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Acquisition hierarchal network of forwarder nodes in WSNs

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Abstract
Wireless Sensor Networks (WSNs) consist of small nodes with sensing, computation, and wireless communications capabilities. Many routing, power management, and data dissemination protocols have been specifically designed for WSNs where energy awareness is an essential design issue. The focus, however, has been given to the routing protocols which might differ depending on the application and network architecture. In this paper, we present a survey of the state-of-the-art routing techniques in WSNs. Wireless Sensor Network (WSNs) is a self-organized wireless network system which has enabled densely deployment of nodes. WSN is a prominent technology in collecting the data from the remote locations by interacting with the physical phenomena and depend on the collaborative effort by huge numbers of low cost sensor nodes. Typically, WSN comprises of large numbers of low cost, low power sensor nodes which are equipped with communication and low computation capabilities. A Sensor node is an electronic device that is capable of sensing the environment condition such as temperature, pressure, light, humidity and vibration etc.

Keywords: Wireless Sensor Networks (WSNs), communications, power management, deployment, hierarchal

Introduction

The nodes collect, process and cooperatively report them using ad-hoc network protocols and algorithms. These nodes are deployed randomly in the distributed area and they work together to perform some application and make a wireless sensor network.

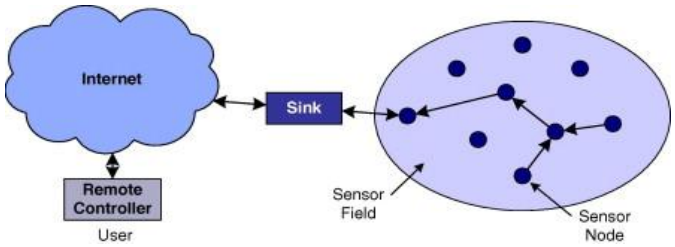

Fig 1: Multi Hop WSN Network Architecture

Components of Sensor Nodes: In WSNs, sensor nodes are very small device which are limited battery powered, low computation capability. Basically sensor nodes consist of four components i.e. sensing (J. Feng, F. Koushanfar, and M. Potkonjak, 2004).

Sensing Subsystem: In real time sensors play an important role as it set up a link between the real-time work and the computational environment, it is used to collect the data of the changing environment. After collecting the data, it sends those data for further processing. Sensors are hardware device which purpose is application specific. Sensors not only collect the data as well as it sends the data for further processing. Sensor node includes analog, digital, and A/D converters and a microcontroller (L. B. Ruiz, J. M. S. Nogueira, and A. A. F. Loureiro, 2005).

Tran receiver: The transmitter and receiver are combined in to a single device called Tran receiver. Sensor nodes often use ISM (Industrial, Scientific and Medical) band. The ISM bands are defined by ITU-R (International Telecommunication Union-Radio communications). The use of these bands in individual countries may differ due to variations in national radio regulations. This gives free radio, spectrum allocation and global availability. WSN uses license free communication frequencies 173, 433, 868 and 915 MHz and 2.4 GHz. The examples of transceivers are chipcon CC1000 (433-915 MHz) and Bluetooth TI CC 24020 (2.44MHz).

Memory: Small size of a sensor node results in corresponding constraints on memory also. Sensor nodes have very simple memory architecture. Sensor nodes use flash memories due to their cost and storage capacity. There are two categories of memory based on the purpose of storage as user memory used for storing application related data and program memory used for programming the devices.

Operating System: A sensor node is a small, highly portable, multitasking system developed for use as a resource constrained networked system. The mostly used operating system in sensor node are tiny OS (Operating System) developed by university of California, Berkeley, 2007 and Lite OS is a newly developed OS which provides UNIX-like abstraction and support for the C programming language. Tiny OS is a free and open source component based operating

system and platform targeting wireless sensor networks.

Processing Subsystem: Processing subsystem basically processes the data using the memory unit as well as processing unit. Collected data are analyzed by the processing subsystems to measure the network performance. Here process means data gathering, data acquisition, data fusion, however it processes the received data either incoming or outgoing.

Communication Subsystem: In WSN, a task is completed by communication. For example, if two nodes are trying to send data to each other, then first they have to be communicated to send the data otherwise it is not possible. There are two types of communication in the WSN, i.e. infrastructure and applications (Martin Haenggi, M. Ilyas and I. Mah-goub, 2005). Infrastructure communication is required, suppose there are huge numbers of mobile nodes. Now if the topology changes or a node fails due to the environment so an infrastructure communication is required to re-construct it. The data which is collected are then transferred to the monitoring end, referred to as application (Martin Haenggi, M. Ilyas and I. Mah-goub, 2005).

Power Subsystem: One of the most important components of a wireless sensor node is the power supply. The battery forms the heart of the sensor system as it decides the lifespan of the system. The battery lifespan needs to be prolonged to maximize the network lifespan. The requirement is that the size of the battery should be as small as possible and energy efficient. Two AA sized batteries of 1.2V each are employed in the battery subsection.

Applications of WSNs: The various WSN applications are as follows (A. Mainwaring, J. Polastre, R. Szewczyk, D. Culler, J. Anderson, WSNA (Wireless Sensor Networks and Applications), Sep 2002).

Disaster relief operations:
- Drop sensor nodes from an aircraft over a wildfire.
- Each node measures temperature.
- Derive a "temperature map".

Biodiversity mapping
- Use sensor nodes to observe wildlife.

Intelligent buildings (or bridges)
- Reduce energy wastage by proper humidity, ventilation, air conditioning (HVAC) control.
- Needs measurements about room occupancy, temperature, air flow, etc.
- Monitor mechanical stress after earthquakes.

Machine surveillance and preventive maintenance
- Embed sensing/control functions into places no cable has gone before.

Eg. - Tire pressure monitoring.

Precision agriculture
- Bring out fertilizer/pesticides/irrigation only when and where needed.

Medicine and health care
- Post-operative or intensive care.
- Long-term surveillance of chronically ill patients or the elderly.

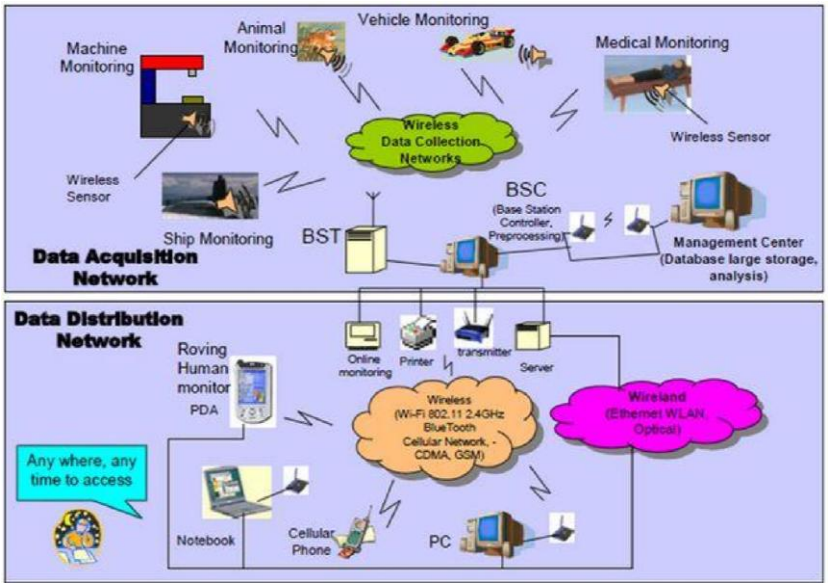

Fig 2: Applications of WSN (A. Mainwaring, J. Polastre, R. Szewczyk, D. Culler, J. Anderson, WSNA (Wireless Sensor Networks and Applications), Sep 2002).

Challenges: It should be understood about the connection and management of the network to achievethe beneficial scalability and efficiency. Sensor networks are differed from the ad hoc network in their characteristics. Both ad-hoc and sensor network have challenges of energy constraints and routing scheme (K. Akkaya and M. Younis, 2005) [1].

Following are some aspects that the WSNs should overcome.

Node Deployment: Basically in WSNs sensor nodes can be deployed in two ways i.e. randomly and manually. But this deployment is solely depending on the application. There may be another way of deploying the sensor nodes i.e. self-organized way where sensor nodes are scattered and topology is formed in an ad-hoc manner. It is evident that uniform distribution of nodes efficiently maintains the network (J. L. Liu and C.V. Ravi Shankar, 2011).

Power Consumption: Power consumption in WSN is an important factor. As sensor nodes have very limited energy and once it is deployed there is no form of recharging it, so to increase the network lifetime energy consumption should be balanced. Mostly in case of real life application, for example in military applications, it is difficult to recharging the battery or replaces the battery.

Latency: In WSN, receiving the exact information without noise or distortion is a crucial problem. There should be a minimum delay. This is ensured by the routing protocol and network topology.

Throughput: As in WSN packet transmission is happened during communication so there may successful or unsuccessful transmission. The successful packet transmission per slot is called throughput.

Scalability: In case of random deployment, network topology may be changed, so it decreases the Network performance. So the routing algorithm should be scalable enough to maintain the sensor states.

Data Aggregation: Data aggregation is a technique which eliminates the duplicate packet. Hence it reduces the power consumption as well as increases the network lifetime.

Fault Tolerance: Some sensor nodes may fail at the time of communication because of link failure, environment change, lack of power supply etc. to overcome these problems routing algorithm should be fault tolerant.

Literature Review

Most popular sensor routing protocols like LEACH and some other, which has some unique features like no collisions, maximum sleep time, and dynamic CH selection and last but not the least power optimization. Many other routing protocols use the idea of LEACH. But conventional leach was not perfect, it has some drawbacks. Form the literature survey we can understand the drawbacks and their solutions too.

To reduce the network complexity assumes that every sensor node always has data to send. But actual scenario is different. Sensor network is event driven, so until the event occurs, the node will not have the data to process or to send, so the corresponding slot becomes idle.

To overcome the above problem and make the scenario realistic, our proposed algorithm considers the above fact. If we want to reallocate the TDMA schedule it increases the network overhead, so it is desirable to make the nodes idle before the cluster joining part.The goal of the scheme is to reduce the energy consumption of the sensor nodes as their radios are in off mode for the long time which reduces the number of dead nodes and increases the network lifetime.

LEACH limitations

- LEACH assumes that all nodes can communicate with each other and are able to reach the sink (therefore, it is only suitable for small size networks).
- LEACH assumes that all nodes have data to send and so assign a time slot for a node even though some nodes might not have data to transmit.
- LEACH assumes that all nearby nodes have correlated data which is not always true
- EACH requires that all nodes are continuously listening (this is not realistic in a random distribution of the sensor nodes, for example, where cluster-heads would be located at the edge of the network)
- There is no mechanism to ensure that the elected cluster heads will be uniformly distributed over the network (hence, there is the possibility that all cluster heads will be concentrated in one part of the network)
- Continuous re-clustering will create extra overhead

Some other old energy efficient protocols like, An Energy Efficient ANT Based Routing algorithm (EEABR) was proposed in (Mesut Gunes, Udo Sorges & Imed Bouazizi, (2002)). In this, mainly concentrated on ANT colony optimization (ACO) heuristic ((Tiago Camilo, Carlos Carreto, Jorge Sa Silva and Fernando Boavida, (2006))) and is focused on the main WSN constrains. EEABR uses a colony of artificial ANTS that travel through the WSN looking for path between sensor nodes and a destination node, that are both short in length and energy efficient, contributing in that way to maximize the lifetime of the WSN. It is used for multi-hop ad-hoc networks and is based on swarm intelligence and on the ANT colony based meta-heuristic. For MANETs. By introducing energy efficiency parameter to this algorithm, it can be adopted in WSN.

And other Hierarchical Routing Techniques like, Power Efficient Gathering in Sensor Information System (PEGASIS) was proposed in (W. B. Heinzelman, A. P. Chandrakasan, and H. Balakrishnan, Oct. 2002) is a near optimal chain based protocol. The basic idea is for the nodes to communicate their sensed data to their neighbors and the randomly chosen nodes will take turns in communicating to the BS. It assumes that the BS is fixed at a far distance from the sensor nodes. The sensor nodes are homogeneous and energy constraint with uniform energy. The energy cost for transmitting a packet depends on the distance of transmission. All the nodes maintain a complete database about the location of all other nodes.

Another Hierarchical Routing Techniques like, Threshold sensitive energy efficient protocol (TEEN) was proposed in (A. Manjeshwar and D. P. Agrawal, April 2001) and Adaptive threshold sensitive energy efficient protocol (APTEEN) (A. Manjeshwar and D. P. Agrawal, April 2002) are the two threshold sensitive hierarchical routing protocols based on the clustering approach used in LEACH. LEACH is targeted at proactive network applications where as TEEN and APTEEN are targeted at the reactive network applications. In proactive

network, the sensed data is sent periodically to the sink which provides the snap shot of relevant parameters at regular intervals.

And also in Hierarchical Routing Techniques, we can discuss like a protocol Energy Aware Routing Protocol (EAP) was proposed in (M. Younis, M. Youssef and K. Arisha, October 2002). In this, mainly focused on minimizing energy consumption (Siva D. Muruganathan, Damiel C.F.MA, Rolly I.Bhasin and Abraham O.FAPOJUWO, March 2008) for in-network communication and balancing energy load among all nodes. It introduces a new clustering parameter for cluster head election which enables better handling of the heterogeneous energy capacities and it also adopts an efficient method known as the intra cluster coverage, which copes with the area coverage problem.

In this, Hierarchical Routing Techniques, we can discuss like a protocol Ring based Energy Adaptive Protocol (REAP) was proposed in (Guanfeng Li, Taieb Znati & Anandha Gopalan, 2014). In this, the nodes self-organize in virtual ring bands centered at the BS. Packets are delivered to the BS along a path with decreasing ring band number. Also, with a probabilistic forwarding approach, the workload among neighboring nodes within the same ring band, is balanced. REAP limits its use of flooding, thereby leading to significant energy savings. Finally, REAP is robust against node failures as it does not require creating and maintaining routing tables.

And some techniques like Location Based Routing Techniques, In this some energy efficient protocols like Geographic Adaptive Fidelity (GAF) was proposed in (Kemal Akkaya and Mohamed Younis, 2013) is a location based routing protocol for WSN. It is also an energy aware routing protocol. GAF works in such a way that; it turns off unnecessary nodes in the network without affecting the level of routing fidelity.

An also in Location Based Routing Techniques like, Minimum Energy Communication Network (MECN) was proposed in (F. Ye *et al.,* (2010),) is a location based routing protocol. It maintains a minimum energy network for wireless networks by utilizing low power GPS. This protocol can be used for mobile networks but it is best suited for sensor networks. This is because sensor networks are not mobile. A master node is included to a minimum power topology for stationary nodes.

In this routing techniques itself, another energy efficient protocol is Greedy Perimeter Stateless Routing(GPSR)was proposed in (Y. Xu, J. Heidemann, and D. Estrin, (2011)), (B. Karp and H. T. Kung, August 2000). In this protocol mainly highlights on position of routers and packets destination to make a forwarding decision for WSN.

And also, Geographic and Energy Aware Routing (GEAR) was proposed in (Y. Yu, D. Estrin, and R. Govindan, May 2012). GEAR is a location based routing protocol for WSN. GEAR is an energy efficient protocol which uses the energy aware neighbor selection to route a packet towards a particular geographical region and then use either the recursive geographic forwarding or restricted flooding algorithms to disseminate the packet inside the destination region.

And also, balanced tree based energy aware routing for wireless sensor networks was proposed in (Ammar Hawbani, Xingfuwang, Husham Gibran, NaziHusain, (2016). In this paper focused on reducing energy dissipation used for communication in each node in order to save the sensor node life and Distributing and balancing energy dissipation over all the nodes in order to maximize the network lifespan.

Another one like Energy neutral clustering for energy harvesting wireless sensors networks proposed in (S Peng, T Wang, C P Low, 2015). In this papers focused on A Distributive Energy Neutral Clustering (ENC) protocol is proposed to group the network into several clusters and ENC employs a novel Cluster Head Group (CHG) that allows cluster to use multiple cluster Heads to share heavy traffic load.

And also, An Efficient adjustable grid-based data replication scheme for wireless sensor networks was proposed in (Tung-Shi Chen, Ning-Chung Wang, Jia-Shiun Wu, 2015). In this paper proposed a data replication scheme called Adjustable Data Replication (ADR), which is based on a virtual grid in order to improve the lifetime of data nodes.

Same like, building efficient multilevel wireless sensor networks with cluster based routing protocol was proposed in (Hnin Yu Shwe, Arun Kumar, Peter Han Joo Chong, 2016).This paper proposed a network coding during data routing in order to achieve additional power saving in CH nodes and Proposed method in terms of the throughput ad end to end delay.

And also, enhancing energy efficiency of wireless sensor network through the design of energy efficient routing protocol was proposed in (Noor Zaman, Low Tang Jung, Muhammad Mehboob Yasin, 2016). This paper proposed Position Responsive Routing Protocol (PRRP), reducing the amount of time in which a sensor node is in an idle state and Reducing the average communication distance over the network.

And also, Load Balanced Energy-Aware Genetic algorithm clustering in Wireless Sensor Networks was proposed in (Ebrahim Farahmand, Saeide Sheikhpour, Ali Mahani, Nooshin Taheri, Oct-2016). GA algorithm proposes fitness function is to minimize the energy consumption leading maximize the lifetime as well as maximize the coverage of the Network and this GA highlights on Picks up theoptimal cluster heads. Assigns appropriate cluster members to these optimal cluster head with propagating GA.

And also, AR-RBFS-Aware – Routing Protocol Based on Recursive Best- First Search Algorithm for Wireless Sensor Networks was proposed in (Farzad Kiani, July-2016). AR-RBFS is a routing based protocol which uses the virtual based classic RBFS algorithm in the lake of energy problem environments and Sensors are placed into virtual layers, to be managed by the duty cycle method.

Another routing approach on message Success Rate, An Energy efficient routing protocol using Message Success Rate in Wireless Sensor Networks was proposed in (Jae-Woo Chang, Min Yoon, Yong – Ki Kim, 2013). This Paper focused on random selection of CH's incurs a node concentration problem. And communication range of each node to transmit the data to words sink node.

And another routing approach, "A New Energy- efficient Cluster based Routing Protocol using a Representative Paths in WSN" was proposed in (Hyunjo Lee, Miyoung Jang and Jae-Woo Chang, 2014). This paper mainly focused on reduce

the energy consumption by decreasing the no of transmitted messages to the sink node. And focused on centralized clustering approach to select CH's by generating Representative Paths.

Opportunistic Routing in multi-hop wireless networks was proposed in (Sanjit Biswas, Robert Morris, 2016) proceedings for MIT Laboratory of Computer Science. This Paper was focused on unicast routing. And implemented an improved Ex OR technique for multi-hop wireless networks.

Conclusions

Routing in sensor networks is a new area of research, with a limited, but rapidly growing set of research results. In this paper, we presented a comprehensive survey of routing techniques in wireless sensor networks which have been presented in the literature. They have the common objective of trying to extend the lifetime of the sensor network, while not compromising data delivery. Overall, the routing techniques are classified based on the network structure into three categories: flat, hierarchical, and location based routing protocols. Furthermore, these protocols are classified into multipath-based, query-based, negotiation-based, or Qo S-based routing techniques depending on the protocol operation. We also highlight the design tradeoffs between energy and communication overhead savings in some of the routing paradigm, as well as the advantages and disadvantages of each routing technique. Although many of these routing techniques look promising, there are still many challenges that need to be solved in the sensor networks. We highlighted those challenges and pinpointed future research directions in this regard.

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