Data-Centric Routing Protocols in Wireless Sensor Network: A survey

Yousef Emami[1], Ali Habeeb[2], Mohammad Jalil Piran[3], Manijeh Keshtgari[4]

[1]Department of Information Technology, Shiraz University of Technology, Shiraz, Iran
Yousef.emami@ieee.org
[2]College of Engineering, JNT University, Hyderabad, India
Ali_hb@ymail.com
[3]Department of Electronics and Radio Engineering, Kyung Hee University, South Korea
piran@khu.ac.kr
[4]Department of Information Technology,Shiraz University of Technology, Shiraz, Iran
keshtgari@sutech.ac.ir

Abstract- **Energy consumption is one of the most important factors in designing Wireless Sensor Networks which can not be neglected. The required energy for transmission of one KB of data is equal to that of processing of 3,000,000 instructions. Therefore, to prolong the life time of wireless sensor networks, energy consumption should be efficient and the efficiency of energy consumption depends on reducing the number of transmissions. Optimal routing techniques manage the number of transmissions within networks. Among different routing algorithms classifications, data-centric routing algorithms do not use ID hence overhead will be reduced and energy saved. In this paper, we outline challenges of routing in wireless sensor networks and survey state-of-the-art in research on data-centric routing protocols in wireless sensor networks.**

Keywords -*wireless sensor network; energy consumption; routing protocols; data-centric routing protocol.*

I. Introduction

Routing in wireless sensor network (WSN) is divided in four categories: data-centric protocols, hierarchical protocols, geographical protocols, Quality of service (QoS) based protocols. In WSN, because of high density and overhead it is not feasible to assign a global identification to a node; therefore address-based routing protocols cannot be applied in WSN and data-centric routing protocols have been proposed. In data-centric routing instead of ID, attribute-based naming is used, in attribute-based naming data related to a particular node are not desired and data related to attribute of the phenomenon are desired [6]. In data-centric routing, the sink which is responsible for gathering data and sending to the base station, issues a query for finding target data stored in the other nodes of WSN. Data-centric routing protocols are composed of two phases: route discovery and communication .In route discovery phase, the optimal route between sink and the target node is established and in communication phase data is transferred from the destination to the sink [7].

In this paper, data-centric routing protocols are investigated. We aim to update the reader with the current status of research in this realm. The rest of this paper is organized as follows: in section II, we state challenges for routing, section III mainly describe data-centric routing protocols, and finally section IV concludes the paper.

II. Challenges for Routing

Since WSNs have their own challenges utilizing traditional routing protocol is not workable .In following these challenges are discussed:

A. *Energy Consumption*

The main concern in developing routing protocols for WSNs is energy consumption. Due to limited energy resource, data shall be delivered in an energy-efficient manner. Thus, Conventional routing protocols are not suitable.

B. *Scalability*

Scalable routing protocol can expand to support increasing workloads. To provide scalability in WSN, distributed protocols are needed. Due to high density of nodes in WSN, full image of topology cannot be obtained in a node; therefore distributed protocols which rely on a limited knowledge of topology are preferred.

C. *Addressing*

Regarding to the high number of sensor nodes in WSN assigning a unique address to each node is not viable. Therefore, address-based routing protocols are not suitable for this type of networks. In addition, in WSN, information from a collection of sensors are preferred over the information from individual sensor nodes. Addressing mechanisms which do not rely on unique ID are used.

D. *Robustness*

There is no dedicated router in WSNs; consequently routing protocols operate on sensor nodes. Regarding the high probability of node failure in WSNs, it is intrinsic for routing protocols to provide robustness to node failure.

E. *Topology*

WSN topology is deemed to be static, but failing nodes can alter the topology especially when failed node is an articulation point. Routing protocol should be aware of topology so that the best routing decision can be taken.

F. *Application*

To select a right routing protocol, the type of application shall be considered. For instance, static routes are good option for monitoring application since information are sent to the sink in periodic manner. Totally, different type of applications requires different type of routing protocols [6].

III. Data-Centric Routing Protocols

In this part, data-centric protocols are discussed as follow: Flooding, Directed Flooding, Constrained Flooding Gossiping,Fuzzy-Gossip, LGossiping, ELGossiping, FELGossiping, SGDF,Flossiping, Rumor, Spin, SPMS,M-Spin, EEM-SPIN, Directed diffusion, Energy-efficient directed diffusion ,Mobile Sink Directed Diffusion, COUGAR, ACQUIRE .

A. *FLOODING*

This algorithm is an old and simple one, it works as follows: the received packet by a node is broadcasted for its neighbors, and this process is repeated until all nodes in the network receive a copy of the packet. No need for a node to keep information about its neighbors and utilize complex route discovery algorithm, despite of these advantages it suffers from the followings [6]:

Implosion: A node is likely to receive a packet from many nodes, thus due to extra transmit-receive operation the resources are wasted.

Overlap: It is possible for two nodes to sense an in common region and then each one send the sensed data to their common neighbors, thus the information are sent twice to the neighbor node [8].

Resource blindness: the amount of available energy of a node is not considered in this algorithm; consequently the behavior is not adopted according the amount of available energy [6].

1) *Directed Flooding:*

In this protocol, data are sent in a specific directional virtual aperture instead of broadcasting. To be specific, the information related to the current transmission virtual aperture (it represents which neighbor nodes are allowed to receive a packet sent from this node) and X and Y coordinates are put in the corresponding fields and then the constructed packet is sent. Whenever one of the neighbors receive the packet, the transmission virtual aperture of the packet's sender is determined, if both are in the same transmission virtual aperture the packet is relayed otherwise it is discarded. This protocol, consumes less energy while maintaining high levels of fault-tolerance [9].

2) Constrained Flooding

Constrained Flooding is an energy efficient and robust version of the flooding. Because of utilizing real time reinforcement learning technique: initial flooding from the sink is not required; the change in network does not result in flooding from the sink. In this protocol, as long as the packet has not reached to its destination, first, the cost and temperature values of the packet are updated; temperature controls the number of transmissions and energy efficiency. Next, the cost difference of node and received packet is computed; to retransmit the packet the obtained value must be less than temperature. Then, to avoid collision, based on the cost difference, random delay is added to forwarding packets. Last, a probabilistic policy is utilized to arbitrate retransmission; this step is special to the constrained flooding.. Probabilistic policy controls number of transmitted packets and energy costs. If the same packet is frequently heard, it is less likely the packet will be retransmitted [10].

B. *Gossiping*

The main objective of this protocol is to address the implosion deficiency in flooding. To address this problem, when a node receives the packet, unlike flooding, the packet is not broadcasted, instead one of the neighbor nodes is randomly selected and the packet is forwarded to it. When the neighbor node receives the packet, this trend is repeated until the packet reaches to the destination. Compared to the flooding, energy consumption is less but latency in propagating the message is high [6].

1) *Fuzzy-Gossip :*

This protocol is a modification of the gossip protocol using fuzzy logic. In this protocol, when an event is detected by a node, to determine the optimal neighbor for relaying data toward sink the fuzzy logic is utilized. The goal of fuzzy logic is to determine the best neighbor regarding residual energy and distance to the sink. Hence the residual energy and distance to the sink for each neighbor of node are selected as inputs to fuzzification then the fuzzified values are processed by the inference engine and finally defuzzification output is selected as fuzzy value .Node with the highest fuzzy value is selected as next hope and data is relayed to it [1].

2) Location-based gossiping (LGossiping):

In location-based gossiping, global positioning system is utilized to relay data in the WSN. When a node has data for transmitting, an in range neighbor is randomly selected and data is transmitted to it, this trend is repeated until data reach to the sink. In LGossiping data can be sent to one of the known neighbors in reliable manner using position knowledge of the nodes whereas in Gossiping data is blindly sent to one of the neighbors which might be far from source and thus data to be lost .LGossiping is a reliable version of Gossiping [11].

3) ELGossiping

In ELGossiping, an additional parameter called distance is considered. when a node has data for sending, a node in its transmission radius with lowest distance to sink is selected for relaying data toward sink. This trend is repeated until data reach to the sink [5].

4) *Fair efficient location-based gossiping (FELGossiping):*

This protocol, aims to prolong network life time by choosing a node with maximum residual energy and less hop count to the sink. In the beginning, the hello messages are broadcasted by sink for its neighbors. When a hello message is received by a neighbor, the value of hop count variable is stored in the memory and before rebroadcasting the message to its neighbors the value of hop count one unit is incremented. This process is repeated until all nodes receive a copy of the hello message. At the end, each node is cognizant of its distance to the sink. When an event is detected by a node a request message is sent to its neighbor. Each neighbor node which receives the message sends back its information to the source. Regarding these gathered data, two nodes with minimum hop count to the sink are selected, and then node with maximum residual energy is selected and data is relayed for it [3].

5) Single Gossiping with Directional Flooding (SGDF)

SGDF is divided into network topology and routing scheme phases. In network topology phase, the sink broadcast the hello message contained the hop-count and threshold values, upon receiving the hello message by the immediate neighbors, the hop-count value of the hello message is saved and incremented then hello message is rebroadcasted until all sensors receive one copy of the hello message. In routing scheme ,prior to sending data by a node a request message is broadcasted to its neighbors, all neighbors send back their distance to the sink ,then to select the next hop one of the neighbors with smaller hop-count is randomly selected .No such neighbor, one with the equal hop-count is randomly selected if not last chance is given to the neighbors with larger hop-count and one of them is blindly chosen. After, the next hop determination, source transmits the packet to the destination in broadcast. Destination receive the packet and relay it, simultaneously the other neighbors listening to the channel generate a random number between 0 and 1 ,if the generated number is less than threshold for a special neighbor, it receives the packet and starts directed flooding [12].

C. Flossiping

The ingredients of flossiping are gossiping and low-probability random selective relaying (LPRSR).When a node has a packet to send, along with other fields it sets the threshold and mode fields of the packet and broadcasts the packet to its next hop neighbor in gossip mode ,meanwhile, other neighbors of next hop neighbor receive the packet and start LPRSP process ,each one generate a random number ,if generated number is less than specified

threshold in packet header ,packet is flooded by a specified TTL otherwise packet is gossiped [13].

D. *Rumor Routing*

In rumor routing, in addition to neighbor list an event table is maintained by each node .When an event occurs, event is added to event table and an agent is generated. The data related to the occurred event is propagated by generated agent, when agent arrives in a node, event table of node can be updated by the contents of agent. When life cycle of agent is finished the path leading event is created. These agent-generated paths are used to route queries. When a query is generated by a node for a particular event, if a route is available for target event in event table, query is forwarded to the neighbor indicated by the event's table entry, otherwise a random neighbor is selected and the query is passed to it [8].

E. *Sensor Protocols for Information via Negotiation (SPIN):*

In spin, negotiation and resource adaptation are utilized to address the deficiencies in flooding. Negotiation is utilized for handling implosion and overlap. Spin nodes negotiate with their neighbors before transmitting data, therefore unnecessary communications are avoided. To handle resource blindness, each spin node uses an energy manager to monitor its energy resource. Hence energy-aware decisions can be taken [6,8].

1) *point-to-point SPIN protocol (SPIN-PP):*

In SPIN-PP, whenever a node intends to transmit data, an ADV packet is formed which contains a description of transmitting data and then the ADV packet is transmitted to the neighbor nodes .Upon a neighbor receive the packet, it checks whether it has already received the descripted data .If not, it replies back with a REQ message to show its interest in receiving the descripted data. Finally, Data packet is sent to the node requested it[8]. SPIN-PP does not address the resource-blindness problem of flooding and just address implosion and overlap problem. The next variation addresses the resource-blindness problem [6].

2) *SPIN with energy consumption awareness(SPIN-EC)*

The resource-blindness problem of flooding is addressed by SPIN-EC. In SPIN-EC, the residual energy of a node before sending a REQ message is checked, if it is higher than a threshold the operation is continued like SPIN-PP otherwise the operation is cancelled and node does not participate in it [6].

3) SPIN for broadcast networks (SPIN-BC)::

First.in SPIN-PP, many nodes can send REQ message and each one receive a DATA packet individually hence, resource are wasted. Second, when many nodes send REQ message it may collision occurs, SPIN-PP does not prevent from this issue. The mentioned issues are addressed by SPIN-BC. In SPIN-BC, whenever a message is sent by a sender all nodes within the sender's radio range will receive a copy of that message, thus resource are not wasted . Randomized backoff mechanism is utilized in SPIN-BC for the nodes before transmitting a REQ packet so that collision to be avoided [6, 8].

3) *SPIN with reliability (SPIN-RL):*

SPIN-RL is a reliable version of SPIN-BC , if a node receive an ADV packet but does not receive DATA packet ,it can solicits the DATA packet from the neighbors that already have that DATA packet. In SPIN-RL the retransmission period of the nodes is limited [6, 8].

4) *Shortest path minded SPIN (SPMS):*

In spin all packets are transmitted at the same power level and the power level is not adjusted according to distance parameter. This problem is addressed by SPMS. In SPMS, the transmitting power level is adjusted based on distance, in other word, variable transmission power levels are used. Because of high density in wireless sensor network, the size of routing table is large therefore maintaining routing table is not feasible and new solution is required. In SPMS, a zone is defined as area which covered by a node in maximum power level. The entries of routing table for each node are restricted to the zone members. To compute the routes for each zone, distributed bellman ford algorithm is utilized. After filling routing tables, data transmission is started. When a node has data for transmitting, it broadcasts ADV packets to its zone member. Upon receiving ADV packet by a zone member, if data described by ADV packet is required a REQ packet is sent back to the source and data transmission is initiated [14].

6.) Modified SPIN (M-SPIN):

In applications, such as alarm monitoring, it is intrinsic to receive a quick response, this protocol is suitable for this kind of applications .To achieve a quick response, a new phase called as distance discovery has been added to the normal phases of spin protocols. In distance discovery, the distance of each node from sink is measured and the

measured distance is used as a parameter in negotiation phase. To measure the hop distance for each node, startup message is broadcasted by sink .Upon receiving startup message by a node, hop value of startup message is stored as hop distance and hop value one unit is incremented and then startup message is rebroadcasted to its neighbor. In the end of distance discovery phase, each node knows its hop distance from sink and consequently, negotiation phase is started .In negotiation phase, whenever an ADV message is received by a node, the following actions are taken:

1. Node checks whether it has already received the associated data with ADV or requested it.

2. It replies with REQ message if its hop value is less than that of ADV's sender, otherwise request is rejected.
Energy efficiency is achieved with this protocol but some nodes are frequently used and there is possibility to die earlier [4].

7) Energy Enhanced M-SPIN (EEM-SPIN) EEM-SPIN:

In M-SPIN, some nodes are frequently used consequently these nodes may be destroyed earlier than other nodes. Energy enhanced M-SPIN has been proposed to address this deficiency. In EEM-SPIN, clusters are used for solving the problem. For cluster formation, and the election of cluster heads the weighted cluster algorithm is used. In cluster-based structures, resources are used efficiently [2].

F. Directed Diffusion

The family of directed diffusion has three members: two phase pull, one phase pull, and push. The involved steps in simple directed diffusion or two phase pull are: 1. Interest propagation, 2. Gradient setup, 3. Reinforcement, 4. Data delivery
To initiate directed diffusion, interest messages are diffused by sink to its neighbor in interest propagation phase, and this process is repeated until all sensors receive a copy of interest message [8].The received interest message is stored by each sensor in interest cache. The required data from sensor network is specified in interest messages. A node becomes a source if it has data matching interest message. In gradient setup phase, each source establish a gradient (a reply link toward the neighbor which the interest message was received) toward sink it may many gradients to be established for the same interest in this case it is the task of reinforcement phase to reinforce a particular path with best link quality and lowest delay by resending the interest message. Finally, the route between source and sink is established and the data delivery phase is started. In push diffusion, interest propagation phase is ignored and data is advertised by the sensor to sink. Upon receiving the advertisements, the sink sends reinforcement packets for source so that routes to be established [6].

1) An energy efficient directed diffusion:

As mentioned, in reinforcement phase of directed diffusion the path with lowest delay and best quality is selected and reinforced. The selected path is not the path with the minimum energy consumption and the residual energy of the nodes on the path is not equal. Whenever source receives data from its neighbors, it computes the cost function for each path to its neighbor, then it compares the computed cost functions and the minimum cost function is selected and the related path is reinforced. The cost function is based on the following factor:
Total communication cost of the path, Average residual energy of the nodes on the path, Minimum node energy on the path and Node connectivity. The mentioned factors are emphasized based on application .Since in selected path nodes have a balanced residual energy; it is less likely a node with low residual energy cause failure in the path. Compared to direct diffusion less energy is consumed and the network has a longer lifetime [15].

2) Mobile Sink Directed Diffusion:

MSDD is based on two-phase pull directed diffusion algorithm .The idea in MSDD is to support sink mobility by utilizing unused routes from source to sink, established in the second phase of two-phase pull. This protocol is composed of route completion and re-routing .In route completion, to follow the new position of sink, the established path in directed diffusion is extended. To extend the available route towards sink, a relay node is used. A relay node is used to monitor sink movements. Upon detecting a sink movement the required route towards the new position of sink is completed. Relay node broadcasts tagged packets with hop-count called as exploratory data packet within two hops from itself in periodic manner. When sink receives these packets, it sends back another tagged packet with hop-count called as positive reinforcement packet. If relay node, receive positive reinforcement packet in its first hop, it means there is no sink mobility and exploratory data packets are rebroadcasted, If relay node, receive positive reinforcement packet in its second hop there is sink mobility therefore relay node becomes an ordinary one and the node received positive reinforcement packet in its first hop becomes new relay node and it broadcasts exploratory data packet. In re-routing phase, constructed path is replaced by new one [16].

G. COUGAR

In cougar a new layer called as query proxy is defined which interacts with network and application layers. This layer is responsible for registering the query, creating a local operator tree and so on . To comprehend cougar, suppose a typical query is available, the query optimizer which is located on gateway node optimizes the query and generates a query plan. The data flow between sensors and computation plan at each sensor and procedure for determining leader are specified in query plan. Leader is a node with high remaining energy and a center for doing computations. The query plan is disseminated to the query proxy of related sensor nodes, each participant non-leader node in the query reads its sensed data and aggregates it with the received data from other nodes and sends it toward leader. Leader aggregates received data from non-leader nodes and under specified conditions send it for gateway [17].

H. ACQUIRE

In ACQUIRE a novel approach for resolving query is utilized. In traditional approaches, Query is disseminated by the sink and response is gathered. The clear point in this approach is distinction between query dissemination and response generation. ACQUIRE aims to integrate query dissemination and response generation. As the query generated by the sink is forwarded in network the query is resolved by each recipient node and forwarded to next node until the query is fully solved and the complete response to be found. In this step response is routed back toward sink [18,19,20,21].

IV. Conclusion

In this paper, we investigated a comprehensive list of data-centric protocols. There are many issues need to be addressed by researchers e.g.: energy efficiency and life time. Great advantages are achieved because of not using ID instead a general question regarding a special phenomenon to be asked and a response to be gathered. The best algorithm which an implement this idea is ACQUIRE and is strongly recommended to be used in future.

References:

[1] *Imad S. AlShawi, Lianshan Yan, Wei Pan, Bin Luo,"A Fuzzy-Gossip routing protocol for an energy efficient wireless sensor networks," Journal of Sensors IEEE, pp. 1-4, 28-31 Oct. 2012.*

[2] *M. Kavitha, K. Karthikeyan," Comparison Of Data Centric Protocols For WSN And Energy Enhanced M-SPIN (EEM-SPIN)," International Journal of Engineering Research & Technology (IJERT), vol. 1 ,issue 9,November 2012.*

[3] *Ali Norouzi, Faezeh Sadat Babamir, Abdul Halim Zaim, "A Novel Energy Efficient Routing Protocol in Wireless Sensor Networks," Journal of Wireless Sensor Network, vol. 3, pp. 341-350, 2011.*

[4] *Zeenat Rehena, Sarbani Roy, Nandini Mukherjee," A Modified SPIN for Wireless Sensor Networks," In Third International Conference on Communication Systems and Networks (COMSNETS), Bangalore ,India, PP. 1-4, 4-8 Jan. 2011.*

[5] *Ali Norouzi, Mehdi Dabbaghian, Alireza Hatamizadeh, Burak Berk Ustundag, " An improved ELGossiping data distribution technique with emphasis on reliability and resource constraints in wireless sensor network," In International Conference on Electronic Computer Technology (ICECT), Kuala Lumpur ,pp. 179-183, 7-10 May 2010.*

[6] *Ian F. Akyildiz, Mehmet Can Vuran, "Wirless sensor networks," john Wiley & Sons Ltd, pp. 139-148, 2010.*

[7] *Huilong Huang, J.H.H., Terril N. Hurst, "Data-Centric Routing in Sensor Network using Biased Walk," In 2006 3rdAnnual IEEE Communications Society on Sensor and Adhoc Communications and Networks, Reston, VA,vol.1 ,pp. 1-9, 28-28 Sept. 2006.*

[8] *Waltenegus Dargie, C.P.," Fundamental of Wireless Sensor Networks," john Wiley & Sons Ltd, pp. 168-175, 2010.*

[9] *R. Farivar, M.F., S.G.Miremadi," Directed flooding: a fault-tolerant routing protocol for wireless sensor networks,"In Systems Communications Proceedings, pp. 395- 399 , 14-17 Aug. 2005.*

[10] *Ying Zhang and Markus Fromherz, "Constrained flooding: a robust and efficient routing framework for wireless sensor networks," In 20th International Conference on Advanced Information Networking and Applications, vol. 1, 18-20 April 2006.*

[11] *S. Kheiri,MB. Ghaznavi Goushchi,M. Rafiee,B. Seyfe, " An Improved Gossiping Data Distribution Technique with Emphasis on Reliability and Resource Constraints," In International Conference on Communications and Mobile Computing , Yunnan, vol. 2, pp. 247-252, 6-8 Jan. 2009*

[12] *Wei Yen, Ching-Wei Chen, Cheng-hsiang Yang, "Single Gossiping with Directional Flooding Routing Protocol in Wireless Sensor Networks," In IEEE Conference on Industrial Electronics and Applications, Singapore , pp. 1604-1609, 3-5 June 2008.*

[13] Yuecheng Zhang and Liaug Cheng, "Flossiping: A New Routing Protocol for Wireless Sensor Networks," In International Conference on Networking, Sensing and Control IEEE, vol. 2, pp. 1218-1223, 2004.

[14] Gunjan Khanna, Saurabh Bagchi, Yu-Sung Wu," Fault tolerant energy aware data dissemination protocol in sensor networks," In International Conference on Dependable Systems and Networks, pp. 795- 804, June 28 2004-July 1 2004.

[15] Shousheng Zhao, Fengqi Yu , Baohua Zhao," An Energy Efficient Directed Diffusion Routing Protocol," In International Conference on Computational Intelligence and Security, Harbin, pp. 1067- 1072, 15-19 Dec. 2007.

[16] Azadeh Lajevardi, Abolfazl Toroghi , Haghighat,Arash , Nasiri Eghbali, " Extending Directed Diffusion Routing Algorithm to Support Sink Mobility in Wireless Sensor Networks," In International Conference on Communications (MICC), Kuala Lumpur, Malaysia, pp. 541- 546, 15-17 Dec. 2009.

[17] Yong Yao, Johhanes Gehrke ,"The Cougar Approach to In-Network query Processing,"vol. 31,September 2002.

[18] Narayanan Sadagopan, B.K., Ahmed Helmy." The ACQUIRE Mechanism for Efficient Querying in Sensor Networks,"In Sensor Network Protocols and Application, 2003.

[19] Mohammd Jalil Piran, G. Ramma Murthy, "A Novel Routing Algorithm for Vehicular Sensor Networks", International Journal of Wireless Sensor Networks, USA, p.p. 919-923, December 2010.

[20] Mohammd Jalil Piran, G. Ramma Murthy, G. Praveen Babu, "Vehicular Ad Hoc and Sensor Networks; Principles and Challenges", International Journal of Ad Hoc, Sensor and Ubiquitous Computing, p.p. 38-49, June 2011.

[21] Ahvar, Ehsan, Pourmoslemi, Alireza, Jalil Piran, Mohammad, "Fear: A Fuzzy-based Energy-aware Routing Protocol for Wireless Sensor Networks", Research Article, Networking and Internet Architecture, 2011.

