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Development of Low Duty Cycle Wireless Sensor Network for Efficient Broadcast

A.Rexi, K.Maheswari, K.Thulasimani

Abstract— Wireless Sensor Networks (WSNs) are used in several communication applications such as military surveillance, infrastructure protection and scientific exploration. In that broadcasting is one of the basic services to pass messages in WSNs. Since Sensor nodes are usually battery powered, WSNs need to be operated under low duty mode, in which the sensor node has less active period compared to its sleeping period where broadcasting becomes a challenging issue in such low duty cycle network. This paper deals with efficient broadcast under such low duty cycle mode. The main objective of this paper is to provide efficiency in message broadcasting. In this, first a low duty cycle network model has been developed. Then the problem for broadcasting message is formulated with the help of shortest path problem. Optimal solution for the broadcast problem is computed using the proposed efficient evolutionary algorithm. The performance of this solution is analyzed with the optimal solution computed using dynamic programming algorithm with the best result of minimum time cost and message cost.

Index Terms— Broadcast, Dynamic Programming Algorithm, Efficient Evolutionary Algorithm, Low duty cycle, Wireless Sensor Networks, Time cost, Message cost

1 Introduction

Broadcast is one of the basic services in Wireless Sensor Networks (WSNs) that allows sensor nodes to spread messages across the whole network [2], [3], [7]. Duty Cycle is defined as the ratio between active period and full operational period [15]. Depending upon the active period percentage, the duty cycles are classified as high, medium and low duty cycle. For saving energy WSNs usually works under low duty cycle mode. The sensor nodes are often alternating between sleeping and active states [4]. But broadcasting in such low duty cycle WSN becomes a typical issue, since the node is in sleeping state for a long period of time. Previous works provides broadcasting service by means of assuming that all nodes are in active state [8], [12]. In such broadcasting, reliability cannot be achieved and thus it becomes impossible. Broadcasting the message by waiting until the node turns to active sate from sleeping state, is also impossible since it increases the latency and decreases the efficiency. Therefore even if the reliability is achieved, the latency and efficiency cannot be achieved. The objective of this work is to provide efficiency in message broadcasting.

In this paper efficient broadcast is achieved by means of implementing optimal solution with certain constraints. The optimal solution is computed using efficient evolutionary algorithm. The efficiency of the broadcast is calculated by means of message cost and time cost.

The rest of the paper is organized as follows: In Section 2, the preliminary works are presented. Section 3 provides a detailed discussion of the proposed work. The implementation details of the proposed approach and the comparative analysis are presented in Section 4. Finally, conclusion and future work are presented in Section 5.

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2 Preliminary Works

The existing work provides reliable broadcast in various circumstances. Basic broadcast approaches are flooding and gossiping [9], [11].

M. Miller, and et al [2005], proposed a probability-based broadcast forwarding which implements a MAC layer solution for flooding in low duty-cycle sensor networks and investigates tradeoffs among flooding reliability, latency, and energy consumption. This work have focused on the MAC layer, where the operations are of much shorter time scales and the duty cycles are subject to change with network traffic[14].

F. Stann et al [2006] presented the Robust Broadcast Propagation (RBP), which extends the flooding-based approach for reliable broadcast. It lets each node flood the received broadcast message only once, and then by overhearing and explicit ACKs, the node may perform retransmissions for local repairs. It targets reliable broadcast but does not explicitly consider duty cycles. When the duty cycle went low, this original RBP performed poorly and even failed to achieve the primary goal of reliability [13].

F.Weng and J.Liu [2012], proposed a reliable broadcast service in low duty-cycle wireless sensor networks which revisited the broadcast problem in low duty cycle wireless sensor network. In this, the broadcast problem is considered as equivalent to a shortest path problem in a time-coverage graph, and accordingly presented an optimal centralized solution using Dynamic Programming Algorithm. For large-scale networks the solu-

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tion will suffer from the higher computation cost

This work targets in providing reliable broadcast under low duty cycle. The reliability is achieved in addition with efficiency while broadcasting messages, which is evaluated through the parameters message cost and time cost. easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it.

3 Proposed Work

A scenario has been created with a set of sensor nodes and a sink node.

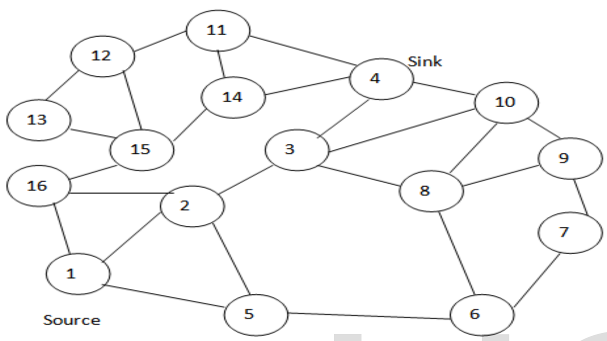
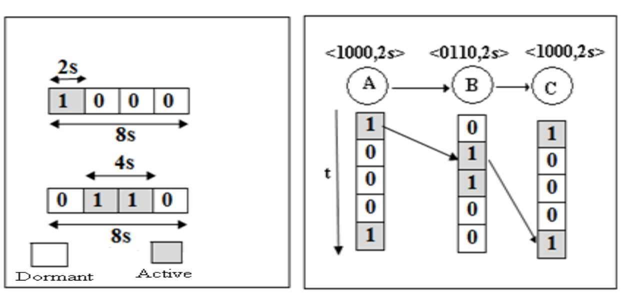


Figure 1 Proposed WSN Model

The network with 16 number of sensor nodes is considered here.

3.1 Development of Low Duty Cycle Network Model

In this work, a particular working schedule is followed by each sensor nodes and this schedule information is shared with its neighboring nodes. Each node will be in active and sleeping state for a particular period of time. When a node is in an active state, it can able to sense, transmit and receive broadcast message and when it is in a sleeping state it can transmit the message, but receive only when it turns to its scheduled active period. The whole operational period is considered as T and it is divided into equal time slots t. Each time unit picks its states randomly which can be represented by 1s and 0s, where 1 denotes the active period and 0 denotes the sleeping period of the node [5], [6].



a b

Figure 2 Low Duty Cycle Network Model

The i_{th} node's working schedule can be represented as $<w_i, t>$ where w_i is a string of '1's and '0's denoting the schedule and t is the length of each time unit.

In Figure 2a $<w_i, t>$ is < 1000, 2s > and < 0110, 2s > where T is 8s and is divided into 4 time units, each of which is 2s long. A node with schedule < 1000, 2s > is in active state during the first 2s and is in sleeping state during the rest 6s.

In the Figure 2b, node A tries to forward a packet to C via B. Since a node can only receive a packet when it is active, a sender waits for its receiver to become active to forward the data.

3.2 Problem Formulation

From the given number of sensor nodes, a forwarding schedule to broadcast message is created starting from time t_0 which is represented as below.

$$S=\{(u_1,t1),\ldots,(u_m,t_m)\}(t_0\le t_1\le\ldots\le t_m) \quad (1)$$

In this (u_1, t_1) denotes the 1st forwarding where node u_1 forward the message to the next node (say u_2) at time t_1. The forwarding schedule formation should satisfy three constraints namely Duty cycle constraint, Forwarding order constraint, Reliability constraint. Duty Cycle constraint is the one in which the active node can forward the message only to its active neighbor. Forwarding order constraint is the one in which the message should be forwarded hop-by-hop. That is the node that recently received the message only can forward the message to the next node. Reliability constraint is the one in which the all the node should receive the broadcast message.

The objective function of the forwarding schedule is given as below

$$f(S,t_m-t_0)=\alpha|S|+\beta(t_m-t_0) \quad (2)$$

Where α and β denotes the weight assigned. Construct a directed graph G (V, E) where the vertices V represent the set of nodes and E represents the set of edges. The shortest path problem is constructed as below

$$F(V_{R',t'})=\min_{V_{R,t}}(F(V_{R,t})+W(V_{R,t},V_{R',t'})) \quad (3)$$

In this $W(V_{R,t},V_{R',t'})$ denotes the weight of the edge from $V_{R,t}$ to $V_{R',t'}$, and $W(V_{R,t},V_{R',t'}) = \infty$ if there is no such edge. $F(V_{R',t'})$ be the total weight of the shortest path from vertex $V_{\{s\},t0}$ to $V_{R',t'}$. R denotes the set of nodes that received the message and R' denotes the set of nodes that recently received the message from set R.

3.3 Implementing Optimal solution

The recurrence relation (3) is solved using evolutionary algorithm to find the optimal solution.

3.3.1 Efficient Evolutionary Algorithm

Efficient evolutionary algorithm is used to compute the optimal solution [10].

Steps in efficient evolutionary algorithm are as follows.
Step 1: Create Initial Population, in which the available paths are initially stored in the array starting from the source node.
Step 2: Compute Fitness Value, in which the best paths from source node is chosen.
Step 3: Termination. If the termination condition is satisfied, then the loop stops with the computed fitness value as its optimal solution, otherwise it proceeds with the following steps.
Step 4: Selection, in which the individual node that have to be changed are selected.
Step 5: Recombination, in which the selected individual crossover with the required sequence.
Step 6: Mutation, in which new set of path is created. Then proceed again from step 2.

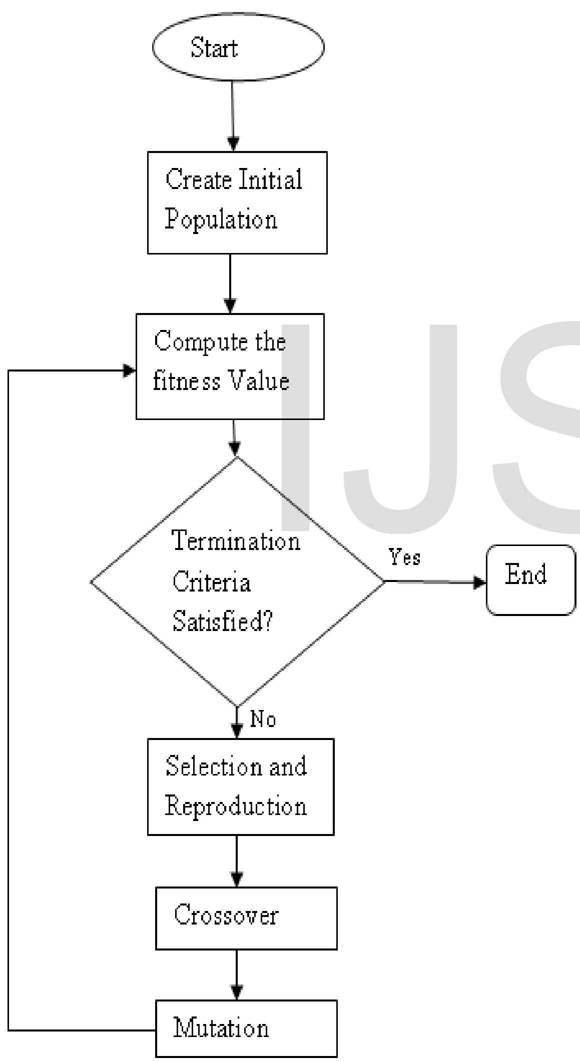


Figure 3 Flow chart for efficient evolutionary algorithm

4 Experimental Works

4.1 Simulation Results and Output

The performance of the proposed solution is measured by using two major metrics called Time cost and Message Cost. Message cost is the number of forwarding. Time cost is the total time slots taken to cover all the Sensor nodes. The experimental result shows that the performance of the optimal solution computed using evolutionary algorithm minimizes Time cost and Message cost, compared to the optimal solution computed using Dynamic algorithm. Simulation is done using J-Sim. It is a dual-language simulation environment in which classes are written in Java.

4.2 Comparative Analysis

Table 1 and Table 2 shows the Performance Evaluation by comparing time cost value and message cost value of efficient evolutionary transmission with dynamic transmission for 16 numbers of nodes respectively.
It is expected that efficient evolutionary algorithm produces more optimal solution than the dynamic programming algorithm by minimizing the Time Cost and Message Cost.

Table 1: Comparison of Time Cost Value

Number of Iterations	Time Cost (Precision(1))	
	Dynamic Transmission	Efficient evolutionary Transmission*
1	0.3	0.2
2	0.5	0.4
3	0.8	0.7
4	1.0	0.9

$$\text{Precision (1)} = \frac{\text{Number of paths taken to forward}}{\text{Total Number of paths available}}$$

For example, to calculate time cost, Given total time,T=8s and let time slots = 2 (1 time slot=2s). Therefore time cost=4s/8s=0.5.

Table 2: Comparison of Message Cost Value

Number of Iterations	Message Cost (Precision(2))	
	Dynamic Transmission	Efficient evolutionary Transmission*
1	0.5	0.4
2	0.6	0.5
3	0.7	0.6
4	0.8	0.7

$$\text{Precision (2)} = \frac{\text{Time Slots taken to forward}}{\text{Total time taken to forward message}}$$

For example to calculate message cost, Given total number of paths available=15 and let number of paths taken to forward message=3. Therefore message cost = 3/15 = 0.2

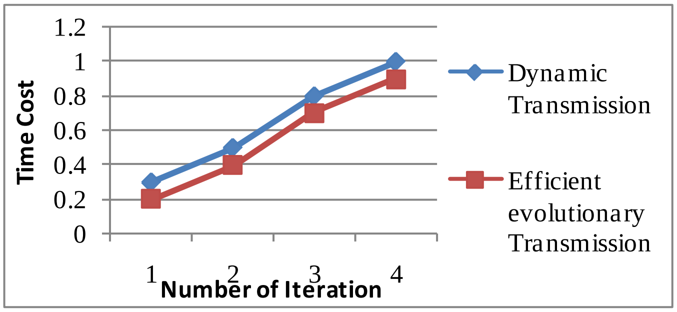


Figure 4: Time Cost with different number of iteration for 16 numbers of nodes

From the data, it can be seen that message cost and time cost is being reduced while using the efficient evolutionary algorithm compared to the dynamic programming algorithm, since efficient evolutionary algorithm selects optimal solution from a set of solutions rather than trying each solution as in Dynamic Programming algorithm

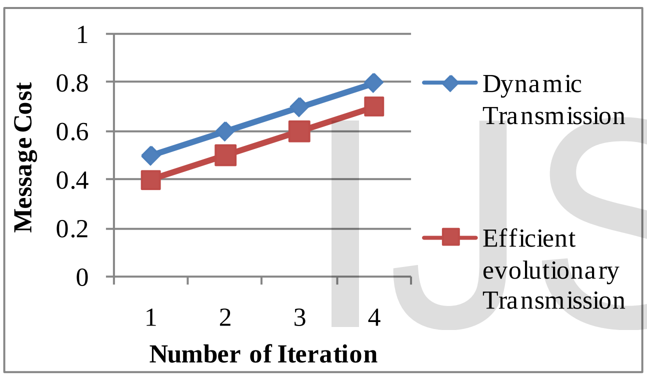


Figure 5: Message Cost with different number of iteration for 16 numbers of nodes.

5 SUMMARY AND DISCUSSION

The Broadcast problem in Low Duty Cycle WSN is considered in this project. The main aim of this project is to provide efficient broadcast. To attain the objective, first the low duty cycle WSN model is developed, in which the active and sleeping time schedule is pre determined. Then broadcast problem is formulated in low duty cycle WSN. Then the problem is transformed into shortest path problem. Using efficient evolutionary algorithm optimal solution is computed. To provide efficient broadcast optimal solution is implemented for 16 numbers of nodes. The performance of the implemented optimal solution is analyzed with the dynamic programming algorithm's optimal solution, by means of Time cost and Message cost.

6 CONCLUSION AND FUTURE WORK

Efficient broadcast solution in WSN under low duty cycle is implemented using efficient evolutionary algorithm. The performance of this solution is compared with the existing Dynamic programming algorithm's optimal solution, which shows comparatively best result with lower time and message forwarding cost.

Even though it minimizes the time cost and message cost, in order to achieve reliable broadcast, a single broadcast message is transmitted more number of times. The future work of this project is to use probabilistic method, which minimizes the redundancy to provide balance between time, message costs, and reliability.

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