Comparative Study of PEGASIS based Protocols in Wireless Sensor Netwroks

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***Abstract*—A comparative study involves comparison of protocols based on some performance parameters. It helps researchers to get insight into the different parameters in relevance with the protocols which ultimately lead the way to the further advancement in the field. As improvements in the field of Wireless Sensor Networks are taking place day by day. PEGASIS is a hierarchical chain oriented protocol for routing in WSN. In this paper, some important protocols based on PEGASIS architecture; PEGASIS, EEPB, IEEPB, PDCH, PEG-Ant, PEGASIS-PBCA, PEGASIS-IBCA, MH-PEGASIS, Multi-chain PEGASIS and Modified-PEGASIS are studied and comparison is done based on parameters which are important to consider while choosing methodology for a particular application of WSNs.**

Keywords—PEGASIS; Wireless Sensor Networks; TOKEN; Chain formation; Leader Node; Data Transmission.

I. INTRODUCTION

Wireless Sensors are tiny, battery powered electronic devices with special sensing capabilities. When these sensors are deployed in any area for a specific application they form Wireless Sensor Network (WSN). Presently, WSNs are widely in use. Some of the important application areas are Environmental Monitoring (temperature, humidity, pressure, pollutants, direction and speed of wind), Traffic Monitoring, Air Traffic Control, Medical Device Monitoring, Video Surveillance, Industrial Automation, structural health monitoring, defense (border area monitoring, intrusion detection, explosive detection, tracking), Agriculture (Soil heath monitoring)etc.[11, 12, 13, 14].

Data transmission consumes most of the power of the sensors in network. So how data is transferred from one node to another in network is crucial for balanced energy consumption to prolonging network lifetime. The cluster oriented and chain oriented routing are two important architectures for WSNs. After the proposal of PEGASIS[1] in 2002 many other enhanced protocols based on it like EEPB[2], IEEPB[3], PDCH[4], PEG-ANT[5], PEGASIS-PBCA[6], PEGASIS-IBCA[7], MH-PEGASIS[8], Multi-Chain PEGASIS[9] and Modified-PEGASIS[10] are proposed.

Large time-delay due to token based data gathering, high probability of formation of long chains due to greedy approach, low load balancing, and problem of long links between nodes are some major limitations with PEGASIS architecture. So later proposed, improved protocols tried to overcome some of these above mentioned limitations of PEGASIS. As EEPB [2] avoids formation of long links between nodes, IEEPB [3] improves the method of leader selection and allows user to decide the priority of energy and distance while considering them as parameters in selection of leader node. PDCH [4] uses Primary CH to gather the data within chain and secondary CH to transmit data to BS. PEG-Ant [5] uses Ant Colony optimization in constructing chains outperforming the greedy approach of PEGASIS and balances each node's energy consumption. PBCA and IBCA based PEGASIS [6]-[7] allows some nodes to enter into sleep mode and only active mode nodes participate in chain formation. MH-PEGASIS [8] is hybrid of Cluster and Chain which forms single chain within cluster and then CHs transmit their data to BS using Multi-hop approach. Modified-PEGASIS [10] improves load balancing capabilities of PEGASIS by considering remaining energy, node degree and distance from BS to select leader node in each round.

II. PEGASIS: BASIC PROTOCOL ARCHITECHTURE

PEGASIS [1] is a chain based hierarchical routing protocol in WSNs. There are some presumptions in this algorithm:

- Base Station (BS) is at far place from the nodes and is stationary.
- Initial energy of nodes is equal.
- Nodes are aware of global positioning of sensors.

This algorithm works in three steps i.e. Chain establishment, Leader node election and data transmission.

A. Chain Establishment

The process of chain establishment is greedy and starts from the node which is farthest from the BS. Then currently joined node selects next node to be inserted into the chain by selecting nearest neighbor based on the signal strength of the neighboring nodes. The nodes which is already linked to the chain cannot be revisited i.e. branching of chains is not allowed. This process continues till the last node gets inserted into the chain. This step produces single chain consisting of all the network nodes.

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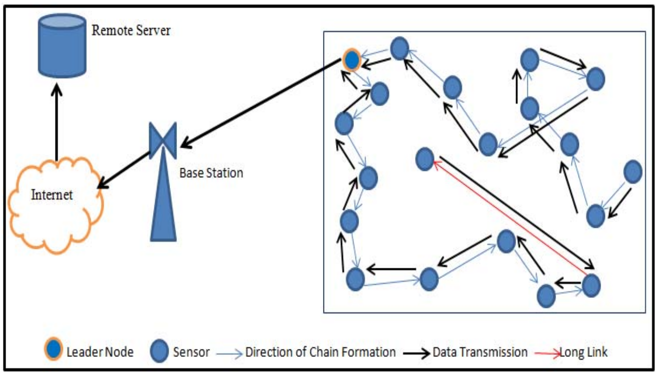

Figure.1. Illustration of Wireless Sensor Network with PEGASIS without branched chains (node degree at most two)

B. Leader node selection

Initially a random node is selected as leader i.e. the leader node will be at random position of the chain which is important for death of nodes at random location which helps in making sensor network vigorous. During establishment of chain, it is possible that some sensors may have relatively distant neighbors along the chain which forces these nodes to dissipate relatively more amount of energy in each round in comparison with other nodes. So a threshold on neighbor distance is taken into account while selection of leader node.

If a node dies, the chain will be reestablished and threshold can be changed to determine the Leader node. A new leader is selected in each round to balance consumption of energy in the network.

C. Data Transmission

If After the selection of leader node, data gathering and fusion starts. A token based approach is used to gather data. Leader node passes a token along the chain to the end node. After receiving the token end node sends its data and token to its next node along the chain. This process continues till data reaches to the leader. Each intermediate node performs data fusion by fusing its neighbor's data with its own and creates a single packet of same length. At last leader node transmits the resultant data packet to the BS.

In case of chains with leader node at the start of the chain, data transmission happens as in figure.2. In this leader node N1 is at start of the chain. N1 passes TOKEN (small sized control packet) to the end node N7 along the chain. After receiving TOKEN, node N7 transmits its sensed data and TOKEN to its next node in the chain i.e. N6. Node N6 on receiving data

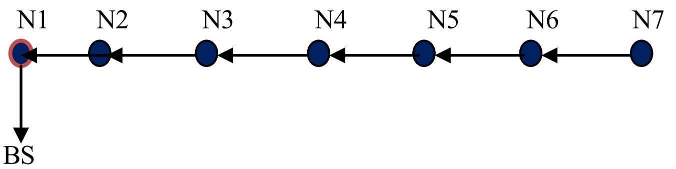

Figure.2. Illustration of Data Transmission (TOKEN passing) in chain with leader at the start of the chain.

packet and TOKEN from node N7, perform data fusion with received packet and its own sensed data and transmits it to the next node i.e. N5.

Similarly N5 sends packet to N4, N4 to N3, N3 to N2, and N2 to N1. Finally, Leader node N1 on receiving packet from N2 fuses its own sensed data with received packet and then sends it to the Base Station.

In case leader node is any intermediate node of the chain then data transmission happens as represented in figure.3. Here leader node is N4. As author in [1] not mentioned any priority criteria to decide to which end node the Leader will transmit TOKEN first, this may be because Leader will transmit data packet to BS only when it will receive packets from both neighbors N3 and N5. So, N4 passes TOKEN to any one of the two end nodes i.e. N1 or N7.

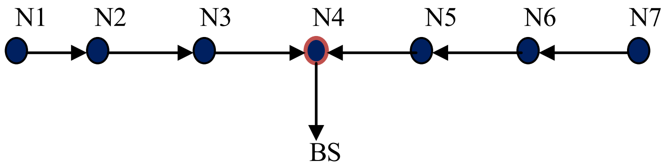

Figure.3. Illustration of Data Transmission (TOKEN passing) in chain with leader is any intermediate node.

Let N4 passes TOKEN to N1 first. After receiving TOKEN, N1 transmits it sensed data and TOKEN to node N2 which is next to it in the chain. N2 fuses its own sensed data with received data packet and transmit it along with TOKEN to N3 and then N3 to N4. Similarly, N4 passes TOKEN to the other end node in the chain i.e. N7. Now, N7 sends data and TOKEN to N6, N6 fuses it with its own sensed data and transmit it along with TOKEN to N5, and N5 to N4. After receiving data from N3 and N5, N4 fuses received data with its own sensed data and then transmit it to the BS. In this way we can see that in each round a node transmits only one data packet irrespective of the position of Leader node, length of the chain or any other factor.

III. Comparison Of PEGASIS Based Protocols

Most of the protocols based on PEGASIS works in three steps including chain formation, leader selection and data transmission. Some protocols differ in the way of forming chain. Some protocols like PEGASIS [1], PEG-Ant [5], PEGASIS-PBCA [6], PEGASIS-IBCA [7] and MH-PEGASIS [8] form chain as in figure.1 while EEPB, IEEPB, Multi-Chain

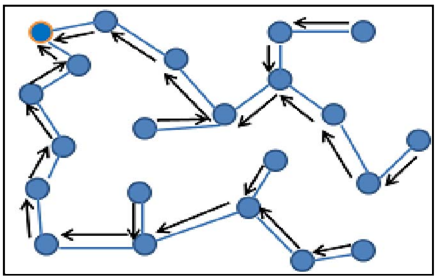

Figure.4. Illustration of chain formation and data transmission in chains having branched chains.

PEGASIS and Modified-PEGASIS form branched chains as in figure.4. PDHC [4] takes layered approach and forms single chain with branching at every layer as in figure.5 and Multi-Chain PEGASIS involves formation of four chains [9]. Some protocols allow branched chains while others don't. Leader selection differs slightly among these protocols. The basic PEGASIS selects Leader node randomly and sometimes based on distance of sensor from BS. EEPB selects leader by taking into account residual energy of node and distance from BS. IEEPB [3] an improvement over EEPB [2] selects Leader by calculating a combined weight for each node considering energy and distance from BS as:

TABLE I. COMPARISON OF PEGASIS BASED PROTOCOLS

Parameter	PEGASIS	EEPB	IEEPB	PDHC	PEG-ANT	PEGASIS-PBCA	PEGASIS-IBCA	MH-PEGASIS	Multi-Chain PEGASIS	Modified-PEGASIS
Deployment	Random	Random	Random	Random	Random	Random	Random	Random	Random	Random
Classification	Chain Based	Chain Based	Chain Based	Chain Based	Chain Based	Chain Based	Chain Based	Chain + Cluster	Chain Based	Chain Based
Number of Chains	Single	Single	Single	Single chain at every level	Single	Single	Single	Single chain per Cluster	4	Single
Number of CH per Chain	1	1	1	2	1	1	1	1	2	1
Data Transmission to BS	Round Leader Node	Round Leader Node	Round Leader Node	Secondary CH	Round Leader Node	Round Leader Node	Round Leader Node	CHs with Multi-Hop Routing	Primary and Secondary CHs depending on the condition	Round Leader Node
Mobility of BS	No Mobility	No Mobility	No Mobility	No Mobility	No Mobility	No Mobility	No Mobility	No Mobility	Yes with Fixed Trajectory	No Mobility
Selection of next node of chain (Chain Formation)	Nearest neighbor based on Signal Strength	Distance Threshold with user defined Constant alpha	Nearest neighbor based on Distance	Based on EEPB	Neighbor Node's Remained Energy, Consumed Energy, quantity of Pheromone	Based on PEGASIS with Active Nodes only	Based on PEGASIS with Active Nodes only	PEGASIS within Cluster	Based on PEGASIS over individual chains	Nearest neighbor based on Distance, connecting with already visited node is allowed
Selection of CH	Based on Distance from BS	Residual Energy of Node and Distance from BS	Based on weight calculated using Residual energy and Distance from BS	Node Degree and Energy	Node Energy	Based on PEGASIS with Active Nodes only	Based on PEGASIS with Active Nodes only	Based on PEGASIS	Based on weight calculated using Residual Energy and Distance from BS	Based on weight calculated using Residual Energy, Node Degree and Distance from BS
Delay	Very Large	Very Large	Very Large	Medium	Very large	Large	Large	Large	Medium	Large
Energy Efficiency	Low	Medium	Medium	Medium	Medium	High	High	Medium	High	High
Load Balancing	Low	Low	Medium	Medium	High	Low	Low	Low	Low	Medium
QoS	No	No	No	No	No	No	No	No	No	No
Query Based	No	No	No	No	No	No	No	No	No	No
Type of Sensors	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous
Type of Protocol	Proactive	Proactive	Proactive	Proactive	Proactive	Proactive	Proactive	Proactive	Proactive	Proactive
Algorithmic Approach	Greedy	Greedy	Greedy	Greedy	ACO	Greedy	Greedy	Greedy	Greedy	Greedy
Branch Chains	No	Yes	Yes	Yes	No	No	No	No	Yes	Yes
Node Connectivity (Degree)	1 or 2	1, 2, or more	1, 2, or more	1, 2, or more	1	1	1	1	1, 2, or more	1, 2, or more
Data Transmission in Chain	Token Based	Token Based	Token Based	Token Based	Token Based	Token Based	Token Based	Token Based	Token Based	Token Based
Long Links Avoidance	No	No	Yes	No	Yes	No	No	No	No	Yes

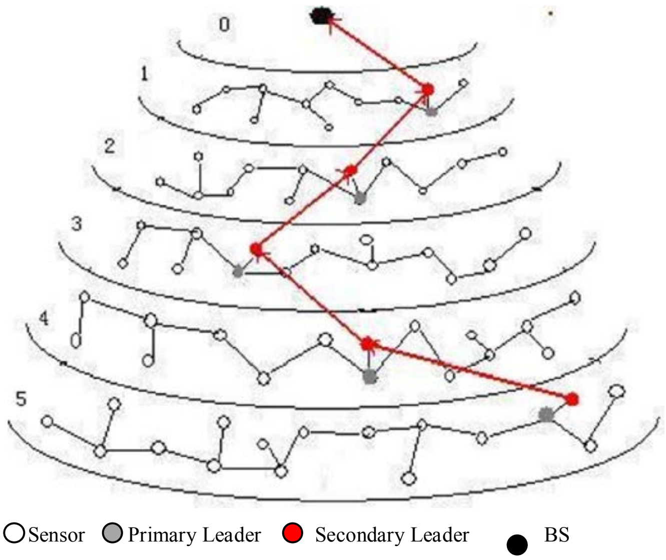

Figure.5. Double Leader selection and data transmission in PDHC [4]

$$W_i = w_1 E_p + w_2 D_{BS} \quad (1)$$

Where $w_1 + w_2 = 1$ (2)

$$D_{bs} = d^4_{toBS} / d^4_{avg} \quad (3)$$

Where, d_{avg} is average of the distances between nodes and BS.

$$E_p = E_{initial} / E_{residual} \quad (4)$$

Weights calculated for all nodes are compared and minimum weight node becomes Leader for this round [3].

PDHC [4] selects two Leaders per chain namely primary and secondary leader in every round. Primary leader is selected from main chain considering node degree and current energy while secondary leader is selected from branched chains connected to primary leader node based on its distance from base station. While Primary leader receives and fuses data from main chain, secondary leader transmits this data to base station as shown in figure.5.

PEG-Ant is same as basic PEGASIS except it applies ACO approach for chain formation which is more efficient than greedy one. The node with maximum current energy becomes Leader node [5]. PBCA and IBCA based PEGASIS selects Leader node similar to basic PEGASIS. MH-PEGASIS uses PEGASIS for intra-cluster communication and Multi-hop approach for inter-cluster communication to send data to BS. Modified-PEGASIS allows multiple degree nodes and leader is selected based on weight calculated as:

W_i = Remaining Energy$_i$ / (DistanceToBS$_i$ * NodeDegree$_i$)

Node with maximum W will be selected as Leader node. Author in [10] said this is 50% more load balanced than PEGASIS this is due to nodes having high degree of connectivity and more distance to BS have least chance to become leader.

Selection of routing protocol for a particular application depends upon the requirements of the application. For example if the application is delay tolerant then PEGASIS architecture of routing can be applied otherwise some real time protocol architecture is needed to maintain the accuracy of results. In the above table relative comparison of protocols is done based on some important parameters which are significant to evaluate the relative superiority of protocols.

IV. Conclusion

Most of the PEGASIS based protocols suffer the problem of large time-delay in transmission of packets. So in current form they are not suitable for real time applications. Other problems are greedy approach of chain formation and poor load balancing capabilities. IEEPB, PEG-Ant and Modified-PEGASIS avoid the long links between nodes but other compared protocols lack this capability. All the compared protocols are proactive and to make them suitable for reactive applications more work is required. Also, they lack the quality of service. However these protocols are somewhat energy efficient but more work is needed to reduce the time-delay, to improve the load balancing capabilities and quality of services.

References

[1]. S. Lindsey, and C. Raghavendra, "PEGASIS : Power-efficient gathering in sensor information systems," IEEE Aerospace Conference Proceedings, 2002, pp.1125-1130.

[2]. YU Yong-chang, WEI Gang, "An Improved PEGASIS Algorithm in Wireless Sensor Network," Acta Electronica Sinica, vol.36, pp.1309-1313, July 2008.

[3]. Feng Sen, Qi Bing and Tang Liangrui, "An Improved Energy-Efficient PEGASIS-Based Protocol in Wireless Sensor Networks," Eighth International Conference on Fuzzy Systems and Knowledge Discovery (FSKD), 2011, pp.2230-2233.

[4]. WANG Lin-ping, BI Wu, CAI Zhen and WANG Zu-feng, "Improved algorithm of PEGASIS protocol introducing double cluster heads in wireless sensor network," International Conference on Computer, Mechatronics, Control and Electronic Engineering, 2010, pp.148-151.

[5]. GUO Wen-yu, ZHANG Wei, and LU Gang, "PEGASIS protocol in wireless sensor network based on an improved ant colony algorithm," Second International Workshop on Education Technology and Computer Science, 2010, pp.64-67.

[6]. Young-Long Chen, Neng-Chung Wang, Chin-Ling Chen and Yu-Cheng Lin, " A Coverage Algorithm to Improve the Performance of PEGASIS in Wireless Sensor Networks," 12th ACIS International Conference on Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing, 2011, pp.123-127.

[7]. Young-Long Chen, Yu-Cheng Lin and Neng-Chung Wang, "an intersection-based coverage algorithm for pegasis architecture in wireless sensor networks," Proceedings of the 2012 International Conference on Machine Learning and Cybernetics, Xian, 15-17 July, 2012, pp.1727-1731.

[8]. Zibouda Aliouat and Makhlouf Aliouat," Efficient Management of Energy Budget for PEGASIS Routing Protocol," 6th International Conference on Sciences of Electronics, Technologies of Information and Telecommunications (SETIT), 2012, pp.516-521.

[9]. Mohsin Raza Jafri, Nadeem Javaid, Akmal Javaid and Zahoor Ali Khan," Maximizing the Lifetime of Multi-Chain PEGASIS Using Sink Mobility," World Applied Sciences Journal 21, 2013, pp.1283-1289.

[10]. Madhuri Gupta and Laxmi Saraswat," Energy Aware Data Collection in Wireless Sensor Network Using Chain Based PEGASIS," IEEE International Conference on Recent Advances and Innovations in Engineering (ICRAIE-2014), May 09-11, 2014, Jaipur, India.

[11]. R. K. Yadav and Arpan Jain, "CHATSEP: Critical Heterogeneous Adaptive Threshold Sensitive Election Protocol for Wireless Sensor Networks," IEEE International Conference on Advances in Computing, Communications and Informatics (ICACCI), 2014, pp.81-86.

[12]. Lewis, Franck L. "Wireless sensor networks." Smart environments: technologies, protocols, and applications (2004): 11-46.

[13]. Akyildiz, Ian F., et al. "Wireless sensor networks: a survey." Computer networks 38.4 (2002): 393-422.

[14]. Akkaya, Kemal, and Mohamed Younis. "A survey on routing protocols for wireless sensor networks." Ad hoc networks 3.3 (2005): 325-349.