RESIDUAL NODE DETECTION IN WIRELESS SENSOR NETWORK

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Abstract: *One of the major challenges a wireless sensor networks face today is security. Such a network normally consists of a large number of distributed sensor nodes. The deployment of sensor nodes in an industrial environment makes the networks vulnerable to eavesdropping attacks and also the performance of the WSN will be degraded due to the presence of the Residual nodes. Various performance improvement techniques are applied. An efficient residual node detection algorithm is proposed.*

1. Introduction

Wireless sensor network technology poses its unique design challenges. One important feature that distinguishes sensor networks from traditional distributed systems is their need for energy efficiency. Many nodes in the emerging sensor systems will be untethered, having only finite energy reserves from a battery. The scale of a sensor net's deployment will make recharging these energy reserves impossible. The requirement for energy-efficiency pervades all aspects of the system design. Another important feature that distinguishes wireless sensor networks from other distributed systems is their unattended nature. In these networks, nodes are not necessarily deployed in a regular way. Because of their compact form factor and their potential low cost, it might be possible for thousand of nodes to be autonomously deployed in an unplanned fashion.

The working environment for those sensor nodes might be unpredictable and could affect the performance of the sensor network dramatically. The high node-to-human ratio also makes it infeasible to maintain individual node constantly. Given their unattended nature and their complexity, it is critical that the users be given continuously updated indications of the sensor network health, i.e., explicit knowledge of the overall state of the sensor network after deployment.

In this work, we propose an efficient monitoring infrastructure for sensor networks. Analogous to weather map or air traffic radar images, our sensor network scans describe the geographical distribution of network resources or activity of a sensor field. We design and evaluate a mechanism for collecting a residual energy scan (eScan). Such a scan depicts an aggregated picture of the remaining energy levels for different regions in a sensor field. Instead of the detailed information of residual energy at individual sensors, this scan provides an abstracted view of energy resource distribution.

Our proposed approach to construct an eScan applied localized algorithms in sensor networks for energy-efficient in-network aggregation of local representations of scans. Rather than collect all local scans centrally, this technique builds a composite scan by combining local scans piecewise. At each step of aggregation, these partial scans are auto-scaled by varying their resolutions. In this manner, the information content of the overall scan scales well with network size. We also propose to apply incremental updates to scans. When the state of a node changes, it should not need to re-send its entire scan. Rather, it should only need to send an update to a scan when its local state has changed dramatically. Furthermore, that update should only traverse up the aggregation hierarchy if it radically impacts some aspect of the overall representation. When local scans are aggregated, detailed information such as the residual energy at each individual node is lost. However, the compactness of such an abstracted representation can reduce the communication and processing cost significantly. The trade-off between reduced fidelity and increased lifetime is acceptable.

2. Overall Energy Consumption Formulation

The overall energy consumption of the entire systems is expressed in terms of relationship among constituents. We suppose a continuous time between t1 and t2 for the energy consumption measurement. Residual energy in time t is defined by omitting consumed energy in Δt from the initial battery power in t-Δt. Thus, the energy consumption will be determined in Δt.

$$E_{residual,i}(t) = E_{initial,i}(t - \Delta t) - E_{consumed,i}(\Delta t) \quad (5.1)$$

$$E(\Delta t) = \frac{\partial E}{\partial t}\Delta t1 \quad (5.2)$$

$$\Delta t = t_2 - t_1 \quad (5.3)$$

Interplay among the components can be taken into account in terms of their weights as some function of the design of the WSN and the application. The total energy consumption of node i in the interval Δt based on constituent of HEDA as follows:

$$E_{consumed,i}(\Delta t) = \lambda_1 E_{individual,i}(\Delta t) + \lambda_2 E_{local,i}(\Delta t) + \lambda_3 E_{global,i}(\Delta t) + \lambda_4 E_{battery,i}(\Delta t) + \lambda_5 E_{snk,i}(\Delta t) \quad (5.4)$$

Subject to:

1. $E_{local,i} > 0$
2. $E_{global,i} > 0$
3. $\lambda_1 E_{individual,i}(\Delta t) + \lambda_2 E_{local,i}(\Delta t) + \lambda_3 E_{global,i}(\Delta t) + \lambda_4 E_{battery,i}(\Delta t) + \lambda_5 E_{snk,i}(\Delta t)$

The first constrain expresses condition for necessity to establish a collaboration connection. The second constrain shows the necessary and sufficient condition for accessibility of the node in the network. The third constrain means a node should have enough energy to do network tasks otherwise it is not active and should be removed from the network calculations. Each constituent is expressed in terms of key parameters (or factors). These key factors are determined based on application requirements. On the other hand, these parameters may influence more than a single constituent; hence energy constituents may partially overlap.

Consequently, the interplay among energy constituents must be taken into account in evaluating the overall energy consumption of the entire setup. For example, the number of neighbors determined by topology in the global constituent has direct influence in energy consumption of the local constituent.

2.1 Individual Constituent

The individual constituent can be a state-based constituent, because every unit has different energy level consumption in different states. In addition, this constituent involves two different types of transitions: transitions between units and transition between states of a single unit. The overall energy consumption in individual constituents is expressed as follows:

$$E_{individual,i}(\Delta t) = \sum_{u=1}^{N} \sum_{s\in S} \sum_{w\in W} I\big(e_{u,s},\ e_{u,w}\ ,t_{u,s}\big) \quad (5.5)$$

$$\sum_{s\in S} e_{u,s} > \sum_{w\in W} e_{u,w} \qquad u \in U \quad (5.6)$$

Since most of energy minimization methodologies use idle and sleep states for avoid of wasting energy in idle states, the above constraint states that the total energy consumed for switching among states should be smaller than the total energy consumption of states. Energy consumption in an active state for each unit depends on several factors as follows:

$$e_{1,active}(\Delta t) = F_1\big(f, b_{processor}\big) \quad (5.7)$$

According to Eqn. (5.7), the energy consumption of the processor unit in an active state depends on the number of processed bits and the frequency based on the following equation:

$$p \propto cv^2 f \quad (5.8)$$

This proportionality expresses that the energy consumption of the processor is proportional to the voltage and the frequency of the operation. Since the frequency and the voltage can be related.

Energy consumption of the transceiver unit for digital signal processing in an active state depends on the number of received and transmitted bits, and the amount of needed energy for coding and decoding packets. The energy wastage in idle and sleep states can be measured according to the base amount of energy consumption in these states which depends on unit type and duration of staying in the state. More over switching among the unit's states also consumes considerable amount of energy, this energy is measured differently for different type of unit.

Generally, transmission is a key task in communication among nodes. Energy consumption for packet transporting in the network is in proportion to the distance. The distance to neighbors can increase or decrease the energy consumption of radio channel to transmit a data bit. Heinzelman et al. (2000) derived the energy consumption of transmit and receive a k-bit message for a microsensor. The needed energy for the transmit amplifier to send a bit is shown as e. Hence, in local and global constituents, the energy consumption for transmitting k bits to a node of distance d from the transmitting node is defined as follows:

$$E_{TX}(d) = e_{amp} d^2 k \quad (5.9)$$

and energy consumption of receiving k bits from a node is proportional to the receiver electronics energy per bit (e_{elec}), is defined as:

$$E_{RX} = e_{elec}\, k \quad (5.10)$$

These equations are general forms of the energy consumption for communication. The important factors, which increase or decrease the energy consumption of transmission and receive operations, should be considered by network designers.

2.2RESIDUAL NODE DETECTION ALGORITHM

Step 1: Select any sensor node NP from WSN with sensor nodes, the value so.

Fp = 1,2 … 3s(N_1ଢ ≤ Nଔ$_s$)

Step 2: RTP_P form has sensor sequence as,

$$NP - NP + 1 - NP + 2$$

Step 3: Call subroutine “RTD Time”. RTD Time subroutine,

(i) If NP+1=NS then replace NP+2 by N_1, else if

NP+1>NS then replace NP+1 by N_1 and NP+2 by N_2 respectively.

(ii) Measure the round trip delay time of corresponding RTP. Initially it is RTP_P.

(iii) Return to main program.

Step 4: If DRTD_P=DTHR then increment NP by 3 (NP=NP+3).

If, NP+3>NS then reset NP+3 to N_S and goto Step 2; else go to Step 2.

Else, Call subroutine “RTDTime”. Measure RTD time of RTP (P+1) having sequence as NP+1–NP+2–NP+3.

Step 5: If DRTD_ (P+1)=DTHR then goto step 7;

else if

DRTDP=∞ then NP node is failed(dead). Otherwise NP node is malfunctioning.

Step 6: go to Step 4.

Step 7: Call Subroutine “RTDTime”. Measure RTD time of RTP (P+2) having sequence as NP+2–NP+3–NP+4.

Step 8: If DRTD (P+2)=DTHR then go to step 5.

Else if

DRTD_P+1=∞then NP+1node is failed (dead). Otherwise NP+1 node is malfunctioning

Step 9: go to step 4.

Step 10: if DRTD (P+2) = ∞ then NP+2 nodes is failed (dead).

Otherwise NP+2 nodes are malfunctioning.

Step 11: if NP+2>NS then go to step 4.

Step 12: Stop

Using the energy consumption rate values, it is possible to estimate sensor network lifetime for different protocols, as long as times they spent in the different states are known.

2.3 SYSTEM MODEL

Collecting Residual Energy Scans

The process of constructing a eScan of a sensor field can be briefly described as follows:

Determining Local eScans

Each node constructs its local scan with its residual energy level and its location, and it only reports when the energy level drop significantly since last time it reported its eScan.

Disseminating eScans

Local eScans are disseminated across the network to compute a composite eScan of the entire network. For this to happen, the user at a gateway expresses a special INTEREST message. This INTEREST message propagates throughout the network by flooding. Upon reception of INTEREST message, each node sets the sender as its parent node leading toward the user. An aggregation tree is constructed with root as the user gateway. Local eScans is sent along the tree towards the user.

Aggregating eScans

Those nodes that receive two or more eScans may aggregate eScans if the eScans are topologically adjacent and have the same or similar energy level. The aggregated scan is a tuple consisting of a polygon that describes a collection of nodes, and the range of residual energy levels at those nodes, which reduces the messaging cost by losing little critical information content in the scans.

Abstracted Representation

A sensor network scan represents an abstracted view of a particular network characteristics. More precisely, we can define a eScan as a collection of (VALUE, COVERAGE) tuples.

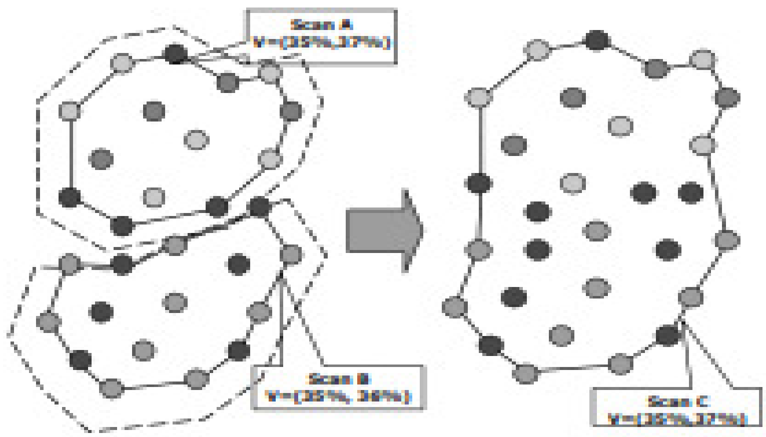

Figure 5.1 Representation and Aggregation of eScans

VALUE is the quantitative representation of the network state we are monitoring. It may have a more complex form than a single scalar value. In eScan, we use VALUE=(min, max), where min, max are the minimum and maximal residual energy level of the nodes, respectively. For example in Figure 5.1, the eScan VALUE in scan A is (35%, 37%). COVERAGE denotes the region that VALUE describes. In eScan, COVERAGE of a scan is described by a polygon, which covers those nodes with energy levels falls in the range of VALUE.min and VALUE.max. The vertices of COVERAGE polygon are the locations of those boundary nodes. The polygon is not necessarily convex, but not self-overlapping. In Figure 5.1, the coverage polygon of the eScan is shown using a solid line.

In-network Aggregation of eScans

1) Aggregation Rules: One of the most important characteristics of scans is multiple scans can be combined. For example, eScan A and eScan B can be aggregated if

(i) A.VALUE and B.VALUE are similar

$$\frac{\max\{A.max,B.max\}-\min\{A.min,B.min\}}{\text{Avg}\{\text{A.min,A.max,B.min,B.max}\}} \leq \text{T} \quad (5.11)$$

(ii) And, A.COVERAGE and B.COVERAGE are adjacent:

$$Distance(A.COVERAGE, B.COVERAGE) < R \quad (5.12)$$

where T (tolerance) denotes the maximum allowed relative error of residual energy value by aggregation. R(resolution) decides when two regions are adjacent. Function Distance gives the minimum distance between any pair of points, each from one of the coverage sets. When both conditions are met, the aggregated eScan C can be obtained in the form of:

$$C.min = \min\{A.min, B.min\} \quad (5.13)$$

$$C.max = \max\{A.max, B.max\} \quad (5.14)$$
$$C.COVERAGE = Merge(A, B, R) \quad (5.15)$$

Aggregation Tolerance Adaptation

To balance the savings in aggregation and the loss of accuracy in scans, each node adaptively adjusts its aggregation operation locally. For example, if a node keeps receiving scan updates, it can increase the aggregation tolerance value to reduce the size of resulted scan. If the node only receives a few eScan updates or those updates are very similar to each other, it can reduce the aggregation tolerance value to generate more detailed scans of residual energy.

Aggregation Path Maintenance

Node failure may partition the aggregation tree thus some nodes are not able to send eScan updates to the user. We propose that tree is maintained by "soft-states" and the user periodically refresh INTEREST messages to adapt node failure and network dynamics. Similar protocols have been well studied in IP routing, IP multicast and others. All the issues above are important and cannot be ignored. However, our experiments in next section shows the key benefits of sensor network scans comes from abstracted representation scheme, in-network aggregation and incremental updates.

3.SIMULATION RESULTS

Packet Delivery Ratio

The Packet Delivery Ratio (PDR) of the proposed residual node detection system is superior to the conventional system as depicted in Table 5.1. Also, it is graphically illustrated in Figure 5.2.

The residual node detection system achieves 66% PDR even the in case of high number of residual nodes (60) in the network environment.

Table 5.1 PDR analysis report

Number of residual nodes	PDR (%)			
	Proposed work	Fenye Bao et al (2012)	Bo Sun et al (2013)	Haripriya et al (2015)
10	94	91	87	86
20	88	82	83	88
30	79	67	70	71
40	80	64	58	61
50	69	61	48	56
60	65	55	44	51

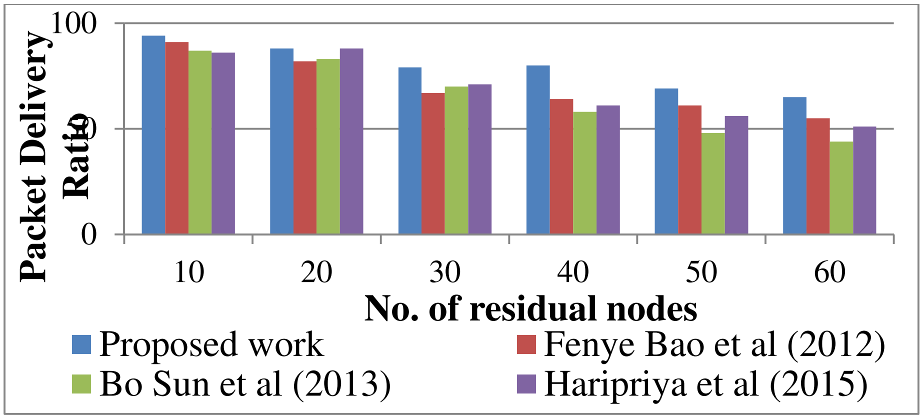

Figure 5.2 Graphical plot of PDR analysis

Average Latency

The average latency of the proposed residual node detection system is superior to the conventional system as depicted in Table 5.2.

Table 5.2 Average latency analysis report

Number of residual nodes	Average Latency (ms)			
	Proposed work	Fenye Bao et al (2012)	Bo Sun et al (2013)	Haripriya et al (2015)
10	29.0	32.1	35.2	31.7
20	39.3	44.2	52.1	49.6
30	52.0	54.9	59.1	62.1
40	54.8	58.8	67.1	67.9
50	56.3	59.0	68.9	71.3
60	57.4	63.5	82.3	77.8

The residual node detection system achieves 57.4 ms average latency even the in case of high number of malicious nodes (60) in the network environment and is graphically depicted in Figure 5.3.

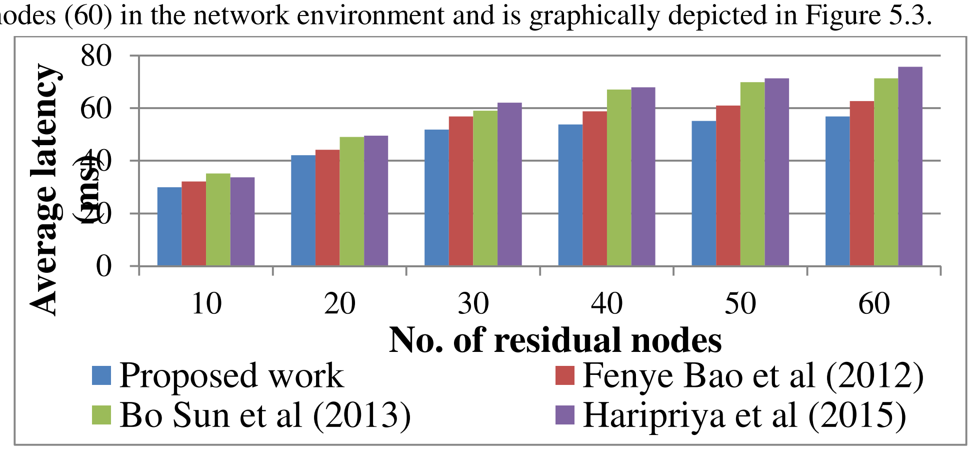

Figure 5.3 Graphical plot of average latency analysis

Throughput

The rate at which the total amount of packets transmitted from source to destination node over a time period 't' is called as throughput. It is simply defined as the number of bits transmitted per second. It is expressed as,

$$Throughput = \sum Total\ number\ of\ bits/\ time\ 't' \quad (5.16)$$

Table 5.3 Throughput comparisons

Time (ms)	Throughput (bps)				
	Proposed method	OEERP	LEACH	DRINA	BCDCP
50	58000	54000	55000	75000	18000
100	59000	52000	54000	79000	26000
150	62000	51000	52000	79000	28000
200	62500	51000	52000	70000	28000
250	62800	50000	51000	64000	27000
300	62900	51000	51000	58000	30000

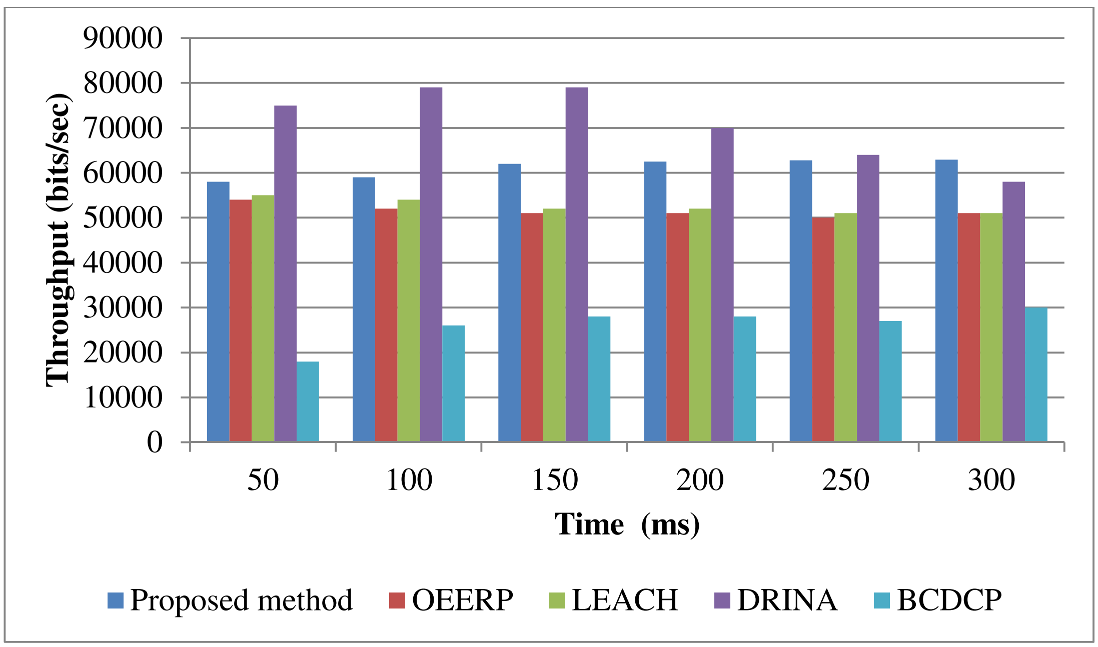

Figure 5.4 Graphical plot of throughput comparison

Throughput is defined as the number of bits successfully transmitted to the destination over a time period. The performance of the system is improved if the throughput is high. Table 5.3 shows the performance comparisons of proposed method with different conventional protocols. From Table 5.3, the throughput of the proposed system is proved to be better than the conventional systems.

Energy consumption

The network life time can be improved by reducing total energy consumption. The energy consumption of the node is based on sensing the data, conversion from one format to another format and transmission. The energy consumption of the individual node in the network is computed as,

$$E_{node} = E_{node-initial} - E_r \tag{5.17}$$

Where, the initial energy of the node is denoted as $E_{node-initial}$ and the energy after processing the data is denoted as E_r.

The total energy consumption of the network is computed as,

$$E_{network} = \sum_{i=1}^{n} E_{node\_i} \tag{5.18}$$

Where, 'n' represent number of nodes in the network.

The total energy consumption is based on the number of nodes available in the network. The energy consumption will be high when there are large numbers of nodes in the network. The energy consumption of the proposed method is compared with conventional methods at different time slots and it is illustrated in Table 5.4 and the same is graphically plotted in Figure 5.5.

Table 5.4 Energy consumption comparisons

Time (ms)	Energy Consumption (Joules)				
	Proposed method	OEERP	LEACH	DRINA	BCDCP
50	4	10	20	5	8
100	12	15	45	15	16
150	18	20	70	19	19
200	27	30	90	52	30
250	32	35	115	84	40
300	41	45	138	122	48

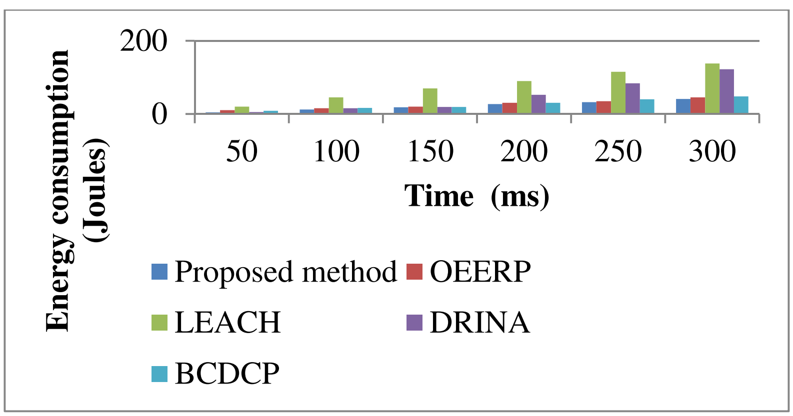

Figure 5.5 Graphical plot of energy comparison

4. Conclusion

The energy consumption of the proposed method is compared with other protocols OEERP, LEACH, DRINA and BCDCP. From Table 5.4, there is a linear increment of energy consumption over different time slots. The proposed method consumes low energy consumption when compared with other conventional protocols. The network life time will be improved by consuming less energy.

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