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A Content Aware Framework with Optimal Path Selection in Wireless Sensor Networks

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Abstract: The energy utilization and route selection are the key challenges for most the routing protocols in wireless sensor network. Wireless sensor network consists of set of autonomous sensor devices which are operated by battery power and have limited resources. In traditional routing most of the routing protocols uses multi-path routing and cluster method to increase the network life time and minimize the energy consumption. In the network model, we have developed a Content Aware framework for data Routing (CAR) with reliable path selection and content specific between source and destination. The network model performs better as compare to existing data-centric protocols such as DD and SPIN in terms of throughput and energy consumption.

Key words: Wireless sensor network, energy consumption, live nodes, cluster head, DD, SPIN

INTRODUCTION

Wireless sensor networks play important role for monitoring the physical environment, chemical change detection, equipments failure detection and climate change (Dalei *et al*., 2017a, b). Wireless sensor network consists of set of tiny sensor devices which are operated on battery power. These tiny sensor devices are composed of set of major hardware components and application interfaces which is shown in Fig. 1.

Wireless sensor networks are application specific that is depending on the requirements of subscriber and sink node the sensor nodes are deployed and designed (Boonma and Sazuki, 2010; Tran and Pham, 2009). The traditional sensor network is based on IP-based routing for small scale applications. Due to demand of Internet of Things (IoT), the researchers have designed many content based routing for large scale and small scale application. In IP-based routing the data transmission take place in regular interval without knowing the interests of the receivers which cause the unnecessary power consumption and overhead on sensor nodes. In content based routing data transmission take place with interests of the receivers and which satisfy the some threshold condition (Taherian and Bacon, 2007). In our model we have develop a Content Aware Routing (CAR) protocol which is based on data-centric and optimal path selection (Aguilera *et al*., 1999).

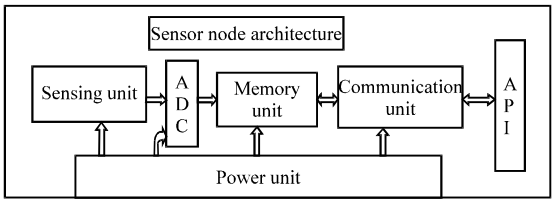

Fig.1: Sensor node

Literature review

Content routing protocols: Content centric routing is different from other conventional address based routing where meta data is routed from sensor device to sink node or base station in periodic manner (Kulik *et al*., 2002; Hall, 2004). In case of address-based routing sensor devices has assigned a address for data transmission in small scale network. In content routing framework the data is requested by the sink node or base station for a specific application (Shi *et al*., 2011). The data is routed through the intermediate node to reach in destination. The intermediate node performs the data processing to eliminate the duplicate data in order to avoid congestion and quick data transmission. In below section some of the data centric framework protocols are discussed for wireless sensor network.

Directed diffusion protocol: In Directed Diffusion Protocol (DDP) which is data centric and operation aware

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protocol. In this process the data is collected and stored by the sensor nodes in attributed based manner (Ma *et al*., 2014; De Couto *et al*., 2003). DDP has four major components for communication in networks. These are queries or requested attributes, data, gradients and reinforcements. A query consists of a set of attributes describing a particular event. Events or data are leveled by using a list up attributes values (Yasar *et al*., 2011). The data is propagated using gradient which include speed of data and orientation data, the reinforcement is the process of selecting path in between source and destination (Shi *et al*., 2013, 2015). In the DCP technique the data is collected from different sensor nodes form different part of the network. The data is collected and combined for aggregation to remove the duplicate information and reduce the overall transmission between source and destination. This leads to energy saving and reduce the congestion in network (Hao *et al*., 2016). In DDP, a subscriber node or sink node injects an interest in the network towards the sources nodes area (Kumar *et al*., 2009). The subscriber request is propagated in the network in one-hop approach. Every node who will receive this query, create a gradient to the sender from where it is received the query. This operation is carried out still a gradient is formed in between source node and Base Station (BS). The sensed information is then back to the sink node or BS in reverse route (Roy, 2015). The neighboring sensor process their data according the request of the intermediate nodes messages it include the data name and context of the data to reduce the transmission metric (De *et al*., 2012). In this framework the data transmission is not reliable as the sink node is refreshed in periodic manner and retransmitted query when it has received the data from the sources event (Yu *et al*., 2014).

Sensor Protocols for Information via. Negotiation (SPIN): In SPIN routing protocol (Abidi *et al*., 2017) the nodes negotiate with the neighbors with set of control packets before the data transmission. SPIN uses meta-data to eliminate the redundant transmission in network. The main objectives of SPIN protocol is, any node detects the events, the events are broadcast to the neighboring nodes immediately with meta-data. Any node interested to get the actual data, may reply back with an acknowledgement (Abdulla *et al*., 2012). The drawback this protocol is implosion and overlap which consume more energy in the network.

Low Energy Adaptive Clustering Hierarchy (LEACH): It is clustering based protocol which minimized the transmission in the network (Kim *et al*., 2010; Pantazis *et al*., 2013). The Cluster Head (CH) is selected locally based on some criteria to reduce the energy consumption in the network. The rotation of cluster head is done among the sensor nodes with the clusters by using the residual energy factor at each node. The drawbacks of this protocol are that it requires time synchronization before the data transmission and it uses single hop communication (Chen *et al*., 2008).

MATERIALS AND METHODS

This model based on data oriented approach. The routing is based on content approached but not in addressed based approached. The operation of the framework is based on receiver initiated service (ELkamel and Cherif , 2017). The receivers request data transmission by sending a set of control messages to source node and followed by interests of receiver. The details architecture is given in Fig. 2. It consists set of sensor nodes having limited resources. The relay node receives the requests from the sink node and broadcast to the sensor nodes for specific content (Senthilkumar *et al*., 2017). The sensor nodes check the requested content available or not. If content is available on specific node then it is declared as source node by the node itself and a control information is transmitted to the relay node regarding information content availability (Esler *et al*., 1999). If the content is available with multiple sources then final decision is taken by relay node for selection of path. The path selection is done using set of parameters which includes the reliable factor, energy consumption and threshold value of different possible path between different sources to relay node (Wang *et al*., 2013; Ogundile and Alfa, 2017).

Problem definition: To design a Content Aware Routing (CAR) with optimal path selection having minimum energy consumption between source and destination (Shi *et al*., 2013).

Objectives:

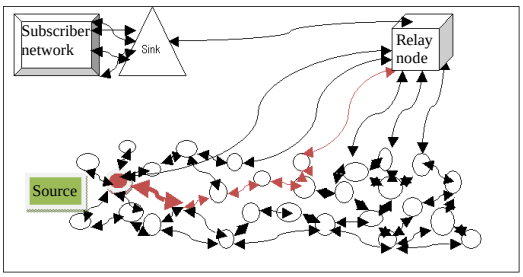

Fig. 2: Proposed framework

- Uniform load balancing
- Optimal path selection
- Maximize network life
- Minimum energy consumption
- Threshold based routing

Election of optimal path: Let n_i and n_j be two nodes. The energy consumption for communication between two consecutive nodes in a path is calculates as follow:

$$E(n_i, n_j) = ET_x(k, d)+ER_Y(k)+Eprocess(k)$$

$$ET_X(k, d) = k*E_{elec} +k*d^2*E_{amp}$$

$$ET_Y(k, d) = k*E_{elec}$$

$$Eprocess(k) = time*k$$

Where:

ET_X (k, d) = Energy required to transmit 'k' bits data over a distance 'd'

$ER_Y(k)$ = Energy required to receive 'k' bits data

$E_{process}(k)$ = Energy required to process 'k' bits data

E_{elec} = Energy required to switch on the radio antenna for transmission

E_{amp} = Energy required to switch on radio antenna for reception

Assume that there are 'n' possible paths from source to destination and a path is consisted up 'p' links. The total energy is consumed in different possible paths is defined as follow:

$$ET[i] = \sum_{j=1}^{p} E(n_j, n_{j+1}), \forall i = 1,2,3, \ldots, n$$

The reliability of link can calculated as follow:

- Let N_{PT} is the number of packets are transmitted
- Let N_{AR} is the number of acknowledgments received
- The Reliable Factor (RF) is computed as: $RF[i] = N_{AR}/N_{PT}$
- The cost of the path is calculated as follow
- Cost Factor (CF) = MinMax ((ET[i]), (RF[i]))

Routing algorithm:

1. Let K is number of cluster heads in sensor network
2. Let N is the number of interests received by the cluster head
3. Assume that N<C where C is a counter to represent number of interests forward by the Relay node to the cluster head
4. Assume that Q_i be the one the query
5. If ($Q_i(a_1, a_2, a_3, \ldots, a_n)$ n(D_i)) = = threshold matching)
6. Then
7. Calculate the CF for each possible path from corresponding cluster head to Relay node
8. Route(matching interests)
9. Else
10. Drop(interests)
11. Broadcast (Q_i, " null " , CHs)
12. End

RESULTS AND DISCUSSION

We have implemented our network model using MATLAB and compare our simulation results with existing data-centric protocols such as SPIN and DD. In our simulation environmental we have considered around 100 nodes with one node is gateway node and sensor field size is 100×100 m^2. Gateway node relays among the different source node for final data transmission. The simulation parameters are given in Table 1.

In Fig. 3, the number of live nodes in beginning is 100 for the protocols DD, SPIN and CAR. Once the network operation started the percentage of live nodes are decreasing as compare to our proposed model. In Fig. 4, the initial energy is same for all three protocols DD, SPIN and CAR that is 50 Joules. After some rounds the energy level is reducing with respect to the simulation time. The proposed protocol CAR has more residual energy at end of the simulation as compare to other two protocols.

In Fig. 5 due the optimal path selection between the source node and destination node in our proposed model the throughput of our network model is better with the existing protocols DD and SPIN.

In Fig. 6, we have calculated the number of retransmission during our simulation, i.e., number of times a same indexed packet transmission. Our proposed model has less number of retransmission with other existing content routing protocols due to optimal path selection and filtering approach.

Table 1: Simulation parameters

Simulation parameters	Parameters value
Number sensor nodes (N)	100
Sensor field size	100×100 (m^2)
Initial Energy (E)	0.5 (J)
Number of cluster heads per round	0.1
Data aggregation energy	5nJ/bit/signal
Transmission energy between CHs and nodes	0.005pJ/bit/m^2
Transmission energy between source node and relay node	10pJ/bit/m^2
Transmission energy between relay node and sink node	20pJ/bit

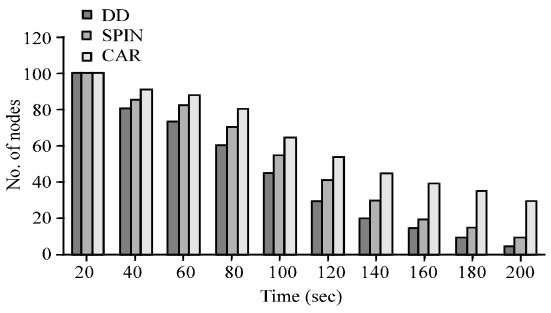

Fig. 3: Live nodes

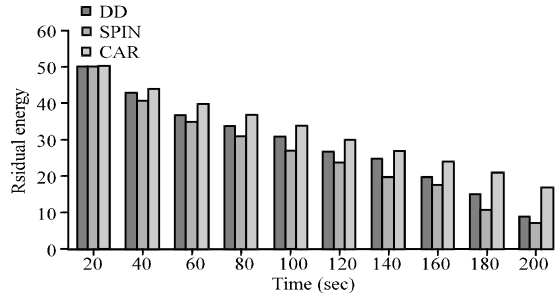

Fig. 4: Residual energy

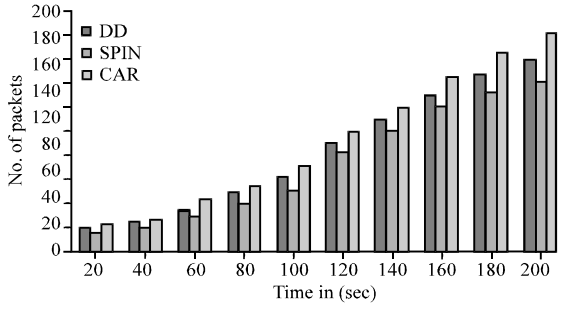

Fig. 5: Throughput of the network

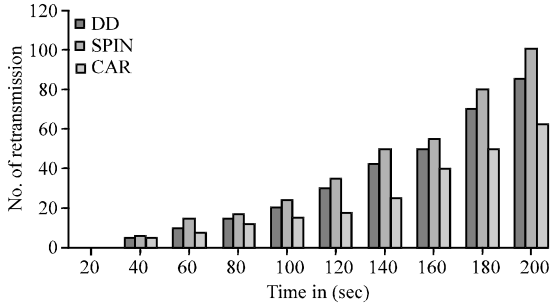

Fig. 6: No. of retransmission packets

CONCLUSION

In this model we have selected different possible path from the sources to the relay node using for our transmission. The filtering is done at the source node before the final transmission to the relay node. The filtering is node using filtering algorithm with some threshold condition for transmission. The optimal path is selected by the relay node based on distance and residual energy.

Our simulation results perform better as compare to the existing content routing protocols. We have calculated a reliable factor for each possible path to the relay node before transmission. The model produce better throughput and also increase the network life span.

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