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Study of Routing Protocols in Wireless Sensor Networks

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Abstract— **Recent advances in wireless sensor networks (WSN) now witness the increased interest in the potential use in applications like disaster management, combat field reconnaissance, border protection and security surveillance. Sensors are expected to be remotely deployed in large numbers and operate autonomously in unattended environments. Many routing protocols have been specifically designed for WSNs where energy awareness is an essential design issue. This paper presents a survey of the state-of-the-art routing techniques in WSNs. We survey different routing algorithms for WSNs from the recent work; highlighting their objectives, features, complexity, etc. This paper also presents a classification for the various approaches pursued. Each routing protocol is described and discussed under the appropriate category.**

Keywords-Wireless Sensor Networks (WSN), Routing Protocols, Hierarchical Routing, Location based Routing, QoS based Routing, Bio-Inspired Routing, In-Network Aggregation based Routing.

I. INTRODUCTION *(HEADING 1)*

With significant advances in technology, sensors have become smaller in size, with more power and low cost that has increased the efficiency of many military and civil applications such as combat field surveillance, security and disaster management. WSN are systems that comprise large numbers (hundreds or thousands) of wirelessly connected heterogeneous sensor nodes that are spatially distributed across a large field of interest [1], and these systems process data gathered from multiple sensors to monitor events. WSN is one of the most interesting research areas with profound effect on technological developments [2]. Data redundancy and classical IP based protocols makes the routing in sensor networks challenging. Routing in WSNs was classified based on the network structure, protocol operation, network flow and depending on how the source finds a route to the destination [3], [4]. Minimizing energy consumption is a key requirement in the design of sensor network protocols and algorithms. In addition to this, WSN design also demands other requirements such as fault tolerance, scalability, production costs, and reliability. It is therefore critical that the designer takes these factors into account when designing protocols and algorithms for WSN [5].

A. Motivation: Related Work

The growing interest in WSN and the continual emergence of new architectural techniques inspired surveying the characteristics, applications and communication protocols for such a technical area [3-5]. In this comprehensive survey of design issues and techniques for sensor networks describing the physical constraints on sensor nodes and the protocols proposed in all layers of network stack with specific focus on network layer (routing) protocols. [3-5] are a good introductory, classification and covers as much protocols and routing techniques as possible. To add on, this survey covers the recent work in network layer of WSN. This work is a dedicated study of the network layer, describing and categorizing the different approaches for data routing and classification for the various approaches pursued. The main categories explored in this paper are Bio Inspired routing protocols, QoS, Hierarchical based and Location-based routing. Each routing protocol is described and discussed under the appropriate category.

II. HIERARCHICAL ROUTING

In a hierarchical architecture, nodes will play different roles in the network; they aim at clustering the nodes so that cluster heads can do some aggregation and reduction of data in order to save energy. Depending on the energy level of the node, higher energy nodes can be used to process and send the information while low energy nodes can be used to perform the sensing in the propinquity of the target [3]. Hierarchical routing lowers energy consumption within a cluster and by performing data aggregation and fusion to decrease the number of transmitted messages.

LEACH [6] is one of the first hierarchical routing approaches for sensors networks. The idea proposed in LEACH has been an inspiration for many hierarchical routing protocols [9], [7], [8], [10], although some protocols have been independently developed [12], [11]. Some of the hierarchical routing protocols are PEGASIS, Hierarchical-PEGASIS, TEEN, APTEEN, MECN, SMECN, SOP, VGA, HPAR, HEED, CPCHSA [3,4]. In this section we have discussed on PBEACP [13], ICE [14] and Clustering method of Enhanced tree Establishment [15].

Priority-based Energy Aware and Coverage Preserving Routing (PBEACP) considers the remaining energy and the node's geographic distribution (sensing intensity) in the selection of cluster-head (CH) nodes. It also improves in guaranteeing the sensing coverage of CH nodes, even if the topology of the network changes when there are nodes

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running out of energy. Although it shows better performance compared to LEACH, at times more than one CH node exists in the sensing coverage of a node [13].

The Energy Efficient Inter-Cluster Communication based Routing Protocol for WSNs (ICE) [14] employs the Publish /Subscribe paradigm. It adopts the idea presented in [6] based on the probability for each node in the network to become a CH node and selects 5% CH nodes. The neighboring clusters are discovered by means of the beacon nodes. The beacon nodes broadcast the coordinates of the discovered CHs. Once a CH receives this information, it learns of its neighboring clusters and builds Nearest Neighbor (NN) tables to these clusters.

A Clustering Method of Enhanced Tree Establishment constructs a tree structure for optimized energy consumption [15]. The parent node is selected by minimum summation of the distances of current-parent CH and parent-grandparent CH in the candidate list. It consists of four phases, cluster construction, Tree Establishment and the data transmission. Since the tree structure between CHs is constructed to optimize the distance, this protocol saves energy consumption.

III. BIO INSPIRED ROUTING

In recent years insect sensory systems have been inspirational to new communications and computing paradigms, which have lead to significant advances [16] like Bio Inspired routing. The most popular ACO (Ant Colony Optimization) a colony of artificial ants is used to construct solutions guided by the pheromone trails and heuristic information they are not strong or very intelligent; but they successfully make the colony a highly organized society [17,18].

The *Many-to-One-Improved Adaptive Routing* protocol is an ant colony-based routing protocol, coupled with a lightweight congestion control algorithm that helps in mitigating the collision. They have employed ant colony optimization and swarm intelligence (forward ants and backward ants) [20] to find the shortest and the best route within a multi-hop WSN. Here each node is aware of its location and location of its destination. Each forward ant uses the ant-routing algorithm detailed in [19] to find the best next-hop neighbor node who is both closer to itself and closest to the sink using probabilistic theory. The subsequent nodes use the binary exponential backoff algorithm to calculate their channel access time. Due to the convergence nature of the *many-to-one* routing paradigm, the shortest paths might merge or cross over at any intermediate node. [21].

Minimum Ant-based Data Fusion Tree [22] is yet another routing algorithm based on ACO for gathering correlated data in sensor networks. It first assigns ants to source nodes; the route is constructed by one of the ants in which other ants search the nearest point of previous discovered route. The chosen formula is Probability function composed of pheromones and costs in order to find the minimum total cost path. MADFT not only optimizes over both the transmission and fusion costs, but also adopts ant colony system to achieve the optimal solution [22].

Swarm Intelligence Optimization Based Routing Algorithm works with the aim of balanced global energy consumption and avoiding some node's prematurely exhausting their energy because of too concentrated routes through the nodes, the algorithm chooses the nodes with less pheromone as next hop, taking less hop numbers into consideration. The algorithm is remarkably different from traditional ant colony algorithms and it is better than the Directed Diffusion routing protocol both in end-to-end delay and global energy balance and can effectively balance the global energy consumption and prolong the network lifetime [23].

IV. QOS BASED ROUTING

In QoS-based routing protocols, the network has to balance between energy consumption and data quality. In particular, the network has to satisfy certain QoS metrics, e.g., delay, energy, bandwidth, etc. when delivering data to the BS [3]. We discuss a sample of these protocols in this section.

Breath-a Self-Adapting Protocol for WSN in Control and Automation [24] is a novel cross-layer protocol with randomized routing in WSNs for real time control and automation. MAC and duty-cycling, which allows it to minimize the energy consumption of the network while ensuring a desired packet delivery end-to-end reliability and delay. The protocol adapts to traffic variations with negligible overhead and also adopts a randomized routing, because it is simple to implement, robust and fault tolerant. The protocol considers physical layer aspects, randomized MAC and routing. It outperformed significantly a standard IEEE 802.15.4 implementation in terms of both energy consumption and reliability. Breath has good load balancing performance, and was well scalable with the number of nodes.

Minimum Energy Relay Routing (MERR) and Adaptive MERR (AMERR) are the two routing protocols that efficiently utilize energy, less complex and have better scalability. They have focused on optimal power consumption of routing in a linear WSN, where a Poisson model was assumed for the distribution of nodes along a linear path. AMERR achieves optimal performance for practical deployment settings, while MERR rapidly approaches optimal performance as sensors are more densely deployed. While MERR only assumes that a sensor node is aware of the distances to its downstream neighbors, AMERR assumes the distance to the base station that allows AMERR to make better routing decision than MERR at the cost of a lower degree of locality [25].

Power Aware Smart Routing in WSN: QoS parameters are network lifetime and Quality of information provided to the sink. Quality of information can be defined in a number of ways, but usually a general definition of relevant data,

sent to the sink in a timely manner. Achieving these goals while minimizing the power used is the aim of the tiny CPN WSN routing protocol. Smart routing involves the use of smart packets to find a reliable low-power route between source and destination pairs in packet switched networks. The smart packets are forwarded in a way that attempts to maximize the quality of service by minimizing some metric such as round trip delay, packet loss, or a combination thereof. Dumb packets, carrying data payloads, can then use these routes [26]. It was shown in [27] that QoS can be maintained through the use of a variation of the less computationally complex Sensible Routing, which involves simply selecting the link or neighbor with the best recorded QoS. The protocol effectively optimize other QoS metrics, and as battery powered sensor motes have finite energy, but does not include reliability and energy into the goal function used by smart messages when selecting neighbors in order to increase network efficiency and lifetime. It also does not build upon the multiple QoS goal functionality to examine the use of smart routing in the effective prioritization of important traffic in WSN.

V. LOCATION BASED ROUTING

Geographic routing, sometimes also called directional, geometric, location-based, or position-based routing, is based on two principal assumptions. Every node knows its own and its network neighbor's positions and the source of a message is informed about the position of the destination. Some of the famous geographic based routing protocols are SPAN, GOAFR, MFR & GEDIR, GEAR and GAF [3,4].

A virtual relative position based routing protocol for sensor networks that provides methods for data management as known from standard DHT services. Virtual Cord Protocol (VCP) is a DHT-like protocol that offers in addition to standard DHT functions an efficient routing mechanism [28]. The key characteristics of VCP are the geographical vicinity of virtual neighbors, which reduces the communication load, VCP only needs information about direct neighbors for routing, and it cannot be stuck with dead ends. The protocol is easy to be implemented on the top of a typical MAC layer. All data items are associated with numbers in a pre-defined range is captured by the available nodes.

VI. CONCLUSION

This paper presents a comprehensive survey of the routing techniques for WSNs from the recent work. Although many of these routing techniques look promising, there are still many challenges that are need to be solved. The main categories explored in this paper are Bio Inspired routing protocols, QoS, Hierarchical based and Location-based routing. Each routing protocol was described and discussed under the appropriate classification.

REFERENCES

[1] Kay Soon Low, Win Nu Nu Win and Meng Jo Er, " Wireless Sensor Networks for Industrial Environments", In the proceedings of International Conference on CIMCA-IAWTIC, 2005 IEEE.

[2] I. Khemapechj, I. Duncan and A. Miller, "A Survey of Wireless Sensor Networks Technology",

[3] Jamal N. Al-Karaki and Ahmed E. Kamal, "Routing Techniques in Wireless Sensor Networks: A Survey", Wireless Communications IEEE, Vol. 11, Issue 6, pp. 6-28, December 2004,

[4] K. Akkaya and M. Younis, "A survey of routing protocols in wireless sensor networks", Elsevier Ad Hoc Network Journal, vol. 3, no. 3, pp. 325--349, 2005.

[5] L. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "A survey on sensor networks," IEEE Communications Magazine, vol. 40, Aug. 2002, pp. 102-114.

[6] W. Heinzelman, A. Chandrakasan and H. Balakrishnan, "Energy-efficient communication protocol for wireless sensor networks", in the Proceeding of the Hawaii International Conference System Sciences, Hawaii, January 2000.

[7] S. Lindsey and C.S. Raghavendra, "PEGASIS: power efficient gathering in sensor information systems", in the Proceedings of the IEEE Aerospace Conference, Big Sky, Montana, March 2002.

[8] S. Lindsey, C.S. Raghavendra and K. Sivalingam, "Data gathering in sensor networks using the energy delay metric, in: Proceedings of the IPDPS Workshop on Issues in Wireless Networks and Mobile Computing, San Francisco, CA, April 2001.

[9] A. Manjeshwar and D.P. Agrawal, "TEEN: a protocol for enhanced efficiency in wireless sensor networks", in the Proceedings of the 1st International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing, San Francisco, CA, April 2001.

[10] A. Manjeshwar and D.P. Agrawal, "APTEEN: a hybrid protocol for efficient routing and comprehensive information retrieval in wireless sensor networks", in the Proceedings of the 2nd International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile computing, Ft. Lauderdale, FL, April 2002.

[11] M. Younis, M. Youssef and K. Arisha, "Energy-aware routing in cluster-based sensor networks", in the Proceedings of the 10th IEEE/ACM International Symposium on Modeling, Analysis and Simulation of Computer and Telecommunication Systems (MASCOTS2002), Fort Worth, TX, October 2002.

[12] L. Subramanian and R.H. Katz, "An architecture for building self configurable systems", in the Proceedings of IEEE/ACM Workshop on Mobile Ad Hoc Networking and Computing, Boston, MA, August 2000.

[13] Yunquan Dong Qingyi Quan and Jian Zhang, "Priority-Based Energy Aware and Coverage Preserving Routing for Wireless Sensor Network", in the proceedings of Vehicular Technology Conference, 2008. VTC Spring 2008, IEEE, May 2008, pp: 138-142.

[14] A. Boukerche and A. Martirosyan, "An Energy-Aware and Fault Tolerant Inter-cluster Communication based Protocol for Wireless Sensor Networks", Globecom, Washington D.C., November 2007.

[15] Jin-Young Choi Joon-Sic Cho Seon-Ho Park and Tai-Myoung Chung, "A Clustering Method of Enhanced Tree Establishment in Wireless Sensor Networks", in the proceedings of 10th International Conference on Advanced Communication Technology, Feb 2008. ICACT 2008. Volume: 2, On page(s): 1103-1107.

[16] Z. (Sam) Ma, A.W. Krings, Insect sensory systems inspired computing and communications, Ad Hoc Netw. (2008), doi:10.1016/j.adhoc.2008.03.003

[17] Colorni A , Dorigo M , Maniezzo V. "Distributed optimization by ant colonies". Proc 1st European Conf on Artificial Life Paris, France:Elsevier Publishing, 1991, pp.134-142.

[18] Colorni A, Dorigo M, Maniezzo V. "An investigation of some properties of an ant algorithm". In Proc.PPSN '92Brussels, Belgium: Elsevier Publishing, 1992, pp.509-520.

[19] R. GhasemAghaei, M. A. Rahman, W. Gueaieb, and A. El Saddik, “Ant Colony-Based Reinforcement Learning Algorithm for Routing in Wireless Sensor Networks,” IEEE IMTC 2007, Warsaw, Poland, May 2007.

[20] G. D. Caro, and M. Dorigo, “AntNet: Distributed Stigmergetic Control for Communications Networks,” J. of Art. Intel. Research, vol. 9, Dec. 1998, pp. 317-365.

[21] Reza GhasemAghaei, ASM Mahfujur Rahman, Md. Abdur Rahman, Wail Gueaieb and Abdulmotaleb El Saddik, “Ant Colony-Based Many-to-One Sensory Data Routing in Wireless Sensor Networks” in the proceedings of International Conference on Computer Systems and Applications, 2008. AICCSA 2008. IEEE/ACS , April 2008, pp. 1005-1010.

[22] Luo Juan, Song Chen, and Zhou Chao, “Ant System based Anycast Routing in Wireless Sensor Networks”, in the proceedings of International Conference on Wireless Communications, Networking and Mobile Computing, 2007, WiCom 2007, Sept. 2007, pp. 2420-2423.

[23] Chao Wang and Qiang Lin, “Swarm intelligence optimization based routing algorithm for Wireless Sensor Networks” , in the proceedings of International Conference on Neural Networks and Signal Processing, 2008, June 2008, pp. 136-141.

[24] Park, P.G., Fischione, C., Bonivento, A., Johansson, K.H. and Sangiovanni-Vincentelli, A., “Breath: A Self-Adapting Protocol for Wireless Sensor Networks in Control and Automation”, Proceedings of 5th Annual IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks, 2008. SECON '08, On page(s): 323-331,ISBN: 978-1-4244-1777-3, June 2008.

[25] Marco Zimmerling, Waltenegus Dargie, Johnathan M. Reason, “Localized power-aware routing in linear wireless sensor networks” in the Proceedings of the 2nd ACM international conference on Context-awareness for self-managing systems (2008), pp. 24-33. Sydney, Australia, ISBN:978-1-60558-010-4 .

[26] L. Hey, “Power Aware Smart Routing in Wireless Sensor Networks”, *Next Generation Internet Networks*, pp. 195–202, 2008.

[27] L. Hey, “Reduced Complexity Algorithms for Cognitive Packet Networks”, Proceedings of the 2007 International Symposium on Performance Evaluation of Computer and Telecommunication Systems, 2007.

[28] Awad, Abdalkarim, German, Reinhard and Dressler, Falko (2008), "P2P-based routing and data management using the virtual cord protocol (VCP)", MobiHoc '08: Proceedings of the 9th ACM international symposium on Mobile ad hoc networking and computing: 443--444.