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STUDY OF ENERGY EFFICIENT ROUTINGS FOR WIRELESS NETWORK

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Abstract— **Recent technological advances in communications and computation have enabled the development of low-cost, low-power, small in size, and multifunctional sensor nodes in a wireless sensor network. Since the radio transmission and reception consumes a lot of energy, one of the important issues in wireless sensor network is the inherent limited battery power within network sensor nodes. Therefore, battery power is crucial parameter in the algorithm design to increase lifespan of nodes in the network. In addition to maximizing the lifespan of sensor nodes, it is preferable to distribute the energy dissipated throughout the wireless sensor network in order to maximize overall network performance. Much research has been done in recent years, investigating different aspects like, low power protocols, network establishments, routing protocol, and coverage problems of wireless sensor networks. There are various On Demand Routing Protocols like location-aided, multi-path, datacentric, mobility-based, QoS based, heterogeneity-based, hierarchical routing, hybrid routing, etc., in which optimal routing can be achieved in the context of energy. In this paper, the focus is mainly driven over the survey of the energy-efficient hierarchical cluster-based available routings for Wireless Sensor Network.**

Index Terms— **network performance, multifunctional sensor, hierarchical routing.**

I. INTRODUCTION

A routing protocol is the mechanism by which user traffic is directed and transported through the network from the source node to the destination node. Objectives comprise maximizing network performance and minimizing the cost of network in accordance with its capacity. The network performance depends upon hop count, delay, throughput, loss rate, stability, cost, etc. and the network capacity is a function of available resources resides at each node and number of nodes in the network as well as its density, frequency of communication, frequency of change in topology. Routing in Ad hoc environment is diverse compared to normal wired networks.

Basis of routing strategy

One of the issues with routing in ad hoc networks concerns whether nodes should keep track of routes to all possible destinations, or as an alternative keep track of only those destinations that are of immediate interest. A node in an ad hoc network does not need a route to a destination until that destination is to be the recipient of packets sent by the node, either as the genuine source of the packet or as an intermediate node along a path from the source to the destination. On the basis of routing strategies used in mobile ad, hoc networks, routing protocols can be categorized in different classes: flooding, proactive, reactive, and hybrid.

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Flooding In flooding sender broadcasts data packets to all its neighbors. Then, each node receiving the data packets forwards these data packets to its neighbors. Thus, flooding provides potentially lower reliability of data delivery because flooding uses broadcasting which creates significantly high overhead cause network congestion. One of the advantages of flooding is to deliver packets to the destination on multiple paths, so from this point of view flooding is reliable

Proactive or Table driven In proactive routing algorithms, each node maintains a routing table containing the next hop information for every other node in the network, and hence a route between the source node and the destination node is always available making the approach proactive. Certain proactive routing protocols are Destination-Sequenced Distance Vector (DSDV), Wireless Routing Protocol (WRP), Global State Routing (GSR), Cluster head Gateway Switch Routing (CGSR).

Distance Vector Distance vector algorithms are so called because each node maintains, for each destination, the distance to that destination from each of the node's neighbors. The neighbor with the shortest entry in this vector of distances is chosen to be the next hop to the destination. This method, the Distributed Bellman-Ford (DBF) algorithm, is computationally efficient and straightforward to implement. However, the DBF algorithm is subject to both short- lived and long-lived routing loops because nodes choose their next hops in a distributed manner using information that may be out-of-date.

Reactive In reactive routing algorithms, a path discovery process determines the path to the destination only when the node has a packet to forward that is it reacts to a request to send data to a host. These types of routing algorithms are also referred to as on-demand routing protocols.

Source Routing In source routing, a node builds up a route by flooding a query to all nodes in the network for a given destination. The query packet stores the .information of the intermediate nodes in a path field. On identifying the target or any other node that has already learned the path to the destination, answers the query by sending a “source routed” response packet back to the sender.

Hybrid Hybrid architectures aggregate a set of nodes into zones. Therefore, the network is partitioned into a set of zones. Each node belongs to two levels topology: low level (node level) topology and high level (zone level) topology.

Also, each node may be characterized by two ID number: node ID number and zone ID number. Normally, aggregate architectures are related to the notion of *zone*. In aggregate architecture, we find both intra-zone and inter-zone architecture which in turn can either support flat or hierarchical architecture.

II. Global State Routing (GSR)

Global State Routing (GSR) is similar to DSDV, with changes to reduce the overhead, which normal DSDV would incur with increasing network sizes. This protocol is based on Link State routing, which has the advantage of routing accuracy. Each node maintains a neighbor listing, a topology chart, a next hop table and a distance table. The neighbor list contains the list of nodes adjacent to the node. The topology table contains the link state information reported by a destination and a timestamp indicating the time at which this is generated. The next hop table and the distance table hold the next hop and the distance of the shortest path for each destination correspondingly.

III. Wireless Routing Protocol (WRP)

WRP is another protocol based on distributed Bellman-Ford algorithm (DBF). It substantially reduces the number of cases in which routing loops (count-to-infinity dilemma) can occur. It uses information concerning the length and second-to-last hop (predecessor) of the shortest path to each destination.

Each node maintains a distance table, a routing table, a link-cost table and a message retransmission list. The distance table of a node includes tuples <destination, next hop, distance, predecessor (as reported by next hop) > for each destination and each neighbor. The routing table of a node encloses tuples <destination, next hop, distance, predecessor, and marker for each known destination where marker specifies whether the entry corresponds to a simple path, a loop or a destination that has not been marked. The link-cost table contains the cost of the link to each neighbor and the number of periodic update periods elapsed since the node received any error-free message from it. The message transmission list (MRL) contains sequence number of update message, retransmission counter, and acknowledgement required flag vector with one entry per neighbor, and a catalog of updates sent in the update message. It records which updates of an update message have to be retransmitted and which neighbors should be requested to acknowledge such retransmission.

IV. Hierarchical State Routing (HSR)

Hierarchical State Routing (HSR) employs a multilevel clustering and logical partitioning scheme. The network is partitioned into clusters and a cluster-head is elected as in a cluster-based algorithm. Cluster heads again organize themselves into clusters up to any desired clustering level as shown in Fig. Within a cluster, nodes broadcast their link information to one another. A cluster head summarizes its cluster information and sends it to neighboring clusters through a gateway node. A gateway node is one, which is adjacent to one or more cluster heads. Here cluster heads are members of a higher- level cluster. At each level, summarization and link information exchanges are executed. The manner in which the information is exchanged in this hierarchy is, first information is collected among the nodes forming the base level cluster, it is then passed on to the cluster head which in turn passes to its next hierarchical cluster head and from there on the information is disseminated into other cluster heads and thus the information traverses down the hierarchy. Here every node has a hierarchical address, which may be obtained by assigning numbers from the top root to the bottom node. But as a gateway can be reached from the root from more than one path, so a gatewa y can have more than one hierarchical address.

V. Clustered Gateway Switch Routing protocol (CGSR)

In this protocol, nodes are aggregated into clusters controlled by a cluster head elected using a distributed algorithm nodes within the transmission range of the cluster-head belong to this cluster. CGSR uses a Least Cluster Chance (LCC) clustering algorithm in which a cluster-head chance occurs only when two cluster-heads come into one cluster or one of the nodes moves out of the range of all the cluster heads. Also, more priority is given to cluster heads during channel allocation to maximize channel utilization and minimize delay. The general algorithm is based on DSDV algorithm. Each node maintains two tables, namely, a cluster member table which records the cluster head for each destination node and routing table which contains the next hop to the destination. The cluster member table is broadcasted periodically. A node will update its cluster member table when it receives a new one from its neighbors using sequence numbers as in DSDV.

On-Demand Routing Protocols

The main motivation of the designing of on-demand routing protocols is to reduce the routing overhead in order to save bandwidth in Ad hoc networks. On- demand routing protocols execute the path finding process and exchange routing information only when there is a requirement by the station to initialize a transmission to some destination. On-demand routing protocols can be again classified as unipath (single path) on demand protocols and multipath on-demand protocols .

Unipath On Demand Routing Protocols

Most currently proposed routing protocols for Ad hoc networks are unipath routing protocols. In unipath routing, only a single route is used between a source and destination node. Two of the most widely used on-demand protocols are the Dynamic Source Routing (DSR) and the Ad hoc On-demand Distance Vector (AODV) protocols.

An example of route discovery in a unipath Ad hoc network .In order for node S to send data to node D, it must first discover a route to node D. Node S discovers a route to node D going through node Y, and sets up the route. Once the route is established, node S can begin sending data to node D along the route. When node D moves out of range of node Y, this route breaks. Node S finds a new route to node D through node Z, and thus can begin sending data to node D again as shown in Fig

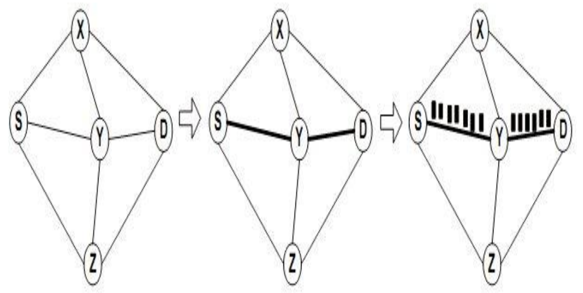
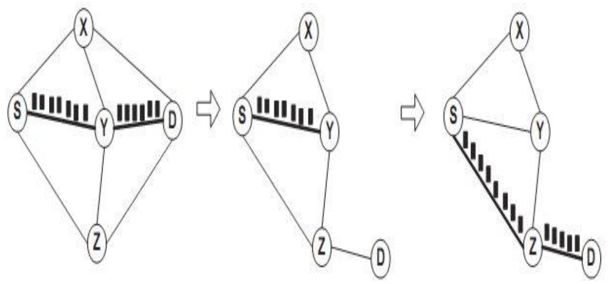


Fig 1: Route Discovery in a Unipath Ad hoc Network

Fig 2: Route Maintenance in a Unipath Ad hoc Network



VI. DYNAMIC SOURCE ROUTING (DSR)

Dynamic source routing is a Source routed On-Demand routing protocol in Ad hoc networks. It uses Source Routing, which is a technique in which the sender of a packet determines the complete sequence of nodes through which the packets have to be traveled to reach destination. The sender of the packet explicitly mentions the list of all nodes in the packet's header, identifying each forwarding 'hop' by the address of the next node to which to transmit the packet on its way to destination host. In this protocol the nodes don't need to exchange the Routing table information periodically and thus reduces the bandwidth overhead in the network. Each Mobile node participating in the protocol maintains a 'routing cache', which contains the list of routes that the node has learnt. Whenever the node finds a new route it adds the new route in its 'routing cache'. Each mobile node also maintains a sequence counter 'request id' to uniquely identify the requests generated by a mobile host. The pair <source address, request id > uniquely identifies any request in the Ad hoc network. The protocol does not need transmissions between hosts to work in bi-direction. The main phases in the protocol are Route Discovery process and Route Maintenance process.

VII. AD HOC ON-DEMAND DISTANCE VECTOR (AODV)

AODV combines the use of destination sequence numbers in DSDV with the on-demand route discovery technique in DSR to formulate a loop-free, on-demand, single path, distance vector protocol. Unlike DSR, which uses source routing, AODV is based on hop-by-hop routing approach. Each node maintains a routing table, which contains a destination address, sequence number of destination; hop count (number of hops to reach the destination), and next hop to reach the destination and expiration timeout.

Multipath On -Demand Routing Protocols

Multipath routing consists of finding multiple routes between a source and destination node. These multiple paths between source and destination node pairs can be used to compensate for the dynamic and unpredictable nature of Ad hoc networks. Multipath routing consists of three components viz. route discovery, traffic allocation and route maintenance.

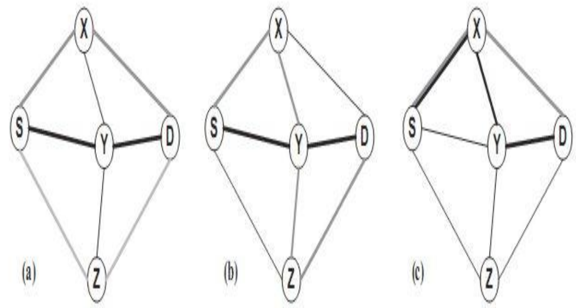


Fig 3: Different Kinds of Multipath Routes
(a) Node Disjoint (b) Link Disjoint (c) Non Disjoint

VIII. SPLIT MULTIPATH ROUTING (SMR)

It is a multipath version of DSR. Unlike many prior multipath routing protocols, which keep multiple paths as backup routes, SMR is designed to utilize multipath concurrently by splitting traffic onto two maximally disjoint routes. Two routes said to be maximally disjoint if the number of common links is minimum.

SMR uses one route discovery process to accumulate as many as possible routes to the destination node. This route discovery process runs in the same way as in DSR. However, there are more steps involved in processing RREQ packets at intermediate and destination nodes. If an intermediate node receives a RREQ packet, it adds its own address and rebroadcasts the RREQ packet. Whenever an intermediate node receives another RREQ from the same source node and with the same request id, i.e. a duplicated RREQ, the node checks the following two things. First, the RREQ packets are checked if they traversed through different incoming link. Second, the hop count (of the RREQ) is checked if it is not larger than that of the first received RREQ. Then the node appends its own id and forwards the RREQ packets. Otherwise the RREQ packet is discarded. Additionally, intermediate nodes are not allowed to reply directly with a RREP on a RREQ packet.

IX. DYNAMIC MULTI-PATH SOURCE ROUTING (DMSR)

DMSR extends DSR's routing mechanism to deal with multi-path routing couple with bandwidth constraint. It consists of three major phases, namely routing discovery, multi-path route selecting and routing maintenance. In multi-path route selecting phase, the ideal number of multi-path routing is achieved to compromise between load balancing and network overhead. A DMSR RREQ includes Source id, RREQ id, Routing list, H_{max} and B_{min}. Source id and RREQ id are used to uniquely identify the QoS request. Routing list is used to keep track of the RREQ by nodes, based on which the Destination node can select node disjoint multi-path routing. H_{max} is used to avoid overhead brought by routing with too many hops. B_{min} is the minimum bandwidth requirement.

X. MULTIPATH-DISTANCE VECTOR ROUTING (MP-DSR)

MP-DSR is an extension of DSR with QoS support. It tries to forward packets on multiple disjoint paths with certain end-to-end reliability requirements. This reliability considers the probability of having a successful transmission between the two mobile nodes within the time period from t_0 to $t_0 + t$, where t_0 is any time instant. The probability successful transmission is shown in the following equation

$$P(t) = 1 - \prod_{k \in K} (1 - p(k,t))$$

Where *k* is a set of node-disjoint paths from the source to the destination. *p(k,t)* is the path reliability of path k, calculated as the product of link availability of all the links in path k. In other words, *P(t)* is the probability that at least one path stays connected for the duration of t. After the value of lowest path reliability requirement and the number of paths to be discovered are set, the source node floods a RREQ packet for a set of paths (neighbor nodes), which can satisfy these requirements

AODV Multipath Router Approach (AODVM-R)

When performing route discovery, the source and intermediate nodes maintain multiple routes to the destination. To ensure loop freedom the RREQ packet includes path information (path from the source to the router). Primary and secondary routes will have the same sequence numbers. When a link breaks, a node tries to reestablish the route using alternate paths. If still there is an unreachable destination, the node sends an RERR message to its neighbors. If the primary route works for a long time, alternate paths might timeout because they are not used. While the primary route is being used, send REFRESH message to the alternate routes occasionally to refresh them. The REFRESH packet is sent every active route_timeout / 2 seconds. The REFRESH packet is forwarded to the destination, refreshing the routes on the way. If an alternate route is detected to be broken, it is simply discarded from the route table.

Ad hoc On-Demand Multipath Distance Vector Routing (AOMDV)

The main idea in AOMDV is to compute multiple paths during route discovery. It is designed primarily for highly dynamic Ad hoc networks where link failures and route breaks occur frequently. When single path on-demand routing protocol such as AODV is used in such networks, a new route discovery is needed in response to every route break. Each route discovery is associated with high overhead and latency. This inefficiency can be avoided by having multiple redundant paths available. Now, a new route discovery is needed only when all paths to the destination break.

Ad hoc On-demand Distance Vector Multi-path (AODV Multipath)

AODV Multipath is an extension of the AODV protocol designed to find multiple node-disjoint paths. Intermediate nodes are forwarding RREQ packets towards the destination. Duplicate RREQ for the same source-destination pair are not discarded and recorded in the RREQ table. The destination accordingly replies to all route requests targeting at maximizing the number of calculated multiple paths. RREP packets are forwarded to the source via the inverse route traversed by the RREQ. To ensure node-disjointness, when intermediate nodes overhear broadcasting of a RREP message from neighbor nodes, they delete the corresponding entry of the transmitting node from their RREQ table. In AODV Multipath, node-disjoint paths are established during the forwarding of the route reply messages towards the source, while in AOMDV node-disjointness is achieved at the route request procedure**.**

XI. NODE DISJOINT MULTIPATH ROUTING (NDMR)

It extends the AODV protocol with new features such as the path accumulation and reverse-route-table. The path accumulation feature is similar to the one of DSR. In order to detect multiple node-disjoint paths with a low routing overhead, NDMR defines a new field in the RREQ packet. If the RREQ packets are generated or forwarded by the nodes, every node has to append its own id to the RREQ packet. If an intermediate node receives a RREQ packet, it checks the hop count of the RREQ packet with respect to the “too-large-hop-count-rule”. This means that the hop count of the duplicated RREQ packet is not larger than the hop count of the first RREQ packet. If the RREQ packet has an acceptable count, the intermediate node adds itself to the RREQ packet and rebroadcasts it; otherwise, the RREQ packet is discarded.

XII. AODV WITH BACKUP ROUTES (AODV-BR)

This protocol description is based on AODV. This protocol does not require any modification to the AODV’s RREQ (route request) propagation process. The mesh structure and alternate paths are established during the route reply phase by slightly modify the AODV protocol. Taking advantage of the broadcast nature of wireless communications, a node promiscuously “over hears” packets that are transmitted by their neighboring nodes. From these packets, a node obtains alternate path information and becomes part of the mesh. When a node that is not part of the route overhears a RREP packet not directed to itself but transmitted by a neighbor (on the primary route), it records that neighbor as the next hop to the destination in its alternate route table. A node may receive numerous RREPs for the same route if the node is within the radio propagation range of more than one intermediate node of the primary route. In this situation, the node chooses the best route among them and inserts it to the alternate route table. When the RREP packet reaches the source of the route the primary route between the source and the destination is established and becomes ready for use. Nodes that have an entry to the destination in their alternate route table are part of the mesh. The primary route and alternate routes together establish a mesh structure.

XIII. TEMPORALLY ORDERED ROUTING ALGORITHM (TORA)

The Temporally Ordered Routing Algorithm (TORA) is a highly adaptive loop free distributed routing algorithm based on the concept of link reversal. It is designed to minimize reaction to topological changes. A key design concept in TORA is that it decouples the generation of potentially far-reaching control messages from the rate of topological changes. Such messaging is typically localized to a very small set of nodes near the change without having to resort to a complex dynamic, hierarchical routing solution. Route optimality (shortest-path) is considered of secondary importance, and longer routes are often used if discovery of newer routes could be avoided. TORA is also characterized by a multi-path routing capability.

CONCLUSION AND FUTURE RESEARCH

Due to the scarce energy resources of sensors, energy efficiency is one of the main challenges in the design of protocols for On Demand Routing Protocols s. The ultimate objective behind the protocol design is to keep the sensors operating for as long as possible, thus extending the network lifetime. In this paper we have surveyed and summarized recent research works focused mainly on the energy efficient hierarchical cluster-based routing protocols for On Demand Routing Protocols s. As this is a broad area, this paper has covered only few sample of routing protocols. The protocols discussed in this paper have individual advantages and pitfalls. Based on the topology, the protocol and routing strategies can be applied. The factors affecting cluster formation and CH communication are open issues for future research. Moreover, the process of data aggregation and fusion among clusters is also an interesting problem to explore. For realization of sensor networks, it is needed to satisfy the constraints introduced by factors such as fault tolerance, scalability, cost, topology change, environment, and power consumption. Since these constraints are highly stringent and specific for sensor networks, new wireless ad hoc networking techniques are required to be explored further. Though the performance of the protocols discussed in this paper is promising in terms of energy efficiency, further research would be needed to address issues related to Quality of Service (QoS) posed by video and imaging sensors and real-time applications.ion of future research.

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