Australian Journal of Basic and Applied Sciences, 9(7) April 2015, Pages: 479-485

ISSN:1991-8178

Australian Journal of Basic and Applied Sciences

Journal home page: www.ajbasweb.com

Bandwidth Estimation and Energy Optimization of Gradient based Routing Protocol for Wireless Sensor Network

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ARTICLE INFO

Article history:
Received 12 December 2014
Received in revised form 26 December 2014
Accepted 28 January 2015
Available online 1 April 2015

Keywords:
Routing protocol, Optimization Technique, Energy, Link bandwidth, WSN

ABSTRACT

The Wireless Sensor Networks (WSNs) comprised of small sensor nodes capable of sensing, processing and transmitting data related to some phenomenon in the environment. However, the sensor nodes have severe constraints, such as: low network bandwidth, short wireless communication range, limited CPU processing capacity, memory storage and power supply. Increasing the lifetime of wireless sensors network, efficient utilizations of link bandwidth are essential for the proliferation of wireless sensor network in various applications. In the past, many energy efficient routing algorithms have been reported in order to maximize network lifetime, in which wireless link bandwidth has been optimistically assumed to be sufficient. In this paper, we discuss the sufficient condition for the use of link bandwidth that makes a routing solution feasible, and then provide ant colony optimization technique to optimize energy and link bandwidth estimation. In Part (a) of the paper, we analyzed the performance of the gradient based routing protocol without optimization technique to calculate the energy utilization for the sensor network area and estimate link bandwidth. In Part (b) of the paper, we have applied the heuristic approach, i.e. ant colony optimization (ACO) to optimize energy consumption and computed link bandwidth in WSN. Results show that gradient based routing with Ant colony optimization provides more feasible routing solutions and provide significant improvement on the lifetime of the sensor network.

To Cite This Article: Rajeev arya and S.C. Sharma, Bandwidth Estimation and Energy Optimization of Gradient based Routing Protocol for Wireless Sensor Network. ***Aust. J. Basic & Appl. Sci.,*** *9(7): 479-485, 2015*

INTRODUCTION

Due to advances in Micro electro Mechanical System Technology, wireless communications and digital electronics have enabled the development of low-cost and low-power sensor node that are small in size and communicate in a small region. These tiny sensor nodes consist of sensing, storing, processing and communicating components. Wireless sensor networks (WSNs) comprised of a large number of sensor nodes dispersed over a geographical area. So WSNs provide reliable operations in various applications like environmental monitoring, health monitoring, earthquake observation, vehicle tracking system and military surveillance (Akyildiz, 2002; Akyildiz, 2002; Gsottberger, 2004; Akkaya, 2003; Priyanka Rawat, 2013; Mainwaring, 2002). Sensor nodes have severe constraints, such as: limited power supply, low network link bandwidth, short wireless communication range, and limited processing and memory storage.

In the last few years research has focused on every layer of sensor network, which includes topology control (Pan, 2003) energy in routing (Srinivas, 2003), energy efficient MAC (Dam, 2003), enhanced TCP (Sundaresan, 2003), link bandwidth (Maggie Cheng, 2008), domain-specific application (Heinzelman, 2000) and other limitations like node displacement, battery power consumption, lifetime of node etc. Wireless sensor network life time are affected by different factors, such as power- aware routing, topology management, error control &flow control technique and MAC design (Kodialam, 2003). In order to get a minimum loss of signal, various digital modulation techniques (ASK, PSK, FSK QAM and QPSK) are used in wireless sensor network or wired network (Weitao, 2012; Daniel santana gómez, 2006). Mainly two techniques QAM and QPSK are used in wireless sensor network (SAM, 2004) as these schemes minimize the consumed bandwidth (Rakesh Sambaraju 2007). The various routing protocols used in wireless sensor network are classified as data- centric, hierarchical and location based. Gradient based routing the part of data- centric routing protocol proposed in WSN. Gradient-based routing protocols are recognized as

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scalable ones, because gradient- based routing is not necessary to maintain information about network topology (Akkaya, 2003). Gradient- based routing suitable for large scale application with multiple sink in wireless sensor network. In gradient-based routing protocols, every sensor node defines the gradient as the minimum cumulative link/node cost along the path which is used to transmit its data to the sink (Huang, 2009).

In this paper we analyze the performance of energy and bandwidth in wireless sensor network. Thus section 2 present the review on related research. Section 3 performance and analysis of developed model for WSN. Section 4 describes the brief concept of gradient based routing protocol. In Section 5 procedures for optimized path based on ant colony algorithm. Section 6 presents the energy model formula In Section 7 gives an computing of bandwidth in source to sink node. Section 8 analyzes the simulated result. And Section 9 concludes the paper.

Related research work:

Several Gradients based protocols have been reported in the literature for the load-balance problem (Akkaya, 2003; Cheng, 2008; Liu, 2007; Basu, 2003; Suhonen, 2006; Lusheng Miao, 2012). Gradient-based routing with load balancing has two classes of protocols, i.e. first one that develops the traffic load information of a forwarder's 1-hop neighbor nodes and a second one which exploit the cumulative traffic load information from sensor node to the sink node (Huang, 2009; Fyffe, 2006). Many researchers have proposed different type of algorithms for reduce energy consumption (data transmit source node to sink node) in wireless sensor network. Some of the approaches analyses how the assignment of sensor node affects the act of wireless sensor network (Kim, 2003). The approach like artificial intelligence (AI), neural network (NN), swarm optimization (SO), genetic algorithm (GA), deferential evaluation (DE), fuzzy logic (FL) and ant colony optimization (ACO) have reported to analyze the optimal use of node energy. Among all, ACO is one of the best heuristics for implementing optimization problems that are based on natural selection. Ant colony optimization has a computational model for optimization inspired by the foraging behavior of real ant (Kim, 2003; Dorigo, 2003). These techniques are easily implemented for path search in wireless sensor network (Liao, 2011; Alaya, 2007; Jung-Yoon Kim, 2014; Sheng, 2013; Arslan Munir and Ann Gordon-ross, 2010). In a wireless sensor network, dispersed bandwidth assured shortest path routing algorithms that offered good performance (Ziming Zeng and Yanyuan Zeng, 2007). Variable bandwidth allocations used frequency slot assignment to optimize energy in WSNs (Juan Sanchez, 2007).

Bandwidth management depending of traffic generated in the wireless sensor network has mostly used bandwidth limitations quantization algorithm (SeongHwan Cho and Kee-Eung Kim, 2005; Jian Tang, 2006). Bandwidth and energy have limited resources in wireless sensor network. In this paper, we have calculated link bandwidth and energy during data transmission from source node to sink node in a sensor network area this analyzes bandwidth allocation in virtual private network (Maggie Cheng, 2008; Mahalakshmi Chidambara Natarajan, 2010).

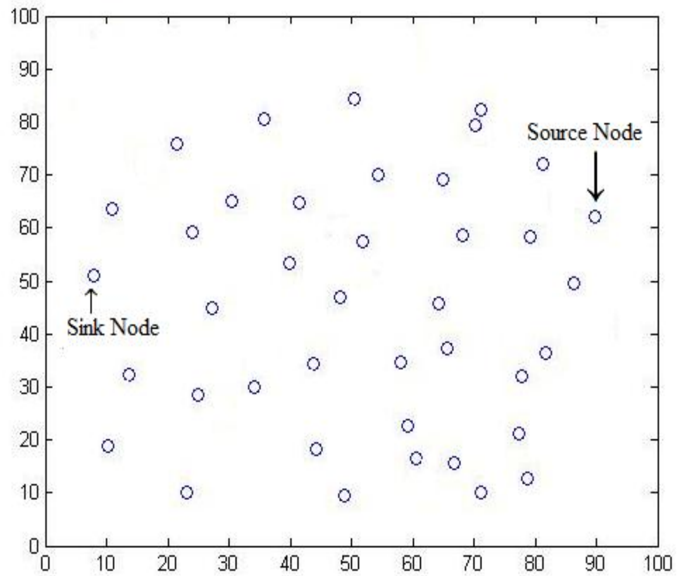

Fig. 1: Wireless Network Area with 40 nodes.

Performance and analysis of developed model for wsn:

Wireless sensor network is a collection of spatially distributed autonomous device that uses sensors to monitor the physical conditions in various applications. The wireless protocol selection depends on the application requirements. In the present analysis, we have taken a grid of 100x100 square meter area. The number of nodes is 40 and each node has the energy of 0.25 j. Every node has same transmission range (50m). The single source node is located at coordinate (90, 63) and sink node coordinate (9, 52).

Gradient based routing protocol:

The classification indicates the OSI layer with corresponding application uses various protocols at network layer. In the present analysis, gradient based routing protocol that is part of the data centric protocol is considered. The gradient routing protocol is appropriate due to its flat nature and data aggregation technique for the network in which traffic is evenly distributed to multiple sinks to prolong the network lifetime. The data aggregation and traffic spreading use in order to balance the traffic uniformly over the network. The node acting as relay for multiple paths can create a data combining entity in order to aggregate data.

The data spreading scheme strive to achieve even distributions of the traffic throughout the whole network that helps with the load balancing on sensor node and increase the life time of the WSN. Gradient based routing has certain limitations like: limited mobility, no position awareness, low sate complexity and limited scalability.

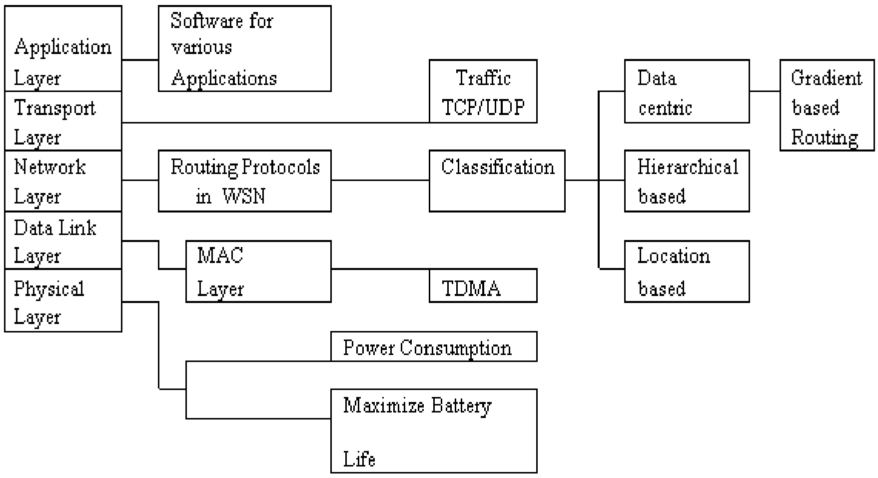

Fig. 2: WSN follows OSI layer with a corresponding application/uses.

Procedure for optimized path based on ant colony algorithm:

Ant colony optimization is an iterative algorithm based on pseudo random proportional rule. In routing problem a set of ants (packet) is simulated form source to sink. The forward ant randomly selects the next node for the first time taking the information from the routing table. The updating of pheromone deposits performed by the ant who successfully reaches the sink by an amount (c/D).

Where

D: the path length of the ant.

c: depend upon the experimental situation to optimize value.

The next setup ant will follow successful visitor ant and guided to the shortest path.

The probability that an ant will select a node (*x*) form node (*y*) is defined as

$$Q_{xy} = \frac{\tau^{\alpha}{}_{xy} \, . \, \eta^{\beta}{}_{xy}}{\sum \tau_{xy} \, . \, \eta^{\beta}{}_{xy}} \qquad (1)$$

(Q_{xy}) =connected two nodes exists if not (Q_{xy}) =0

(τ_{xy}) = the pheromone of all edge connecting node (x) and node (y)

$$\eta_{xy} = 1/r_{xy} \qquad (2)$$

(r_{xy}) = the distance connecting the nodes (x) and (y). α, β are two parameters which resolve the comparative influence of the pheromone trail and the heuristic information.

The main property of ACO is that pheromone value is updated by the total packet which has successfully reached the target. Pheromone evaporation (ρ) on the edge connecting node (x) and node (y) is given by

$$\tau_{xy} = (1-\rho)\tau_{xy} \qquad (3)$$

So, at each instant of time, t= {1, 2, 3,4…..n} signify one iteration in which all the ants in the colony will execute one move towards the selected node. Following that we consider, all the ants find the solution after (n) iteration and leave the pheromone known by the equation.

$$\tau_{xy}(t+n) = \rho\,\tau_{xy}(t) + \Delta\tau_{xy} \quad (4)$$

The total of pheromone which diverse ant k, add to the edge which accepted is 0. if not, if the ant k has agreed during a few edge connecting the nodes, it left the quantity of pheromone, which is inversely proportional through the total cost of each the edges ant k has accepted on its path from the preparatory node to sink node.

$$\tau_{xy} = \tau_{xy} + \sum_{k=1}^{m} \Delta\tau_{xy}^{\ k}\ , \quad \forall(x,y) \in D \quad (5)$$

$\Delta\tau^{k}_{\ xy}$ = the total of pheromone ant *k* deposits on the edges call. It is consider by the following equation

$$\Delta\tau_{xy}^{\ k} = \begin{cases} 1/C^{k} \\ 0, \end{cases} \quad (6)$$

Where C^k has the total cost of each the edges ant k has conceded on its path from the initial node to the sink node. This will tolerate for the enhanced ant to disappear extra pheromone on the edge this is the route of the shortest path.

Energy model:

The standard energy expenditure is computed across the complete random sensor network area. It is a calculable difference between the initial energy and use energy on every node.

Initial energy of node= E_i Joule, Final use energy of node= E_f Joule, Total Sensor Node= S, Total Consume energy= E_c Joule

$$E_C = \left\{ \frac{\sum_{q=1}^{n} (E_{iq} - E_{fq})}{S} \right\} \quad (7)$$

The energy of node in wireless sensor network area must satisfy the above equation (7).

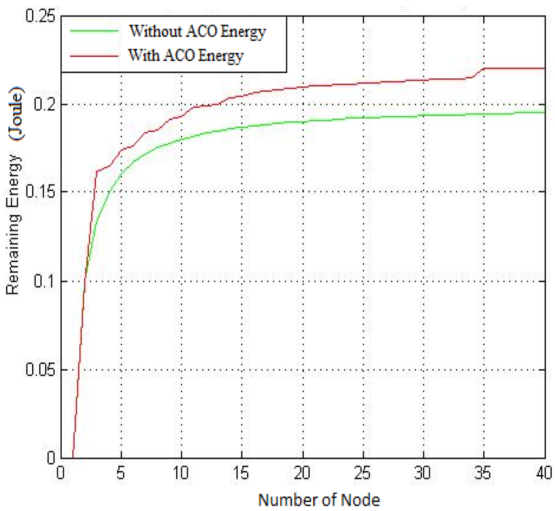

Fig. 3: Comparison of Without ACO and with ACO Energy in Sensor Network Area.

Bandwidth computing:

We suppose link bandwidth allocation of random nodes to non real time traffic demand, to satisfy the delay and traffic rate obligations. The referred nodes create packets. The Packet could contain a collective message from the near non-backbone nodes. In the next, the end to end latency refers the delay are incurred on a multi-hop route from base station to a random node. The transmitted packet, and routed packet are consuming allocated bandwidth. Suppose that the time slot be long enough to transmit coordination message and data packets. The used slot range like the unit of time and data packet transmitted source node to sink node in accordance with link rate.

In the present analysis, we consider a sensor network of all node with each wireless link has a capacity B bit per second and each node x has an initial battery every $E_x(y)$ each node x generate sensory data at a rate of R_x bit per second R_x >0 If the node x is a source

R_x =0 if it is a pure relay node

R_x =1 if it is sink

The source node is preselected and node "*x*" rate R_x is known. The transmission rate is unknown from "*x*" node to "*y*" node. Compute data rate R_{xy} on the link (*x*, *y*) for given node *x*'s E_x, R_y and link capacity *B*.

The each node is similar transmission power and all symmetric links. We assume N_i nearest nodes of "*x*" without "*x*" itself. We commence variable f_x .

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$f_x = 1, \quad if \ \sum_{y \in N} R_{yx} > 0;$

$f_x = 0; \quad otherwise$

If the node x is a receiver then the value of f_x will be 1. Therefore, we can formulate the rate allocation problem as follows.

$$\sum_{y \in N_x} (R_{xy} - R_{yx}) = R_x, \quad (8)$$

$$\sum_{y \in N_x} R_{xy} + f_x \sum_{y \in N_x} \sum_{k \in N_y} R_{yk} \le B, \quad (9)$$

$$0 \le R_{xy} \le B, \quad (10)$$

$$f_x = \{0,1\}. \quad (11)$$

Management as each node satisfies according to equation (8) for every construct and bandwidth construct an equation (9) and (10) respectively is defined. The link $f(w,z) \le C(w,z)$ where $f(w,z)$ is a flow network for that link and $C(w,z)$ is fixed link capacity for used link transmitter over one link depend on raw capacity B and data transmitted over other link in the collision domain. Equation (11) represents that all possible transmission in the same collision has a total depend less than B. Without conflict transmission the sufficient condition is find out if TDMA scheme uses MAC layer. It has been found out bandwidth of the shortest route by following algorithm.

1. Let f_x =1 for destination, f_x =0 remaining nodes; change f_x =1 if $\sum_{y \in N_x} R_{yx} > 0$; for every x otherwise go step 2
2. Find out shortest path source nodes to destination
3. f_x =1 for receiving nodes. If $\sum_{y \in N_x} R_{ys} > 0$; an f_x =0, update f_x =1
4. Iteration step 3 until there is no change for (f_x) or the linear program is not feasible.
5. If f_x converges output link R_{xy} for all links (x, y).
6. If it is not a feasible means if f_x =1 but $\sum_{y \in N_x} R_{yx} = 0$, set f_x =0 and $R_{yx} = 0, \forall_y \in N_x$ as input, if solution is not feasible then solve the linear program again.

In most of the cases it requires 5 to 6 times of epoch to get a sub optimal solution.

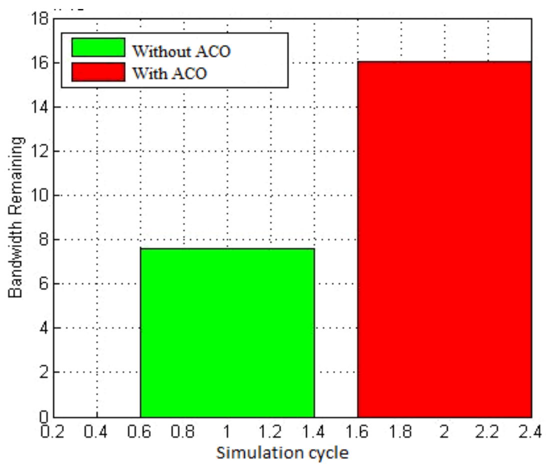

Fig. 4: Bandwidth Remaining without ACO and with ACO.

Table 1: Simulation parameter for bandwidth and energy.

Components	Values
Simulation area	100*100m square
MAC Layer	TDMA
CBR Packet Size	20 bytes
Routing protocol	Gradient based Routing
No. of node	40 nodes
Transmission range	50 m
Channel Bandwidth	18 MHz
Data rate	450kbps
Weight of pheromone (α)	0.5
Weight of heuristic (β)	0.5
Initial pheromone (τ)	0.3

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Simulation parameter and result analysis:

To analyze the sensor network performance in term of energy and bandwidth has been calculated considering different parameter in table. 1. The performance of without ant colony optimization Gradient based Routing (ACO GBR) and optimized with ant colony optimization Gradient based Routing (ACO GBR) in wireless sensor network has been compared energy and bandwidth with respect to same scenario. The bandwidth has been analyzed between the nodes on the followed path during Without ACO GBR and path optimized with ACO GBR in figure.4. The remaining energy has been computed of nodes in wireless sensor network area in figure.3.

Conclusion:

In this paper the performance analysis of without ACO Gradient based routing and with ACO Gradient based routing is compared for average energy consumption and link bandwidth. The results show that the Gradient based routing Algorithm implemented by ACO, reduced the energy consumptions effectively, when the number of nodes increases in the wireless sensor network area. The implies that an ant colony optimization could be efficiently used in for solving the network routing problem with reduction in energy consumption to maximize the lifetime of wireless sensor network.

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