A Survey on Routing Protocols for Wireless Sensor Networks in Various Environments

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ABSTRACT
Extensive use of wireless sensor networks have started due to the wide variety of applications of them including military, health, space exploration, vehicular movement, environment monitoring, disaster management etc. Hence different protocols should be designed based on the QoS requirements of the application. Also sensor nodes have limited storage capacity, energy and computational requirements. Hence the designed protocols should make efficient use of the available resources. A survey and comparison of various routing protocols designed for terrestrial wireless sensor networks with static and mobile sinks and for underwater sensor networks has been done in the paper. The required areas of future research have also been discussed.

General Terms
Wireless Sensor Networks, Routing Protocols, Survey

Keywords
Wireless sensor networks, Routing, Network lifetime, Node mobility, Data Aggregation, Node failure, Communication Overhead

1. INTRODUCTION
The advent of micro electro mechanical systems(MEMS) which combines advanced communication and signal processing capabilities lead to the development of low cost energy constrained sensor nodes[2][3][4].A Wireless Sensor Network(WSN) consists of the sensor nodes, the environment to be monitored and a gateway to the user called sink. WSNs have a wide variety of placements ranging from public to military and underwater to space shuttle placements.

Wireless Sensor Networks(WSN) consists of numerous small energy constrained nodes. Each node consists of a sensing or actuating unit, a processing unit(CPU, micro controller or DSP kit), memory(to store data or program),an RF transceiver(usually with an omnidirectional antenna) and power(battery or solar)[5]. Desirable functionality of sensor nodes in a WSN include: ease of installation, self-indication, self-diagnosis, reliability, time awareness for coordination with other nodes, some software functions and DSP, and standard control protocols and network interfaces[76].Route maintenance and data dissemination are the two processes that consume energy in WSNs. Frequent network maintenance and node replacement isn't possible in WSNs due to the nature of the environment where they are deployed. Hence WSN must be fault tolerant. Multipath routing is an option to continue the networking in the presence of faults. But this requires more control overhead[6].The main challenges involved in the design of a reliable protocol for WSN are[74]:

- The computation time of the route selection is to be kept as low as possible as the delay may have a great impact on preventing harmful consequences.
- Confrontation of the dynamically changing link statistics is intricate.
- Energy consumption of the nodes is to be kept very low.

A WSN may consist of heterogeneous or homogenous nodes. Homogenous nodes are easily maintainable because of lesser complexity. Peer to peer protocols support mesh like structure to switch data between thousands of nodes[5]. Hence such protocols are more scalable and can be used to add more nodes to extend the geographical region. These can adapt better in case of node failure also. The nodes can be deployed in random or deterministic manner. Wint ye Poe[7] considered three architectures-uniform random, square grid and tri hexagonal tiling(THT) and the metrics were energy consumption, worst case delay and coverage.THT had better performance in case of delay and energy consumption whereas square grid had better coverage[7].

All together it is expected that an ideal WSN must be networked, scalable, fault tolerant, consumes less power, smart and software programmable, bandwidth efficient, has faster data acquisition, reliable and accurate over long period of time, costs little and doesn't require maintenance[5]. Although all these cannot be obtained perfectly, each protocol aims in optimizing two or three of these factors based on the application for which the sensor network is deployed .

2. SOURCES OF ENERGY INEFFICIENCY IN WSN
Radio Communication is the most power hungry process[8].Hence sleep/wake cycles are introduced according to the duration through which the node must be on. But the sleeping state can increase latency and reduce the spectral utilization efficiency[9][10].WSNs work in ISM(Industrial Scientific and Medical) band which is prone to interference[1]. Collision, idle listening ,overhearing and control overheads also consumes energy[11].Transmitting raw data as such can also consume energy.

Another factor that reduces the performance of WSNs are faults. The faults in WSNs can be divided into transmission fault and node fault[8]. Transmission fault occurs due to link breakage because of the varying environmental conditions. Node fault can again be divided into five viz. power fault, sensor circuit fault, micro controller fault, receiver circuit fault and transmitter circuit fault[12][13][14][15]. Hence additional alternative paths need to be maintained to route the data in case of failure of the main path. This also calls for more control head and larger routing table which increases energy consumption and memory usage. Moreover, There are several sources of power consumption in the sensing unit viz sampling unit, signal Conditioning unit and ADC unit All these sub systems consume power[75].

Protocols used in traditional wired networks cannot be used in wireless networks. In wired networks, even if the sender detects collision, the signal strength remains the same throughout. But in wireless networks, the signal strength is inversely proportional to the square of the distance between the transmitter and receiver and hence a collision can lose or corrupt the data packet. Wireless networks also face the hidden terminal problem. Wireless networks unlike wired ones are decentralized and runs for longer time. Wired networks aren't energy constrained and the protocols for them were not designed with energy constriction in mind.

Many protocols have been designed for MANETs(Mobile adhoc networks). However using the same for WSNs may not be a good idea because of the following differences between MANETs and WSNs[16]. MANETs are closer to humans in the sense that one of their nodes will be of human interaction(like laptops, PDAs, mobile radio terminals etc). The number of nodes in WSNs and their density will be orders of magnitude higher than that of MANETs. The topology of WSN may frequently change either due to the sleep/wake cycle of the nodes or due to node failure because of their place of deployment(top of a volcano, deep under the ocean etc) where as in adhoc networks the topology changes are usually due to the mobility of nodes. Nodes may be unattended in WSN for a long period of time(months, years etc).The communication in sensor networks is in the range of few meters, at the rate of kilobits/sec, the memory is of kilobytes and the processing speed is in the range of megahertz. The job of a sensor network is not to move a few bits but it should consider the geographic scope since they actuate upon a phenomenon. That is the communication paradigms are application specific[16].

3. ROUTING PROTOCOLS IN WSN

Various types of categorization has been done to the routing protocols in WSN. One such categorization is based on the way the source finds the route to the destination. A *proactive* routing protocol maintains a route even when there is no traffic where as a *reactive* protocol makes a route based on the demand. A *hybrid* protocol combines both[5].

3.1. Data Centric Protocols

In these protocols, the sink sends data queries to sensors in a specific region and hence the data will have high redundancy. Attribute based specifications are given to the data.

3.1.1. Flooding and Gossiping

Both of them are a primitive form of routing data[17]. In flooding, each node broadcasts its data to all neighbours until the boundary or the destination. In gossiping, the data is broadcasted to randomly selected neighbours. Although the problem of implosion in flooding is avoided in gossiping, additional problem of latency is there. Both have the disadvantage of resource blindness and overlap

3.1.2. Spin (Sensor Protocol For Information Via Negotiation)[17]

Here the since advertises it's data and the nodes negotiates before transferring data. Most prominent protocols in this family are spin1 and spin2. In spin2, an energy threshold is also kept besides negotiation to balance the energy consumption. But there is no guaranteed data delivery and its not suitable for densely deployed networks. Figure 1 compares the data acquired for a given amount of energy[5].

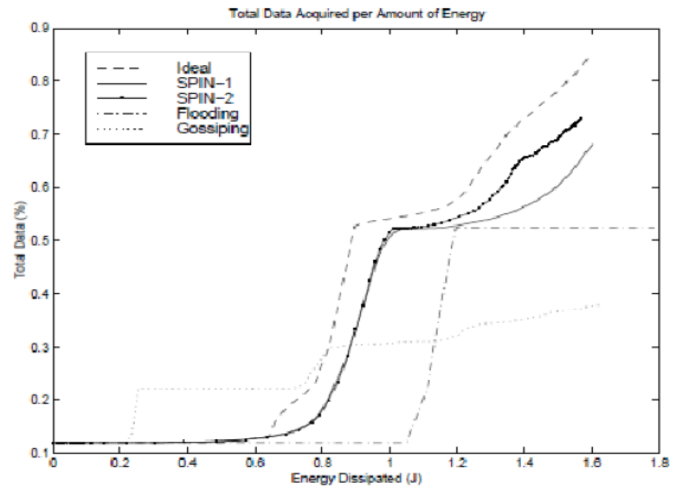


Figure 1:Data acquired for a given amount of energy. SPIN 2 distributes 10% more data per unit energy than SPIN 1 and 60% more than flooding[5].

3.1.3. Directed Diffusion

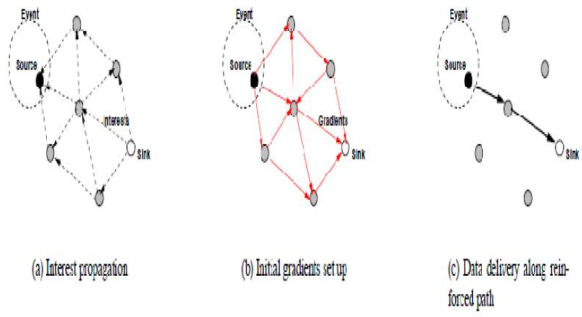


Figure 2:A simplified schematic for directed diffusion[5]

Here the nodes are application aware and find empirically good paths and has in-network processing[18].Here the sink requests for data in the form of interest message. The elements in this protocol include interests, data messages, gradients and reinforcements. Since the communication is between neighbours, there is no need for addressing. Also the protocol is reactive and hence knowledge of global topology isn't needed. Caching can reduce delay and energy consumption. But directed diffusion is not good for environment

3.1.4. Rumour Routing

This is used in contexts where geographical routing isn't applicable[19]. Here a query finds the path to an event using random walks and only a single path is taken from the source to the destination as shown in figure 3[5].When events are flooded each node maintains an event table and generates an agent. The event table consists of the event, the source node and the last hop node. The agent spreads the information about local events to distant nodes. This protocol has better query reliability. The data delivery rate decreases linearly with increase in the number of dead nodes[5].

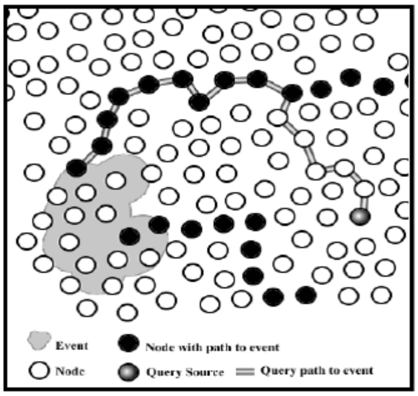


Figure 3:Rumour Routing[5].

3.1.5. *Gradient Based Routing*

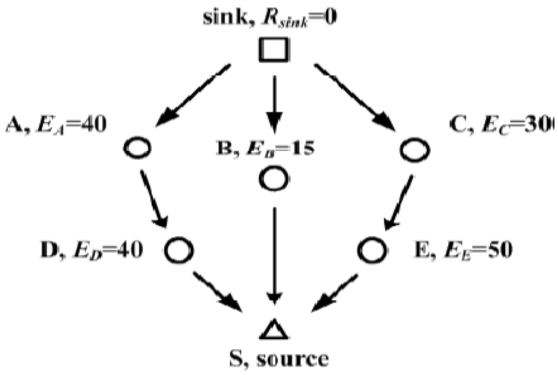


Figure 4:Procedure for creating minimum cost gradient[5]

In traditional gradient based routing the minimum hop path between the source and sink are found. Lixia[20] proposed another one where along with hop,the residual energy of the relay node is also considered to prevent quick node failure.In a third one a cost field is established. Here during set up phase all nodes wait for a time T_{wait} to receive set up messages from sink through all possible routes. After this time, it sets up the route having the lowest cost and residual energy greater than the threshold. Hence the number of control messages can be decreased but the route set up time increases. Figure 4 illustrates the procedure for creating a minimum cost gradient[5].

3.2. Hierarchical Routing Protocols

Hierarchical routing protocols has the advantage of scalability and efficient point to pint communication with a small route state[21].Here the nodes play different roes according to the network topology.

3.2.1. *Low Energy Adaptive Clustering Hierarchy (LEACH)*

LEACH[22] is a self organising protocol n which the nodes are arranged into clusters. To prevent the inter and intra cluster collisions during data access TDMA or CDMA are used. The data is accessed periodically and hence LEACH is appropriate for constant monitoring. LEACH run in rounds.

To decide whether a node becomes a cluster head for a specific round it selects a random number between 0 and 1.If this chosen number is less than the following threshold, then that node becomes the cluster head.

$$T(n)=\frac{p}{1-p*r\mathrm{mod}(1/p)} \text{ if } n \varepsilon G \qquad (1)$$

where n is the node, p is the a priori possibility of node becoming cluster head, r is the current round, G is the set of nodes that has become cluster head in the last 1/p rounds[5].

Modifications in LEACH include LEACH-C and TL-LEACH[5].In LEACH-C there are two phases, setup phase and data transfer phase. In set up phase, the nodes communicate to the base station regarding their positions and energy and data communications occur in the data transfer phase. In TL-LEACH there are two cluster heads instead of one so as to reduce the number of nodes directly communicating with the base station.

3.2.2. *Power efficient gathering in Sensor Information systems (PEGASIS)*

PEGASIS[23] forms a chain through the nodes using a greedy algorithm and the nodes takes turns in communicating with the base station. The control overhead and the number of nodes in direct communication with base station are lesser and hence PEGASIS has better performance than LEACH[23]. But in a densely deployed network, the chain formation increases delay. Also PEGASIS can’t be applied in networks whose global topology isn’t available. It also doesn't consider the energy of the routing node. Hierarchical PEGASIS is a modification in which nodes are concurrently allowed to route data if they are not adjacent[5].Figure 5 illustrates the chain construction[5].

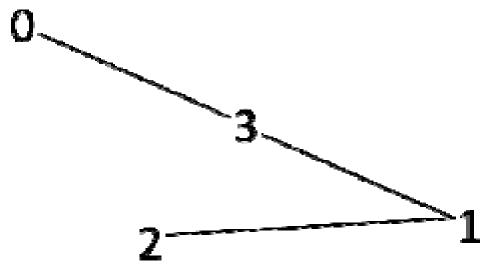


Figure 5:Chain construction using greedy algorithm[5]

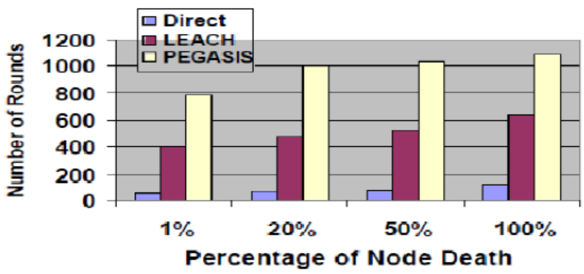


Figure 6: Performance results for 50mx50m network with initial energy 0.25J/node[5]

3.2.3. *Threshold Sensitive Energy Efficient Sensor Network Protocol (TEEN)*

TEEN[24] was the first reactive protocol formed. In TEEN the nodes are divided into clusters and two cluster heads 1st level and 2nd level are selected. Similarly two thresholds are kept. The hard threshold allows transmission only when the sensed attribute is in the range of interest and the soft threshold allows transmission only when there is sufficient change in the sensed quantity.

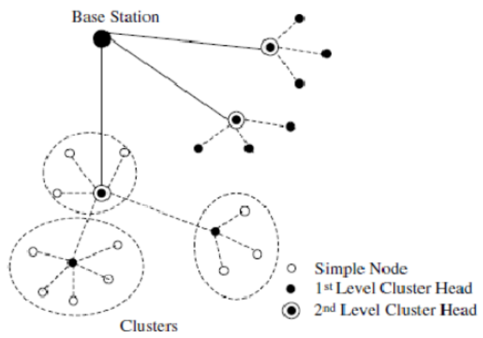


Figure 7:Hierarchical clustering in TEEN and APTEEN[5]

The aim of these thresholds are to avoid unwanted transmissions. But because of the same TEEN can't be used for periodic data monitoring as surveillance or environment monitoring. But it can be used to detect intrusion, explosion etc Since these are time critical applications, using of TDMA is not advisable. CDMA is a better option. The clustering model is illustrated in figure 7[5].

In adaptive TEEN(APTEEN)[24] data is collected periodically along with responding to time critical data. Here, once the cluster heads are decided, they broadcast attribute, threshold, schedule and count to the member nodes. The main disadvantages of both TEEN and APTEEN are overhead and cluster forming complexity. APTEEN has better performance than LEACH but poorer than TEEN in terms of energy efficiency and network longevity.

3.2.4. Energy Aware Cluster based Routing Algorithm (ECRA)

ECRA was an idea to remove the disadvantages in LEACH and it was proposed by Jyh-Huei Chang[25].The main disadvantages of LEACH are

1. If the range of a cluster head is small, there won't be any members in that cluster.
2. It involves long distance communication between cluster head and sink.
3. The re-election of cluster heads are done globally, increasing the processing and communication overhead[5].

Hence in ECRA, after each round there is intra-cluster cluster head rotation to avoid the cluster heads concentrating in a small area.ECRA-2T(ECRA two tier) is an improved version, where a higher tier is provided. All the cluster heads are members of the higher tier and the cluster head having the maximum energy is selected as the main cluster head of the 2nd tier. After a round, the lower tier cluster heads are re-elected and from them, the main cluster head is selected. ECRA outperforms LEACH, static clustering, direct communication etc[5].

3.3. Location based Routing Protocols

3.3.1. Minimum Energy Communication Network (MECN)

MECN[26] forms a subnetwork for the communication between the current source and destination. It is self organising and can adapt to node failure and addition of nodes. Between two consecutive wake ups of nodes, all nodes can update the minimum cost link based on joining or leaving nodes. Small MECN(SMECN) is an extension to MECN where the possible obstacles between two pairs of nodes are assumed. If the broadcasts are able to reach all nodes within a circular region of the broadcaster, subnetworks constructed by SMECN has lesser number of edges than MECN and hence consumes lesser energy[27]. But the setup overhead for SMECN is comparatively larger than MECN. The relay region for node pair (i,r) is depicted in figure 8[5].

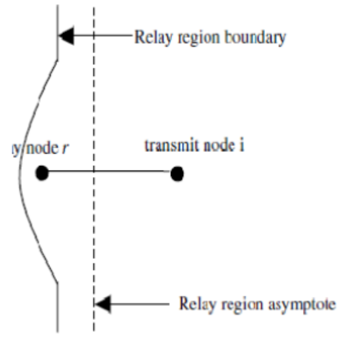


Figure 8:Relay region of transmit relay node pair(i,r) in MECN[5]

3.3.3. Geographic Adaptive Fidelity (GAF)

Here, the node are deployed densely in the sensing area, but only one node is made active in each area of interest[29].The idea is to reduce the number of nodes forming the network. If the sensor network area is considered to be divided into cells, to ensure proper connectivity, there should be at least one active node in two adjacent cells. This limits the cellular size to be, 1 active node in $R^2/5$ m where R is the range of each node. Hierarchical GAF(HGAF)[5] aims to increase the area covered by one active node, by adding a layered structure for selecting the active node in each cell. It limits the position of active node placement in each cell and synchronises that position in each cell. Thus HGAF outperforms GAF in dense networks in terms of survival of nodes and packet delivery ratio.

3.4. Multipath Routing Protocols

The wireless links are highly dynamic and the capacity of the multihop paths are limited. Hence, for efficient and reliable high rate data transmission, multipath routing protocols were deployed.

3.4.1.N-to-1 multipath routing protocol.

This protocol forms multiple node disjoint paths to the sink from each node[30].Initially in the branch aware flooding stage, the sink sends route update request towards each node. Each node makes the sender of this update request to it ,as the parent towards the sink. If a neighboring node overhears this request, it forms a disjoint path towards the sink. Thus initially a spanning tree is formed. Next the network enters multipath extension flooding stage where alternate paths to the sink are found. This protocol tries to increase reliability by employing a per hop packet salvaging strategy. But concurrent data transmissions can degrade the network.

3.4.2. Multipath Multispeed (MMSPEED)

The protocol provides a cross layer design between network layer and MAC, for QoS differentiation in terms of reliability and timeliness[31].This is an extension of SPEED[32] protocol which has various speed levels and layers. Each data packet is placed in the appropriate layer and hence the corresponding queue. All queues are treated in a FCFS basis.

MMSPEED aims in enhancing reliability by sending the packet through different paths. Each sender selects one node among it's one hop neighbours based on the link packet loss information and distance to destination. But it has been experimentally proved that[33],for low power wireless links ,reliability depends on the distance and interference power of receiver. Moreover, long distance links can degrade the energy of the network. Hence MMSPEED is not advisable for long life applications.

3.4.3Braided Multipath Routing Protocol

This is a seminal protocol for fault tolerant networks[33].It has the same idea as directed diffusion.The sink node uses two reinforcement messages,primary path reinforcement message and alternative path reinforcement message. The sink node sends the primary path reinforcement message to it's best neighbour towards the source node.At the same time,it sends the alternative path reinforcement message to it's second best neighbour towards the source node.Each node that receives these messages forwards it to their corresponding best neighbour towards the source node.Thus two partially disjoint paths are formed.This protocol has lesser overhead than n-to-1 multipath protocol.

3.4.4. Energy Aware Routing Protocols

These protocols select their next hop neighbour based on some probability so as to balance the load throughout the network.One such way of selecting the next routing node is to select the one having the maximum residual energy and signal strength above a predefined threshold[35].The route discovery starts from the sink to the source.If two neighbours have the same metric,both of them start a random back off timer.The one whose timer finishes first will sends an implicit acknowledgement to the sender which is also received by the other node running the timer.This process is continued till the source receives this broadcast.The source than replies with a route reply message to the node that has broadcasted to it and it continues till the sink.Those nodes that aren't part of the route goes to a sleep state.This protocol provide a reliable link for unicast transmission since data is cached in the sender until an acknowledgment is received.In case of no acknowledgement,an error message is generated and data is send back to its sender node.The disadvantages of the protocol are that neighbours need to exchange local information and needs unified addressing increasing the cost of route setting**.**

3.5. Network and QoS aware routing protocols

Some protocols model the route set up and solve them as a network flow problem.QoS aware protocols consider end to end delay while setting up the route.Protocols that aim at maximum lifetime consider the residual energy of the nodes and the transmission cost of the link before the route set up.

3.5.1. Minimum Cost Forwarding Protocol[36]

The protocol selects the minimum cost path which will also be simple and scalable.The protocol isn't based on data flow,but flow rate can be considered since data flows through the minimum cost path and consumes the node's and the link's resources/It has two phases.The first phase is the cost set up phase where a cost field id established.It starts from the sink and diffuses through the nodes.The nodes add the cost of the nodes from which it received the message to the link cost to find their own costs.

In the second phase,the source broadcast the message to the neighbours[36].The message is deferred for a predefined time until the minimum cost message arrives.The transmission cost of the node to the sink is added to the message cost.If the remaining cost of the packet is sufficient to reach the sink,the message is forwarded,else it is dropped.There is no need for a node to remember the next hop neighbours or addressing and hence the number of unwanted advertisement messages can be reduced.

3.5.2. Sequential Assignment Routing(SAR)[37].

It is the first protocol that uses the notion of QoS in it's routing decisions.It is a multipath table driven protocol that strives to attain fault tolerance and minimum energy consumption.SAR creates multiple trees rooted at the sink's one hop neighbours with QoS metric,energy use in each path and priority level of each packet in consideration.Fault tolerance is achieved by routing table consistency between the downstream and upstream nodes.A local fault is removed by a locally run path restoration algorithm.SAR has minimum energy requirement than protocols that only use energy as the metric and not packet priority.But the control packet overhead is very high due to the maintenance of tables and states at each node especially in the case of large networks.

3.5.3. SPEED

SPEED[32] is a QoS aware protocol that guarantees soft real time end to end delivery.It requires the information about the neighbouring nodes and uses geographic forwarding.Moreover,SPEED ensures a minimum speed for each packet.This helps the applications in calculating the end to end delay by dividing the distance to the sink by the speed of the packet for admission control.

The routing module in SPEED is called stateless geographic non-deterministic routing(SNGF) and works in co-ordination with four other modules in the network layer.It uses beacon exchange mechanism to obtain information about other nodes and their location.The delay at each node is calculated by finding the elapsed time when an ACK is received in response for a transmitted packet.Using this delay values,the neighbour that ensures the promised speed is selected.If no neighbour provides the speed the real ratio of the nodes is checked.

The relay ratio is provided by the neighbourhood feedback loop and is calculated from the miss ratio(modes that didn't meet the requirement) of the neighbouring nodes.This is then fed back to SNGF.If the relay ratio is less than a randomly generated number between 0 and1,the packet is dropped)[32].

The back pressure rerouting algorithm helps to prevent void and congestion avoidance by sending the packet back to the source node for re-routing.SPEED outperforms source dynamic routing(SDR) and adhoc on demand vector routing (AODV) n terms of end to end delay and miss ratio. Transmission energy required is also less due lo lesser overhead and dispersion of the packets to a lager relay area.

3.6. Comparison of Routing Protocols in WSNs

Table 1:Comparison and classification of routing protocols in WSNs[5]

Routing protocols	Classification	Power Usage	Data-aggregation	Multipath	Query-based	Qos
SPIN	Flat	Ltd.	Yes	Yes	Yes	No
Directed Diffusion	Flat	Ltd.	Yes	Yes	Yes	No
Rumour Routing	Flat	Low	Yes	No	Yes	No
GBR	Flat	Low	Yes	No	Yes	No
LEACH	Hierarchichal	High	Yes	No	No	No
PEGASIS	Hierarchichal	Max.	No	No	No	No
TEEN & APTEEN	Hierarchichal	High	Yes	No	No	No
ECRA	Hierarchichal	Max.	Yes	No	No	No
MECN & SMECN	Hierarchichal	Low	Yes	No	No	No
GEAR	Location	Ltd.	No	No	No	No
GAF	Location	Ltd.	No	No	No	No
N-to-1 multipath	Flat	Ltd.	Yes	Yes	No	No
MMSPEED	QoS	Low	No	Yes	No	Yes
Braided Multipath	Flat	Ltd.	Yes	Yes	Yes	No
Energy Aware	Flat	N/A	No	No	Yes	No

4. ROUTING PROTOCOLS IN UNDERWATER WIRELESS SENSOR NETWORKS

Underwater wireless sensor networks(UWSNs) are used for ocean sampling,underwater exploration,disaster management,seismic monitoring,assisted navigation etc[39].UWSNs face the same problems of limited battery power and bandwidth,varying channel conditions and propagation delay.The requirement of power is worsened due to the absence of solar power. Acoustic waves are preferred over radio and optical waves under water.Moreover,the nodes are mobile due to water movements and other aquatic activities.These difference leads to the need of new routing protocols[40].

4.1. Preliminaries on UWSNs

UWSNs consists of various sensors like cabled sea floor sensors,moored sensors,acoustically connected sensors and autonomous underwater vehicles[41] as illustrated in figure 9[38].All of these are deployed to perform collaborative monitoring over a given volume.

These sensors transmit to a surface station with an acoustic transceiver on the surface which can handle multiple parallel communications from different sensors.The surface station also has a radio/satellite transceiver to communicate to the on shore sink or the surface sink[42].UWSN architecture is classified into two dimensional with fixed nodes and three dimensional with autonomous underwater vehicles(AUVs)[42].This classification is based on the geographical position of nodes and their mobility.The type of architecture deployed depends on the concerned application.

There are 2-D static sensors for ocean floor monitoring which are anchored to the ocean floor and are used for monitoring environment and ocean floor for tectonics. The 3-D static sensors for ocean column monitoring constitutes a network and their depth are controlled by connecting them to a surface bout using regulated length wires. These are used for environment monitoring and surveillance. There are 3-D UWSNs constituting mobile portions of AUVs and fixed portions of anchored sensors.

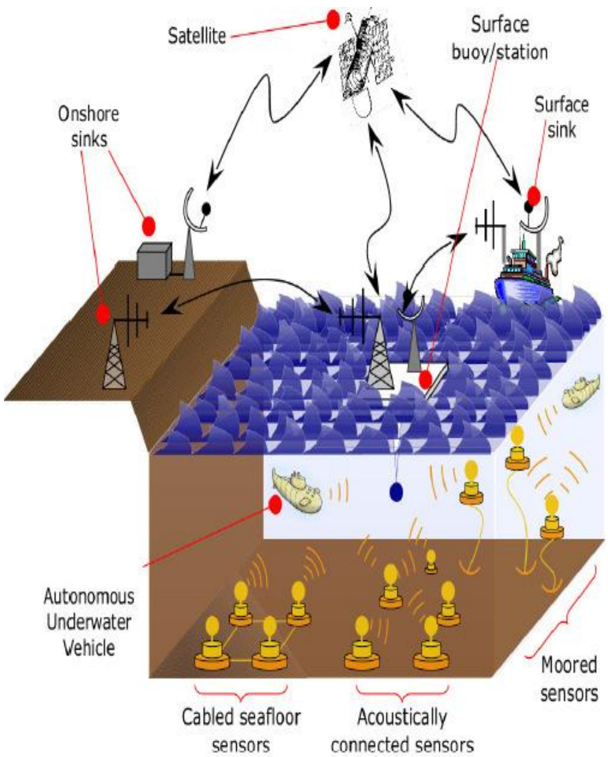


Figure 9:Different ways of deployment of UWSN[38]

4.2. Challenges Faced by UWSNs [42]

1. Limited available bandwidth.
2. Highly impaired channels mainly due to multipath propagation and fading.
3. Propagation delay is five times in order of magnitude greater than terrestrial channels.
4. Limited available power aggravated by the absence of solar energy.
5. High bit error rate and temporary lose of connectivity (shadowing zones) due to the nature of under water channel.
6. Impairment of sensors due to fouling and corrosion.

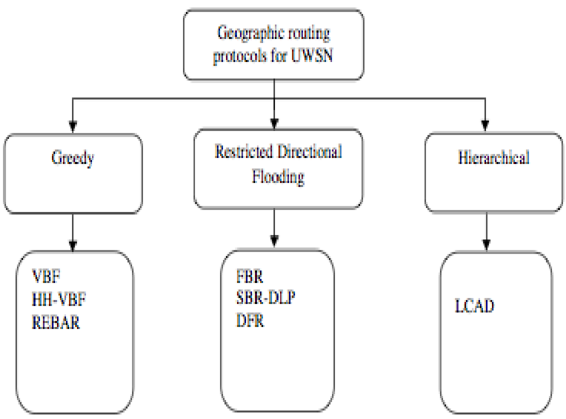


Figure 10:Classification of geographic routing protocols for UWSN[38]

4.3. Classification of Geographical Routing Protocols for UWSNs

Geographical routing uses the location information in routing decisions.Hence the nodes need to know the location of its one hop neighbours only.This is an advantage over topological routing which need network wide dissemination of control messages.This increases the problems of energy usage and memory usage of the nodes and it worsens in large scale networks.In figure 10,geographic routing protocols are classified into three[38].

The most important information for the source in geographical routing is the location of destination.This should be known to the source using some location services.Based on which all nodes host the location service,four different combinations are possible;some for some,some for all,all for some,all for all[43].

4.3.1. Protocols based on greedy Algorithm

In greedy algorithm the nodes send the packet to it's one hop neighbour nearer to the destination than itself without maintaining a complete route between the source and the destination[43][44].Alternatively,the data packet can contain an approximate position of the destination so as to route the packet properly.All nodes periodically broadcast a beacon to inform their one hop neighbours about their location.These types of routing are scalable,size independent and aren't affected by topology changes.But the beacons can create congestion in the network and mitigate the node's energy[45].

4.3.1.1. Vector Based Forwarding(VBF)

Each node calculates it's position based on angle of arrival(AOA) technique and signal strength[46].The location of the sender,destination and forwarding node are embedded in the packet.The path transmission is along a vector situated at the centre of a pipe.All nodes within the pipe are members of the route.

To minimise the energy consumption the selection of an eligible node for packet fro wading is given by a desirableness factor α

$$\alpha = \frac{p}{w} - \frac{R - d\cos\theta}{R} \qquad (2)$$

where p is the projection of the node A on the routing pipe S1S0

A is the node whose desirableness is calculated

w is the radius of the routing pipe

R is the range of transmission

d is the distance between the current forwarding node F and A

θ is the angle between vector FS0 and FA

Each node holds the packet for a time $T_{adaptation}$ given by

$$T_{adaptation} = \sqrt{\alpha} \times T_{delay} + \frac{R - d}{v_0} \qquad (3)$$

where T_{delay} is a predefined time called maximum window period and v_0 equals the speed of acoustic signals in water(1500m/s).If the node receives a duplicate packet during $T_{adaptation}$ it compares the desirability factor of both and decides the forwarder of the packet.

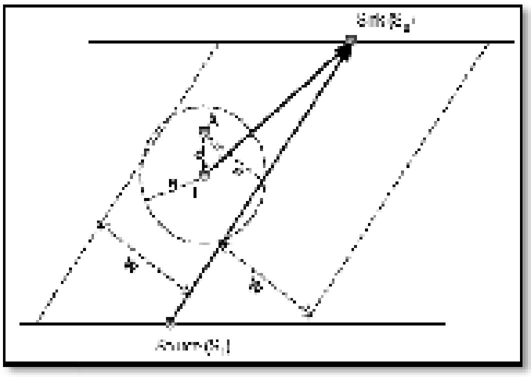


Figure 11:Desirableness factor of VBF[38]

4.3.1.2. Hop by hop VBF (HH VBF)

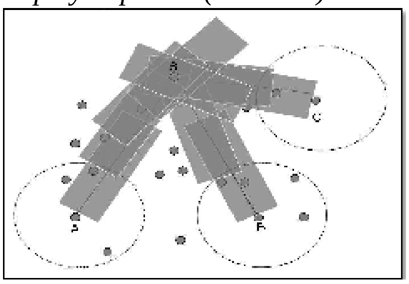


Figure 12:HH VBF routing protocol[38

The main problems associated with VBF protocol is the sensitivity of the radius of the routing pipe and low packet delivery ratio in sparse networks. Hence the same routing is done in a hop by hop basis in HH VBF[47].Here in each hop,a virtual routing pipe is created instead of a single one from the source to the destination.Once a node gets a packet tom the sender or a forwarding node,it calculates a vector from the source to the destination.Then it finds it’s distance to this vector.If the distance is less than the radius of the routing pipe,then the node is eligible to forward the packet.

The desirability factor is given by

$$\alpha=\frac{R\text{-}d\cos\theta}{R} \qquad (4)$$

The node holds this packet for $T_{adaptation}$. If during this period ,it receives a duplicate packet,it calculates the distance between it and the forwarding neighbouring nodes. If the smallest distance among this is greater than a predefined threshold,then it forwards the packet or else drops it.

4.3.1.3. Reliable and Energy Balanced Algorithm Routing(REBAR)

This protocol addresses three issues -unbalanced energy consumption,low packet delivery ratio and void problems[49].Here a spherical energy depletion model is assumed which is later extended to include the mobility of the nodes.Mobility is considered as an advantage since it helps in balanced energy consumption.The broadcasting is kept to a specific domain based on the geographical position of the source to minimise energy consumption.Every packet will have an ID consisting of the source ID followed by a sequence.

The receiver will have a buffer to store recent packets.The received packets is compared with these stored packets and duplicate transmissions are avoided.The constrained radius of the nodes are variedly set according to their positions.For example the nodes nearer to the sink has lesser radius to prevent them from taking part in the routing.Every source calculates a vector v to the destination and its distance d to the sink.Both these information are embedded in the packet.The packet is then broadcasted.

To ensure that the packet is going in the correct direction,a node i,upon receiving a packet calculates its distance to the sink,d(i).If the difference between d(i) and d,i.e d(i)-d is greater than a predefined threshold and if the node i’s distance to the vector v is greater than the constrained radius of the node the packet is discarded.Figure 13 illustrated the routing process of REBAR[38].

The nodes are divided into boundary nodes and non-boundary nodes.The routing process for non-boundary nodes are asexplained above.For boundary nodes,they broadcast to all neighbours without considering the vector and radius,so as to avoid the void problem[50][51]

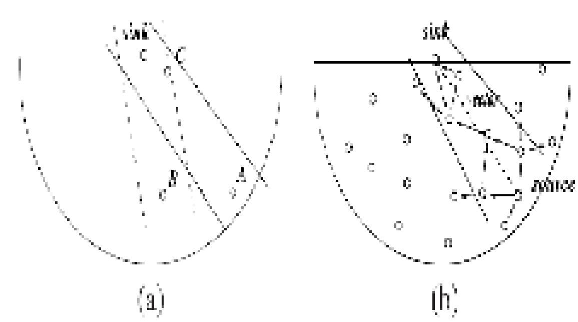


Figure 13:Routing process of REBAR[38]

4.3.2. Protocols Based on Restricted Directional Flooding.

Here the source broadcasts the packets to all its single hop neighbours towards the direction of destination.When a node receives the packet,first it will check,if it is among the set of nodes that should forward the packet.If yes,it will forward the packet,else it will drop it.Here instead of a single neighbour,the packet if forwarded to multiple neighbours for[38**]**

1. Increasing the probability of finding the shortest path.
2. To increase reliability during node failures.
3. To correct positon inaccuracies.

4.3.2.1. Focussed Beam Routing (FBR)

This is an energy aware location based protocol.Here each node knows only it’s location and the location of the destination.Various transmission power levels are used ranging from P_1 to P_n and the corresponding radius of transmission d_n [52]. This transmission radius equals the cone of the angle emanating between the source and the destination.The selection of the next forwarder node is done as follows:

- The source node sends an RTS(Request to Send) using the transmission power level P_1.
- If only one CTS(Clear to Send) is received,then that node is the next hop node.
- If Multiple CTS are received,the source selects the node nearer to the destination.

- If no CTS is received,then the transmission power is increased to next level until a CTS is obtained.
- Even after increasing to the maximum power level,if no CTS is received,the cone of the angle emanating is shifted to the left or right and the process is continued.

Figure 14 illustrates FBR[38].

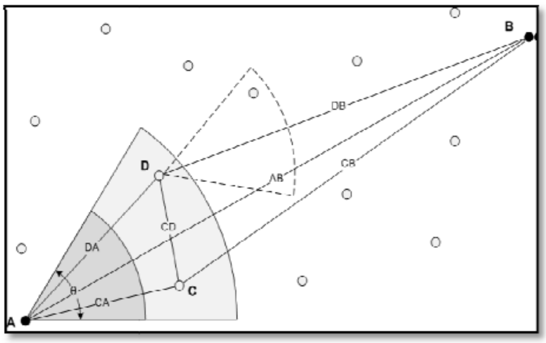


Figure 14:Illustration of FBR:Nodes within the transmitting cone are candidate relays[38]

4.3.2.2. Directional Flooding Routing(DFR).

The main aim of this protocol is to reduce the packet loss due to node mobility and aquatic movements[53].Here each node knows its geographical position,its one hop neighbour's position and the position of the sink.It can also calculate the link quality to its one hop neighbours. Initially a predefined value called BASE_ANGLE is set to a predefined value A_MIN and is involved in the packet.When a forwarding node F receives a packet,it calculates the angle SFD(where S is the source and D is the destination).If the angle SFD called the CURRENT_ANGLE is less than A_MIN,then it discards the packet,as the node is outside the flooding zone.Else,the node F calculates the link quality to its one hop neighbours.If the average link quality is worser than a predefined threshold,then the BASE_ANGLE,A_MIN is decremented by an amount A_DCR or else it is incremented by an amount A_ICR and the packet is forwarded. This adjustment on BASE_ANGLE is done to adjust the size of the flooding zone based on the quality of the link.Thus DFR supports scoped flooding.An example of packet transmission is shown in figure 15[38].

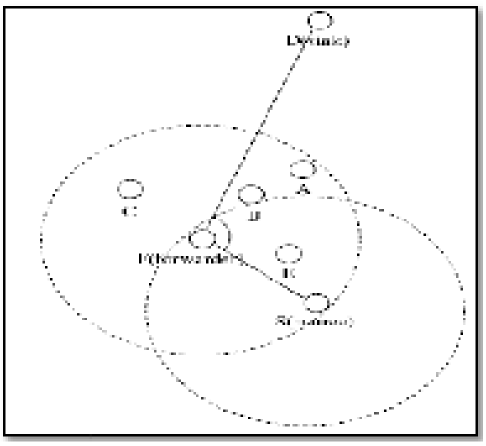


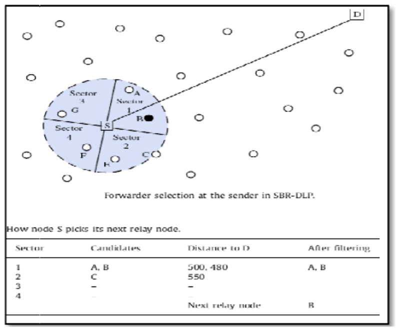
Figure 15:An example of packet transmission in DFR[38]

4.3.2.3. Section based Routing-Destination Location Prediction(SBR-DLP)

The destination location is usually assumed fixed where as it is not so because of the under water currents and the self propelling capability of the node.In SBR-DLP the source need to know only its location and the predefined motions of the destination which are defined even before launching the network[54].There is no need to know the network topology or the location of the one hop neighbours.Routing is done in a hop by hop basis.

To forward a packet,the source broadcasts a Chk_Ngb packet which includes source location and packet ID.The nodes that receive he packet checks if they are closer to the destination than the source.If so, they reply with a Chk_Ngb_Reply packet. Figure 16 illustrates the process[38].

Thus SBR-DLP is like in FBR in case of selecting the next hop node unlike VBR or HH-VBR in which the relay node decides whether to relay the packet or not.But FBR considers only a section of the network for relaying where as SBR-DLP considers the entire network area.FBR requires to re-transmit the RTS every time a candidate node is not found in the relay zone where as SBR-DLP doesn't need to do so.



Sector	Candidates	Distance to D	After filtering
1	A, B	500, 480	A, B
2	C	550	
3	–	–	
4			
		Next relay node	B

Figure 16:The SBR-DLP Routing Protocol[38]

4.3.3. Protocols based on Hierarchical Forwarding Strategy

Several clustering algorithms like LEACH[22],HEED[54] and PEGASIS[23] are used in terrestrial networks.These can't be used for underwater networks due to the nature of aqueous media. Hierarchical forwarding strategies are mainly used to make the network scalable. Some protocols combine hierarchical strategy along with location based strategy for dominating set routing such as grid in LCAD (Location Based Clustering Algorithm for Data Gathering)

4.3.3.1. Location based Clustering Algorithm for Data Gathering(LCAD).

In LCAD[55],the entire network is divided into 3 dimensional grids as shown in figure 17[38].The optimal horizontal range is 50m and vertical range nearly 500m.Each grid is set approximately to 30x40x500.Each grid contains a cluster.Within the cluster,a cluster head is selected based on sleep wake pattern and residual energy and memory.The cluster heads are placed on the vertical centre of the grids to have efficient communication with the member nodes.To increase reliability and to help in load balancing,multiple cluster heads are used. The data communication is done in 3 phases.

1. Set up phase:The cluster heads are selected in each grid.
2. Data gathering phase:The member nodes send their data to the cluster heads.
3. Transmission phase.The data are sent by the cluster heads to the base station.

The grids are arranged just like cells in cellular network.LCAD uses 32 bit addresses asin IPV4 and has two level addressing scheme-one for intra-cluster and one for inter-cluster communication.The intra-cluster communication is of the form GRID.X.Y.Z where GRID represents the grid number,and X,Y and Z the positions with respect to the X position.Addresses beyond 255.0.0.0 are reserved for cluster heads.

The addresses for inter cluster communication are of the form 255.GRID.X.Y.Here the Z position isn't required since the cluster heads are ensured to be in the vertical centre of the grid.Thus there can be 256x256x256 unique addresses in the grid and the sensor deployment density can be as high as 27 nodes/m^3[38].

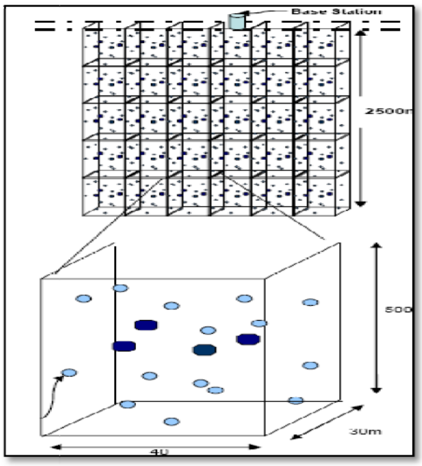


Figure 17: Architecture used in LCAD protocol with projection of a single grid[38]

Table 2: Comparison of routing protocols for UWSN[38]

Protocol	Forwarding Strategy					Location Service		Design Goal			
	Type	**Shape routing**	**Robustness**	**Scalability**	**Packet Overhead**	**Type**	**Robustness**	**Density**	**Mobility**	**Void Handling**	**Destination Mobility**
VBF	Greedy	Single pipe routing	high	high	Low	All for some	Medium	Dense	Both	No	No
HH-VBF	Greedy	Per hop pipe routing	High	High	Low	All for some	Medium	Sparse	Both	No	No
REBAR	Greedy	Specific Domain	High	High	Low	All for some	Medium	Dense	Mobile	Yes	No
FBR	RDF	cone	Medium	Medium	Medium	All for some	Medium	Sparse	Both	No	No
DFR	RDF	Base angle	Medium	Medium	Low	All for some	Medium	Sparse	Mobile	Yes	No
SBR-DLP	RDF	sector	Medium	Medium	Medium	-	-	Sparse	Mobile	No	Yes
LCAD	Hierarch ical	Grid Routimg	Medium	HIgh	Low	-	-	Dense	Mobile	No	No

5. ROUTING PROTOCOLS FOR WSNS WITH MOBILE SINKS

Recent researches have shown that introducing mobility in wireless sensor network is advantageous as the mobile nodes can relocate after initial deployment to achieve the desired density requirement and reduce the energy holes in the network thereby increasing the network life time[77]. Networks with mobile sinks were thought of to mitigate the hot spot issue.The hot spot issue refers to the problem of quick energy depletion of the neighbouring nodes of the sink due to the converging nature of the traffic[57].Hence,if the sink is mobile,it's neighbouring nodes change and the energy consumption can be balanced.But the mobility of the sink causes change in network topology and data path.Hence extra signalling needs to be done to update the data paths which calls for more efficient and scalable routing protocols.

5.1. Classification of Routing based On Design Criteria.

5.1.1. Delay sensitive and Delay tolerant Routing.

In delay sensitive routing[58-67],it is ensured that the data reaches the sink in a timely manner.Hence quick routing updates according to the position of the sink need to be given.At the same time,care should be taken not to overload the network with communication overhead.

In delay tolerant routing[68],the collected data can be buffered in any node and can be dumped to the sink when the sink comes in close proximity with the node.Later when the sink moves near the wired connection of the base station,these data can be sent to the base station.

5.1.2. Centralised and Distributed Routing.

This classification is based on where the routing decisions are taken.If they are taken by a centralised server58][59],the routing is centralised.The server runs a protocol for all the communication requests maintaining the global state of the network.Route discovery and updating can be jointly considered with sink trajectory programming.But the problem arises when the network needs to be scaled or when there is a single point of failure.The whole network routing needs to be changed to accommodate the changes.

In distributed routing[60][67],a node makes a local route discovery based on the network state (global or local) it maintains. The main focus is not to burden the network with the communication overhead for routing update along with successful packet delivery ratio.These type of protocols are more scalable and robust than centralised types.

5.1.3. Routing based on the mobility pattern of the sink.

The sink movements are classified as discrete and continuous. In discrete case,the sink sojourns at some places and collects data only when it is not moving[58].Routing for continuous movement of the sink is more complex[60][67].The continuous movements of the sink are agin classified as random,fixed and controllable.In random type,as the name suggests the sink moves in a randommanner[60][61].In fixed type,the sink moves in a predefined manner periodically[57]. Controllable type of movements are based on the traffic allocation,QoS requirements of the application and the network state information[59][60].Controllable sink movement provides better data quality and QoS requirements but requires extra hardware and information.

5.1.4. Location based and Topology based Routing.

This classification is based on the type of routing information required.In location based routing[60][61],the location of a node is found out using it's own GPS module or localisation technique.The main issue here is to learn the trajectory of the sink with minimum overhead.Existing methods address this issue by "frequent local updating followed by infrequent global updating"[60] and "backward path learning through data path discovery"[61].

Topology based routing[62-67] is based on packet gradient,sink tracking or opportunistic route learning through sink overhearing.Here also the main issue is to suppress the control overhead along with maintaining good outputs.Existing methods address the issue by hiding the sink's short movement.For the same,the sink selects a neighbouring sensor node as it's anchor node.This anchor collects all the data towards the sink and transmits it to the sink.

5.2. Centralised Routing Protocols

These protocols jointly consider traffic allocation with sink tracking.The protocols discussed consider single or multiple sinks,node with or without power control and continuous sink movements or sinks that adjourn at discrete locations.

5.2.1. Constrained Mobile Base Station(C-MB) / Unconstrained Mobile Base Station(U-MB)[59].

In C-MB,the sink moves in a controlled manner and adjourns at discrete locations.Here the optimal data schedule and trajectory is controlled by the locations where the sink adjourns and the time it adjourns at each location.The optimal schedule is obtained in polynomial time by liner programming.

In U-MB,the search area for the optimal solution is continuous and infinite and thus more complex.Hence, this search area is divided into sub areas and each sub area is projected into virtual points.Then the optimal solution for C-MB is applied.The optimal solution for C-MB is 1 to ε times the optimal solution of U-MB case.

5.2.2. Maximising Network Lifetime(MNL).

Here multiple sinks moving at discrete locations were considered[58].It assumes a fixed transmission power[59].The authors initially proposed a $(1-\varepsilon)^2$ approximation algorithm for the MNL-SMS(MNL-Single Mobile sink) problem.Then they proposed a polynomial $(3+w)(1-\varepsilon)^2$ approximation algorithm for the multiple sink problem.They proved that under their framework,there is always a scheme using multiple sink(s) that achieve more network network lifetime than the deployment using fixed sink(s).

5.3. Distributed Routing Protocols

5.3.1. Location based Routing Protocols.

5.3.1..1. Local Update based Routing Protocol [60].

Here the sink mobility is confined to a particular area called the destination area.The sink selects it's current position as it's virtual centre(VC) and defines an update range L.The destination area is a circular region with VC as it's centre and L as the radius.V and L are flooded through the network.Nodes outside the destination area route their packets geographically to VC and nodes inside route them topologically.When the sink moves out of the destination area,a new VC and L is updated and again flooded through the network.

The adaptive LURP(ALURP)[60] further restrains the mobility of the sink.Here the update range is not L but depends on the distance between the VC and the current position of the sink.This distance will be smaller than L.The performance of both LURP and ALURP depends on the choice of L.A small L calls for frequent global updating and bigger L for frequent local updating.Only single sink cases are considered.

5.3.1. 2. Elastic Routing[61].

Here the source learns the sink location by employing backward learning through data path.The sink periodically transmits a beacon.The second to last hop node in the data path learns the sink location from this beacon.This location is overheard by the predecessor in the data path and thus it reaches the source.This works well for continuous reporting but fails in the case of sporadic reporting.Also a time stamp is required in the location information to determine the freshness of the location in case of mobile sinks.

5.3.2. Topology based Routing Protocols
5.3.2.1. Anchor-based Voronoi Routing Protocol(AVRP)[62].

A Voronoi daigram is the partitioning of a plane into subregions based on the closeness of the points to a previously defined specific set of points called seeds or sites or generators.AVRP works on Voronoi scoping and dynamic selection of anchor nodes.Here multiple sinks roam in the sensing field in an uncontrollable manner.Each sink selects the neighbour with best link quality as it's anchor node.The anchor nodes then disseminates the interest through the network region to find the Voronoi scoping.The nodes then sent their data to the respective anchor nodes (closest to them)which transmit them to the sink.

Figure 13 illustrates at the working of Voronoi scoping for an mWSN with three sinks[57].The advantage of AVRP is that the interest message dissemination initiated by the anchor node is constrained by the Voronoi scope. The communication overhead is too high in AVRP if the anchor nodes are changed frequently.AVRP is suitable for high data traffic and infrequent anchor node shifting.

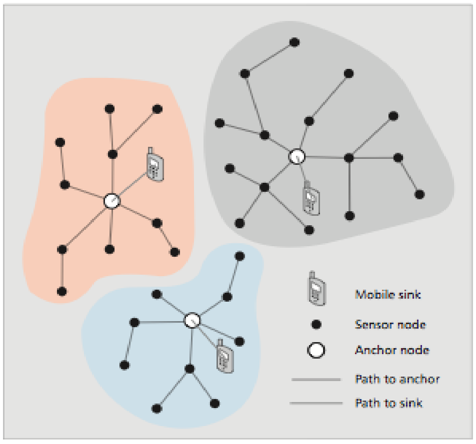


Figure 18:An example of how Voronoi scooping with three mobile sinks works[57]

5.3.2.2. Multi-stage Data Routing Protocol(MDRP)[64]

MDRP has a slight advantage over AVRP in terms of communication overhead.In MDRP each Voronoi scoped region is again divided into layers based on the sensor node's gradient.The gradient is measured in hops.If the gradient of a sensor node is h hops then it's level is $\lceil h/L \rceil$ where L is the width of each layer.Thus the first level consists of the small region including the sink and the last level includes the slice containing the boundary of the sink's Voronoi scope.

When the sink moves inside the first level, it needs to update it's routing information inside the first level only.But when it moves to the kth level,it needs to update it's routing information in 1st∪2nd∪…..∪kth levels.Thus MDRP reduces the frequency of Voronoi re-scoping and thus reduces the communication overhead in terms of a slight compromise in routing performance.

5.3.2.3. TRAIL based Routing(TRAIL)[62].

The mobile sinks leaves a trail by periodically transmitting a beacon to it's one hop neighbours.When a sensor node wants to transmit data,it forwards the data through a combination of random walk and trail based forwarding.It triggers a random walk until the data reaches a node that has a sink trail and then forwards along the trail.New trails can intercept old trails for updating the position of the sink.Neighbouring sensor nodes overhear the data transmission for gratuitous route learning,there by extending the sink trail and reducing the probability of random walk.TRAIL is best suitable for light traffic and highly mobile sinks.Figure 19 illustrates working of TRAIL in networks with one and two mobile sinks respectively [57].

5.3.2.4. Data Driven Routing Protocol(DDRP).

The route learning in DDRP [63]is a combination of random walk and data driven learning.Thedata packet has an additional option of learning the number of hops from a node to sink.When such a data packet is being forwarded,a neighbouring node can overhear the hop count and update it's route for a fresher or shorter route.When a valid route does'nt exist from a node to sink,the protocol performs random walks until it reaches the sink or a node having a route to the sink.This protocol has less overhead and can be used along with other protocols like AVRP.DDRP is best when sensor nodes have continuous data to report.

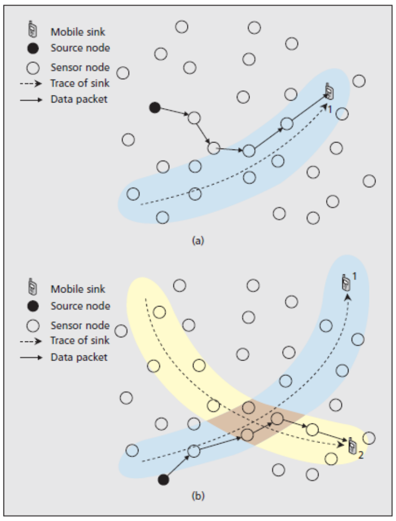


Figure 19:Example of how TRAIL works in mWSNs with a) 1 mobile sink and b) 2 mobile sinks[57]

5.3.2.5. λ Flooding.

λ flooding [65]puts a bound to the worst case stretch ratio when a sensor node changes it's anchor.The worst case stretchratio is the maximum value of the ratio between a sensor node and it's anchor through a pre-built spanning tree and the actual shortest distance between them.In the initialization stage of the network,the sink builds a minimum spanning tree through the network with it's current anchor *u* as the root.This is done by flooding a control message throughout the network. Now,when the sink changes it's anchor to node *v*,the protocol pa r t i a l l y upda t e s the rout ing t r e e a s follows.Firstly,the new anchor *v* notifies *u* of the change and then *v* broadcasts a control message to it's one hop neighbours.This update message consists of the distance between *u* and *v* through the tree Tu(u,v) and the distance the message actually travelled from v to u.When a sensor node *x* receives the message,it calculates the route cost to the new anchor *v* through the tree i.e Tu(v,x) and the actual distance the update message travelled denoted by Tv(v,x).If Tu(u,v)+Tu(u,x) is greater than λ times Tv(v,x) then the sensor node updates it's routing path by changing it's one hop neighbour to the one from which it received the message.The protocol considersonly one mobile sink[65].The value of λ can affect the routing control overhead and worst case stretch ratio.Also the selection of the initial root of the spanning tree will have a great impact on the network performance and needs to be optimised.

5.3.2.6. Whirlpool Routing Protocol(WARP).

WARP[66] uses gradient information and speculative routing to route data packets to the sink.The sender sends the data packet based on the sensor gradient information towards the sink.Once the sink moves from it's position,speculative routing forms spiral trajectories around the mobile sink's last known position.For this trajectory formation,no geographical information and only gradient information is required.

As in the figure[57],the source S sends data to the sink through the shortest path found through gradient based routing.Here,A is the second to last hop node.Once.the mobile sink moves it's position,upon the next packet arrival,A finds that it has lost the connectivity to the sink.Then A forms spiral trajectories using speculative routing around the sink's last known position.Speculative routing in other words can be told as random walks around the gradient based contours.To increase the probability of finding the sink,the searching radius can be probabilistically increased. If the sink doesn't receive any data for sometime,it transmits a beacon.in the figure,the sensor node D receives the beacon and finds that it has got a connectivity to the sink.When the data packet reaches D through speculative routing, a new route to the sink is found.Then a reverse notification is sent to stop the speculative routing.WARP also uses overhearing to refine the routing and converge to the shortest tree.The performance of WARP is highly dependent on the data rate.Higher the data rate better the performance,since data packets are used to probe and refine the routing structure.Data packets may not be successfully delivered in sparser networks,if speculative routing fails to find the sink.

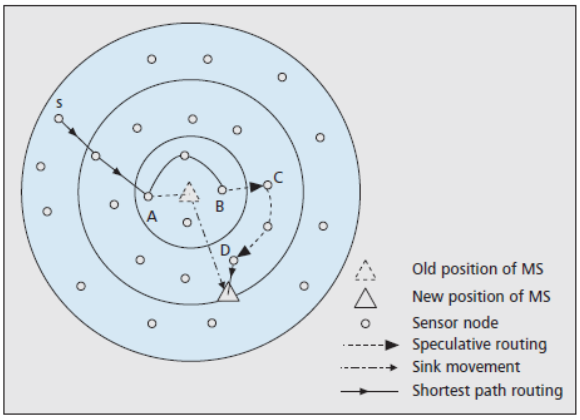


Figure 20:An example of how speculative routing in WARP works[57]

5.3.2.7. Prdeictive QoS Routing(PredQoSR)

PredQoSR [67]uses information potential based routing and mobility prediction to ensure successful packet delivery incase of sink mobility.To assist the routing,the protocol creates a potential field and establishes information gradients in the network.The information gradient associated with a node can be interpreted as the probability that a random walk triggered from this node reaches the sink before it reaches the network boundary.The potentials in the network induces a spanning tree which points to the current anchor node which has the highest potential.

Kusy et al[67]found that for local movements(within one or two hops) of the sink,information potential based routing converges to a new tree within one or two iterations.For nonlocal routing PredQoSR creates a mobility graph,a data structure recording that records the mobility pattern of the sink and can be used for mobility prediction.Using this graph,the most likely next anchor node can be predicted by matching the current RSSI of the sink with the previous RSSI traces recorded in the past.The information potential for this next anchor is calculated and stored for future packet routing and easy route convergence.

Table 3:Comparison of routing protocols for mWSNs[57]

Properties Protocols	Centralized/Distributed	Location Aware	Routing Method	Consider Multiple Sinks	Use anchor node	Overhearing	Update Range
MNL	Centralized	Y	Traffic allocation	Y	N	N	-
C-MB&U-MB	Centralized	Y	Traffic allocation	N	N	N	-
LURP	Distributed	Y	Geographic+topology	N	Y	N	Local+Global
ELASTIC	Distributed	Y	Geographic	N	N	Y	Continous overhearing via one hop neighbours
AVRP	Distributed	N	Shortest path	Y	Y	N	Voronoi Scope

TRAIL	Distributed	N	Random walk+Trail based	Y	Y	Y	One hop neighbours
DDRP	Distributed	N	Random walk+data driven	Y	N	Y	Continous overhearing via one hop neighbours
MDRP	Distributed	N	Shortest path	Y	Y	N	layered voronoi scope
λ FLOODING	Distributed	N	Approx shoretst path	N	Y	N	Local
WARP	Distributed	N	shortest+speculatv	N	N	Y	Local
PredQoSR	Distributed	N	information potential+mobility	Y	Y	N	Global

6. CONCLUSION AND FUTURE SCOPE.

All protocols designed for wireless sensor networks have the common objective of maximising the network lifetime[5].Most of the protocols require the location information of the nodes to calculate the distance between them and thereby find out the required energy for communication.Any single protocol among the discussed one's cannot be applied for all situations.Also single path routing protocols cannot offer high data rate transmission due to limited channel capacity and highly dynamic links.

In mWSNS,all distributed protocols aim to achieve low overhead practically[57].Many methods like local updating using location or gradient information,opportunistic route learning through channel overhearing,hierarchical route learning,voronoi scoping,use of anchor nodes or a combination of these have been tried.No single approach can be used in all scenarios.For example in mWSNs using greedy geographic forwarding,the location updating of the sink should be very efficient.Yan[72] proposed a method of hierarchical location service(HLS),where the network is divided into equal grids and location service is locally done grid wise.This reduced the overhead required and the latency in retrieving a location update.Li[73] proposed two geographic routing protocols which guarantees data delivery to a mobile sink with random movement and predictable movement respectively.Along with efficient routing protocols other factors that should be taken into consideration are the traffic pattern(periodic or sporadic reporting),network working mode(always on or duty cycled),mobility pattern of the sink,application requirements(time criticality of the data),existence or lack of mobile sink,existence of a link between mobile sink and it's neighbours[57].

Machine to Machine(M2M) communication is a recent paradigm and in wireless networks and internet these communication has been realised separately[69][70]. When these are integrated with WSNs,these M2M devices need to act as mobile sinks and need to work in dual mode(interfaces for WSNs and internet).A hierarchical network architecture [70]can be thought of to adapt to the future billions or trillions of M2M devices.In such cases,when M2M devices act as mobile sinks,the design and management of network architecture need to be considered along with the matching of uplink capacity of M2M devices and WSN requirements and in future billing of M2M devices that really data to WSNS[70].

In UWSNs,there exists issues which are open for more development.Improving the location service can improve the routing performance under water[38].Void,unlike that in terrestrial networks can be mobile under water.As an example,when a ship moves above,connections can be temporarily impaired .which can create a void that moves along with the ship.The same attack that happens in terrestrial networks happen under water also.For example,the location information that has been broadcasted can be replaced by the location of a malicious node.But the security measures above water can't be applied because of propagation delay,low bandwidth,inability to recharge batteries and mobility of the nodes[38].Energy consumption is also crucial.The protocols need to take into consideration the limited energy and scalability of the network while providing the minimum QoS requirements.

7. REFERENCES

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