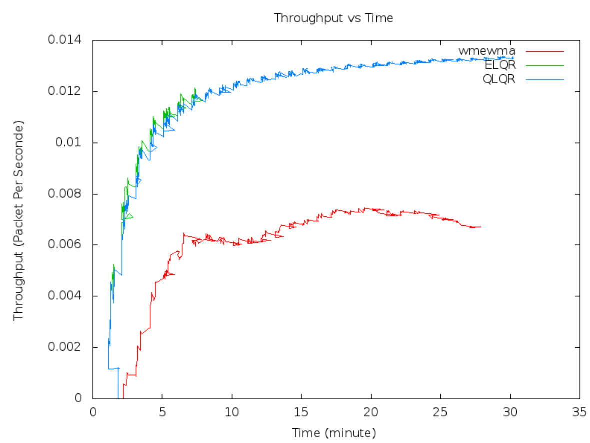

Figure 5: Throughput of WMEWMA, ELQR and QLQR

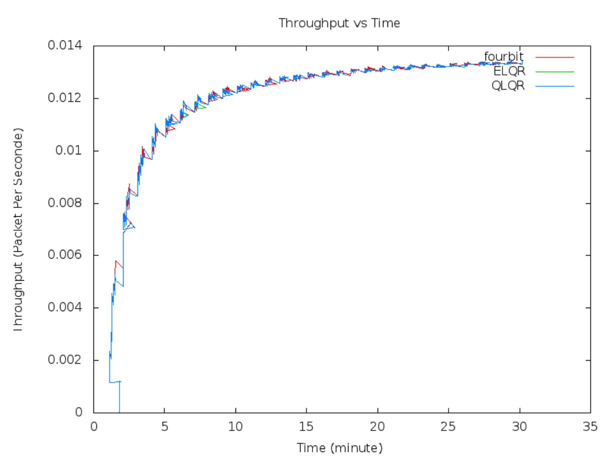

Figure 6: Throughput of Four Bit, ELQR and QLQR

In the normal case one uses only the estimate (PRR, WMEWMA, RNP, ETX and Four Bit). The energy of the intermediate nodes consequently is weakened compared to the extreme nodes which have the greatest probability of use. This causes a problem in our network. As a solution, adding a parameter of energy or quality of link to the estimate would enable reaching all the extreme nodes and consequently the flow of the network increases.

In previous Figures, we obtained that the WMEWMA is important than PRR, ETX, RNP and Four Bit. WMEWMA is based on passive estimation and coefficient equals 0,6.

2. Packet Delivery Ratio

The second experiment evaluates the Packet Delivery Ratio which is defined by the ratio of packets successfully received divided by packets sent multiplied by 100 (7).

$$Pd = \frac{total\_received\_packet}{total\_sent\_packet} * 100 \qquad (7)$$

Figure 7 shows the results of PDR for each node when they use PRR, ELQR and QLQR as the routing Method. Figure 7 establishes an interval from 50% to 60% to make the performance evaluation clearer. On the basis of the results of figure 7, the total packet loss of QLQR is 58%, ELQR is 55% and the PRR is the 20%. Thus, PRR increases the PDR by 45%.

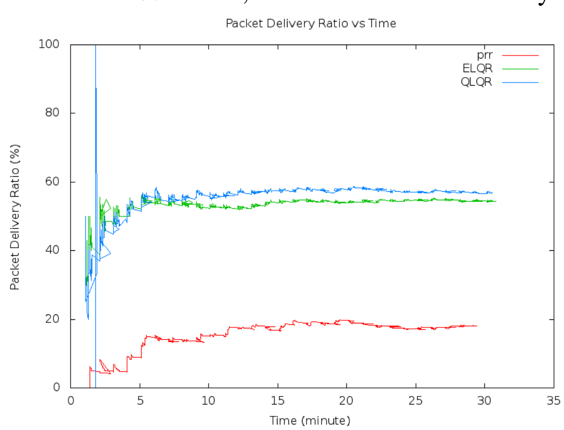

Figure 7: PDR of PRR, ELQR and QLQR

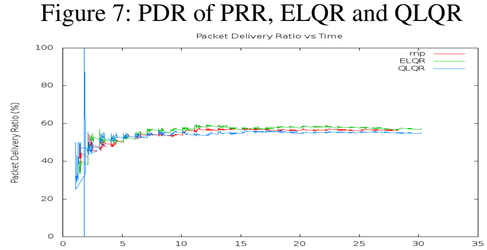

Figure 8: PDR of RNP, ELQR and QLQR

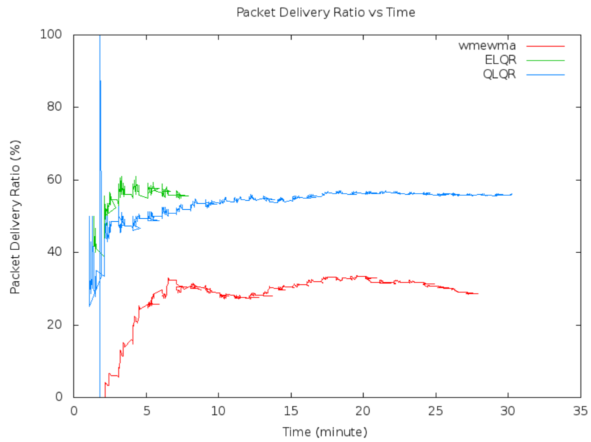

Figure 9: PDR of WMEWMA, ELQR and QLQR

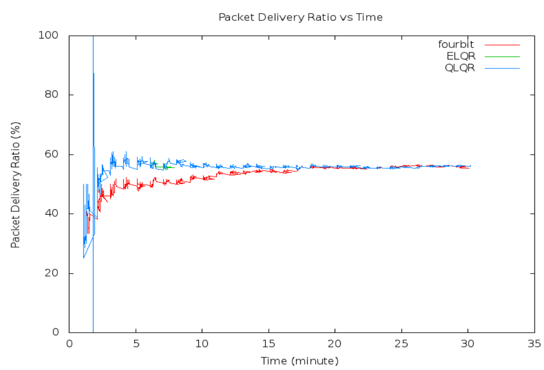

Figure 10: PDR of Four Bit, ELQR and QLQR

Like Throughput, the PDR increases in the event of use of the parameters of energy or quality of link because the packets are distributed to the nodes according to the case and consequently the Packet Delivery Ratio increases i.e. the loss of the packets decreases in a remarkable way.

The analysis showed that results with 12 nodes, i.e., those with a high density, had a PDR difference that reached 60% when compared with CTP. Obtaining high PDR and low latency was due to the use of QLQR or ELQR.

7. CONCLUSION

Energy is an important resource in WSN to enhance the lifetime of the network. The Link Quality Indicator and Energy Residual of the nodes can increase the performance of network. The link quality increases when the hop count decreases thus the node with high value of link quality will be chosen as the forwarding candidate. In this work, the threshold for the link quality is changed throughout the lifetime of the network to make it alive by selecting the longer routes with more energy. The optimal path will be chosen when the route has more Residual Energy or through Link Quality Indicator.

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