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Advancements in Routing Algorithm Techniques for Wireless Sensor Networks

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Abstract: Wireless sensor networks (WSNs) are widely utilized across various applications due to their ability to monitor and transmit data. Despite their broad usage, WSNs face significant challenges in efficiently conveying data between sensor nodes. Routing algorithms have been specifically developed to address these challenges within WSNs, and this paper explores several of these protocols. WSNs share similarities with ad hoc networks as both rely on hop-to-hop routing mechanisms. Consequently, many protocols originally designed for ad hoc networks are also applied in sensor network applications. However, sensor nodes often lack the capabilities to fully support these protocols without modifications. This paper focuses on the Angle-Direction-Based Source Routing (ADSR) protocol, specifically developed for WSNs. ADSR is derived from the Dynamic Source Routing (DSR) protocol, initially created for Mobile Ad Hoc Networks (MANETs). By implementing certain modifications, DSR has been adapted to meet the unique requirements of WSNs. The primary objective of this paper is to demonstrate that protocols developed for MANETs can be effectively utilized in WSNs through appropriate adaptations. The ADSR protocol exemplifies how an angle-based mechanism can enhance routing efficiency in WSNs, suggesting that similar adaptations can be applied to other MANET protocols for improved performance in sensor networks.

Keywords: *Wireless Sensor Networks, Mobile ad-hoc networks, routing algorithm, ADSR.*

I. INTRODUCTION

Wireless networking technology is evolving as an inexpensive alternative for building federated and community networks (relative to the traditional wired networking approach). Besides its cost-effectiveness, a wireless network brings operational efficiencies, namely mobility and untethered convenience to the end user.

A wireless network can operate in both the ‘‘AdHoc’’ mode, where users are self-managed, and the ‘‘Infrastructure’’ mode, where an authority manages the network with some Infrastructure such as fixed wireless routers, base stations, access points, etc. An Ad-Hoc network (Figure 1) generally supports multi-hopping, where a data packet may travel over multiple hops to reach its destination. Among the Infrastructure based networks, a Wireless Mesh Network also provides the flexibility of multi-hopping. Therefore, how to route packets efficiently in wireless networks is a very important problem.

A variety of wireless routing solutions have been proposed in the literature. This paper presents a survey of the routing algorithms proposed for wireless networks. Unlike routing in a wired network, wireless routing introduces new paradigms and challenges such as interference from other transmissions, varying channel characteristics, etc. In a wireless network, routing algorithms are classified into various categories such as Geographical, Geo-casting, Hierarchical, Multi-path, Power-aware, and Hybrid routing algorithms. Due to the large number of surveys that study different routing algorithm categories, we select a limited but representative number of these surveys to be reviewed in our work. This survey offers a comprehensive review of these categories of routing algorithms. In the early stages of development of wireless networks, basic routing algorithms, such as Dynamic Source Routing (DSR) and Ad-Hoc On-demand Distance Vector (AODV) routing, were designed to control traffic on the network. An ad-hoc routing protocol is a convention, or standard, that controls how nodes decide which way to route packets between computing devices in a mobile ad hoc network .

In ad-hoc networks, nodes are not familiar with the topology of their networks. Instead, they have to discover it. The basic idea is that a new node may announce its presence and should listen for announcements broadcast by its neighbours. Each node learns about nodes nearby and how to reach them, and may announce that it, too, can reach them.

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Figure 1. Adhoc Network

Wireless sensor networks (WSNs) have many wirelessly connected sensor nodes spread over any region or area to take control or maintain many environmental or physical conditions. WSNSs are used in various applications, e.g. to monitor area, heath care, air pollution etc., to detect forest fire, landslide etc. WSNs are popularizing nowadays because they are flexible, cost-effective, reliable, easy to deploy and accurate. WSNs are mainly designed for sensing, collecting and disseminating information about environmental conditions. All sensor nodes sense the difference then collects important information and then sends it to base station or gateway by multi hop communication. WSNs firstly convert data into radio waves and then amplify it and then radio waves are received at receiving node. In many applications of WSNs routing is based on the routing algorithms developed for mobile ad-hoc networks. WSNs are usually very similar to mobile ad-hoc networks (MANETs).As both are distributed network connected wirelessly, use hop-to-hop routing for communication and are battery powered. MANETs are mostly used for communication purposes and to transfer data from one device to another device through internet. But both are different in many points. Nodes used in WSNs have very limited memory power and are of very high magnitude i.e. in order of many hundreds, as compared to MANETs. For WSNs communication is not very big issue, but collecting data is more important, while in MANETs communication is the only purpose. Because of so many differences routing mechanism for WSNs should be different.

II. ROUTING ALGORITHMS

WSNs have many routing algorithms, each one of these protocols is developed for specific application. Every protocol is developed to work only in its desirable condition or environment. Some of them are described here. In WSNs, routing protocols used have flat, hierarchical or location-based structures. Hierarchical routing protocols are Low Energy Adaptive Cluster Hierarchy (LEACH), Two Level Hierarchy LEACH (TL-LEACH), Threshold sensitive Energy Efficient sensor Network protocol (TEEN), Adaptive TEEN (APTEEN), Energy Efficient Cluster Scheme (EECS), Hybrid Energy-Efficient Distributed clustering (HEED), Power Efficient Gathering in Sensor Information System (PEGASIS) and CCS. A new algorithm namely e3D is also proposed. To maximize information flow 2 more protocols are also proposed, i.e. Maximum Information Routing (MIR) and Conditional MIR (CMIR). These are better than LEACH, PEGASIS and Geographical and Energy aware routing (GEAR) on number of hop count. GEAR is a location-based routing protocol which uses energy aware and geographical informed neighbor selection heuristic to route a packet towards the target region. A best hop algorithm is proposed to a Wireless sensor network Longevity (CRAWL) used for scalability and adaptability feature with 20% longer network life. An intra-cluster routing algorithm is used for high density WSNs. Energy-Efficient Minimum Routing algorithm (EEMR) improves energy utility in sensor network by changing activity of wireless communication module. It is better in high density deployment and low traffic. An adaptive transmission range assignment algorithm for in-routing image compression (ARIC) was also proposed which uses collaborative image compression to distribute the computational cost among the sensor nodes. This method had shown the increased lifetime of the network. Geographical routing based algorithm i.e. Energy Efficient Geographic Routing Algorithms interferences and computational costs. To achieve 100% coverage a new protocol named Adaptive Coverage – Preserving Routing Protocol(ACPRP) is proposed. ACPRP uses Particle Swarm Optimization (PSO) algorithm, to find optimal weight parameters which are fed into cluster head mechanism and hierarchy routing selection mechanism. Accuracy of data transmitting node and increase in energy efficiency of sensor node is also necessary are also important issues in sensor networks. So, a new algorithm was proposed to cover these issues named as A Trust Degree of node based on Aware Routing Protocol (TDAR). TDAR uses energy aware mechanism, gives extended network lifetime and improved reliability of data transmitting in networks. In multi-hop routing algorithms, low-power radio properties are ignored, so a novel link loss tolerant data routing protocol, called TABS (Try-Ancestors-Before-Spreading) was designed. TABS combines the benefits of wireless network broadcast advantage with traditional retransmission based routing. It eliminates the need of periodic link quality estimation or backlisting and is designed for both static and dynamic topologies. Shortest Path Routing Protocol (SPRP) is a new routing algorithm designed for wireless network, which uses the Dijkstra's algorithm for choosing shortest path. A beaconless multi hop routing protocol (BMR) is developed to achieve energy

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efficiency in sensor networks for prolong network lifetime. BMR is light weight, energy efficient and makes routing decisions based on residual energy of nodes. For energy efficiency a protocol named Correlation based Collaborative Medium Access Control (CC-MAC) is also proposed. CC-MAC used spatial correlation based medium access control protocol compared with IEEE 802.11. A gradient-based routing algorithm for load balancing (GLOBAL) is also proposed, with a gradient model to increase lifetime of the sensor network. In GLOBAL each sensor node determines its gradient by a weighted average of the cumulative path load and traffic load of the most overloaded node over the path. GLOBAL uses least-loaded path for forwarding.

III. CLASSIFICATIONS OF ROUTING ALGORITHMS

1 Centralized / Distributed algorithms

Centralized routing model carries out routing using a centralized database, while distributed routing model deals with carrying out routing using a distributed database. In simple terms, one central node holds the routing table in the centralized model, while each node keeps a routing table in the distributed model. Because much of the information does not change frequently, many believe that this information is much suitable to be resided in a centralized database. The pre-computations needed for restoration can take the advantage of global information available in a centralized database. But, unlike the distributed routing system, the centralized system cannot be relied upon to bear the responsibility of the on-demand computation of paths of recovery for each of the light-paths that have failed (at a time of detecting an expected failure). Unlike the centralized approach, the distributed routing model is highly consistent with the existing Internet's own distributed routing philosophy.

2 Proactive / Reactive algorithms:

Proactive routing model maintains fresh lists of destinations and their routes by periodically distributing routing tables throughout the network. The main disadvantages of such algorithms are:

• Respective amount of data for maintenance.
• Slow reaction on restructuring and failures.

Reactive routing model finds a route on demand by flooding the network with Route Request packets.

The main disadvantages of such algorithms are:

• High latency time in route finding.
• Excessive flooding can lead to network clogging.

3 Geographic routing

(Geo-routing or position-based routing) is a routing principle that relies on geographic position information. It is mainly proposed for wireless networks and based on the idea that the source sends a message to the geographic location of the destination instead of using the network address. The idea of using position information for routing was first proposed in the 1980s in the area of packet radio networks and interconnection networks. Geographic routing requires that each node can determine its own location and that the source is aware of the location of the destination. With this information a message can be routed to the destination without knowledge of the network topology or a prior route discovery. There are various approaches, such as single path, multi-path and flooding-based strategies. Most single-path strategies rely on two techniques: greedy forwarding and face routing. Greedy forwarding tries to bring the message closer to the destination in each step using only local information. Thus, each node forwards the message to the neighbor that is most suitable from a local point of view. The most suitable neighbor can be the one who minimizes the distance to the destination in each step (Greedy). Following are some routing algorithms fall in this category: DREAM Distance Routing Effect Algorithm for Mobility; LAR Location-Aided Routing protocol; OLSR Optimized Link State Routing Protocol; GEDIR Geographic Distance Routing; BGR Blind Geographic Routing; GPSAL GPS Ant-Like Routing Algorithm; GLS Geographic Location Service; ZHLS Zone-based Hierarchical Link State routing; SiFT Simple Forwarding over Trajectory; SLURP Scalable Location Update-Based Routing Protocol; GPSR Greedy Perimeter Stateless Routing; GFG/FACE [44]Greedy FACE Greedy; GRLI Geographic Routing without Location Information; GDSTR Greedy Distributed Spanning Tree Routing; LBCR Load Balancing Curveball Routing; ALARM Adaptive Location Aided Routing Protocol – Mines; BVGF Bounded Voronoi Greedy Forwarding.

4 Multipath routing:

Multipath routing is the routing technique of using multiple alternative paths through a network, which can yield a variety of benefits such as fault tolerance, increased bandwidth, or improved security. The multiple paths computed might be overlapped, edge-disjointed or node-disjointed with each other. Extensive research has been done on multipath routing techniques, but multipath routing is not yet widely deployed in practice. This method provides better transmission performance and fault tolerance by providing:

• Simultaneous, parallel transport over multiple carriers.
• Load balancing over available assets.
• Avoidance of path discovery when reassigning interrupted stream. Shortcomings of this method are:

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• Some applications may be slower in offering traffic to the transport layer, thus starving paths assigned to them, causing under-utilization.
• Moving to the alternative path will incur a potentially disruptive period during which the connection is re-established.

IV. MODELS OF WIRELESS SENSOR NETWORKS

Sensor nodes used in wireless sensor networks can be fixed or mobile. So, according to this WSNs can be classified in two types:

- Static Wireless Sensor Networks
- Mobile Wireless Sensor Networks

These are briefly discussed as follows:-

a) Static Wireless Sensor: Network Static wireless sensor network, have all nodes fixed at one place, i.e. there is no motion among the nodes placed in the sensor networks. This type of network model is reliable, easy to implement. To communicate between two nodes is simple as all the nodes are static.

b) Mobile Wireless Sensor Network: In mobile wireless sensor networks (MWSNs), nodes are mobile, i.e. nodes can move from place to place. Due to which communication between two nodes can be very complicated. Routes selected for communication also have to change with respect to movement of nodes. Node which has to transfer the data, called source node, and node to which the data has to be sent is called sink node. But MWSNs are more advantageous over static WSNs in terms of MWSNs can be further divided in two parts: (i) Sensor networks with mobile source node and (ii) sensor network with static source node.

V. ISSUES IN ROUTING TECHNIQUES

Developing a routing algorithm for a wireless network should consider the distinct wireless physical characteristics. Following are some of the issues such as:

• Large area of flooding
• Empty set of neighbours (when GF used)
• Fat addressing
• Widely distributed information
• Large power consumption
• Interference and load balancing

1 Large area of Flooding: Flooding is a simple routing algorithm in which every incoming packet is sent through every outgoing link. Flooding is used in bridging and in systems such as Usenet and peer-to-peer file sharing and as part of some routing protocols, including OSPF, DVMRP and those used in adhoc wireless networks. Flooding algorithm work roughly as: Each node acts as both a transmitter and a receiver; each node tries to forward every message to every one of its neighbours except the source node. This results in every message eventually being delivered to all reachable parts of the network. Algorithms may need to be more complex than this, since, in some case, precautions have to be taken to avoid wasted duplicate deliveries and infinite loops, and to allow messages to eventually expire from the system. A variant of flooding called selective flooding partially addresses these issues by only sending packets to routers in the same direction. In selective flooding the routers don't send every incoming packet on every line but only on those lines which are going approximately in the right direction.

2 Empty set of Neighbours: Greedy Forwarding is one of the techniques on which single-path routing relies. GF works as follows: when a source node needs to send a data packet to a destination node, the source node forwards the data packet to the geographically closest neighbour towards the destination among its neighbours. This procedure is repeated at each intermediate node until the destination is reached. Unlike flooding, GF forwards the data packet to a single neighbour instead of broadcasting the packet to all neighbours. However, GF can have a critical issue which we call 'GF empty-neighbour-set problem' where a node cannot find any neighbour which is closer to the destination than itself. Hence, the forwarding process reaches a dead end.

3 Fat addressing and widely distributed information: In a wireless network, the distribution of mobile nodes over the network area and the limitation of each node's wireless coverage may cause a lack of information at some nodes about the structure of the network to which the nodes belong. Information-gathering process is an important phase of any routing approach. Therefore, a structural overview of a wireless network is significant to facilitate the routing process. In addition, a structured addressing scheme is needed to achieve the same goal and enhance the network performance. Large power consumption: In a multi-hop Ad-Hoc network, the existence of any intermediate node depends on its battery power; once the battery of a node is drained out, then the routing process should reroute the traffic which used to pass through this node. Hence, minimizing the power consumption of a node is important to stabilize the network and reduce its cost.

VI. CONCLUSION

In this paper different routing protocols, which are developed for wireless sensor networks, have been discussed. And a solution to most common problem for WSNs is proposed, i.e. an idea for developing a new protocol for sensor networks with the help of other routing protocols, which were basically developed for ad-hoc network. In our future work, the angle-based mechanism will be used in other routing protocols of MANET. This

effort will provide new routing algorithms for WSNs. Algorithms of protocols e.g. AODV, DYMO, DSDV, OLSR, etc. will be slightly changed by adding angle-based mechanism to it.

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