Development of Cluster Based Routing Protocol in Underwater Acoustic Wireless Network

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Abstract*—Underwater communication has become a popular research area because of many applications such as oceanography data collection, ocean exploration, undersea navigation, and control of autonomous underwater vehicles (AUVs). Since electromagnetic wave communication does not propagate well in underwater, long communication ranges are only possible through the use of acoustic waves. Acoustic communication is the most versatile and widely used technique in underwater environments due to the low attenuation (signal reduction) of sound in water. Underwater acoustic communication is a technique of sending and receiving message below water. The implementation of underwater acoustic communication (UWAC) system is rendered challenging by factors such as limited available bandwidth, throughput, long propagation delay, large Doppler spread, and time-varying channel conditions. From this limitation in underwater wireless networks, throughput is one of the main parameter will be affected. Based on network structure, routing protocols in Underwater Communication Networks can be divided into two categories: flat routing and hierarchical or clustering routing. Due to a variety of advantages, clustering is suitable an active branch of routing technology in underwater communication Networks. Based on these findings, to developing cluster based routing protocol is designed to improve the throughput of the network by considering connectivity and coverage.

Keywords: Underwater Acoustic Network, Coverage, Connectivity, Throughput, Energy consumption.

I. INTRODUCTION

The past 30 years have seen a developing interest in underwater acoustic communications because of its applications in marine commercial operations, oceanography, the offshore oil industry, marine research, and defense. Underwater acoustic sensor networks are the technology that allows many underwater applications. Underwater Acoustic Sensor Networks (UASNs) performs a cooperative checking tasks over a three-dimensional arrangement space. Anchored nodes are equipped with moving buoys by pumps, and the depth of the anchored node is controlled by adjusting the length of the wire. The buoyant force from buoys is far better than the gravity of nodes. The measurements of environmental events are locally monitored by the anchored nodes, and shifted to a surface sink by multi-hops. Both laser waves and electromagnetic waves are not suitable for acoustic communication and underwater transmission is the typical physical layer technology in UASNs.

A. *Applications*

- Environment monitoring
  -Criticism how human activities affect the marine ecosystem
- Undersea explorations
  -Detect underwater oilfields
- Disaster prevention
  -Monitoring ocean currents and winds (Tsunamis)
- Assisted navigation
  -Find dangerous rocks in shallow waters
- Distributed tactical surveillance
  -Intrusion detection (Navy)

B. *Limitations*

- Battery power is limited and usually batteries cannot be recharged easily.
- The available bandwidth is severely limited.
- Underwater sensors are prone to failures because of corrosion, fouling, etc.
- Extremely affected by environmental and natural factors such as heterogeneities of the water column, variations of sound velocity versus depth, bubble clouds, multiple and random sea reflections and significant scattering by fish, temperature and salinity, and plankton.

C. *Challenges*

- Available bandwidth is limited
- Propagation delay is five times of Radio Frequencies
- High bit errors
- Temporary loss of connectivity
- Battery power is limited
- Failure of tendency in the underwater sensors because of corrosion.

II. PROBLEM OBJECTIVE

In summary, Coverage, Connectivity, reduction of propagation delay and energy consumption are the primary objectives of UASNs. The topology control objectives of UASNs can be formally presented as follows:

1. Coverage
2. Connectivity
3. Min Consumption
4. Delay
5. Throughput

III. SYSTEM MODEL AND ASSUMPTION

A. Model description

Nodes: $V_k \in V$, its current communication radius, sensing radius, and residual energy are denoted as RC (*k*), RS (*k*), and RE (*k*), respectively. We suppose that $0 \leq RC(k) \leq RC\chi$, $0 \leq RS(k) \leq RS\chi$, $0 \leq RE(k) \leq RE\chi$. $RC\chi$, $RS\chi$ and $RE\chi$ are the maximum communication radius, maximum sensing radius and maximum battery energy, respectively. Any ordinary node V_k can be in either SLEEP or AWAKE state; if V_k is in SLEEP, then

$RS(k) = RC(k) = 0$. $\forall V_i, V_j \in V$, the distance is referred to as *d(i, j)*.

B. Cluster Parameters

Number of Clusters:
It may be varied according to the CH selection algorithms. In some cases this count will be the predestined one.
Intra-cluster Communication:
Communication between the regular node and CH may be one-hop communication or multi-hop communication.
Nodes and CH Mobility:
Cluster formation is dynamically changed in the case of sensor nodes are in mobility.
Node Type and Roles:
Nodes may be in homogeneous or heterogeneous nature. In homogeneous, all sensor nodes have same capabilities such as same energy level configurations. In heterogeneous, all sensor nodes are varied in configurations.
Cluster Head Selection:
CHs are selected from the deployed nodes based on the criteria such as connectivity, communication cost, residual energy, and mobility. CH choice could be in deterministic or probabilistic manner.
Multiple Levels:
In very large networks, multi-level clustering approach is used to achieve better energy distribution.

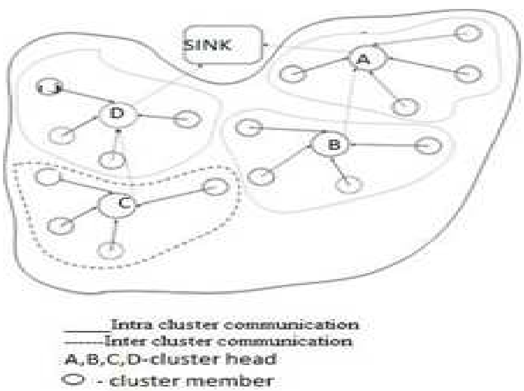


Fig-1.Data communication in a clustered network

C. Cluster Head Selection

Select CHs using three criteria

- Residual Energy,
- Number of Neighbors, and
- Distance from the Base station of the nodes.

IV. ROUTING

Several of the routing approaches are based on the shortest path algorithm. In this technique, each link in the network is allocated a cost which is a function of the physical distance and congestion. The algorithm tries to find the shortest path, i.e., the path with the lowest cost, from a source node to a destination node. In a distributed implementation, each node determines the cost of sending a data packet to its neighbors and shares this information with the other nodes of the network. In this way, every node maintains a data base which reflects the cost of possible routes. In ad hoc networks, the main problem is to obtain the most recent state of each individual link in the network, so as to decide on the best route for a packet. However, if the communication media is highly flexible as in the shallow water acoustic channel, the number of routing updates can be very high. Present research on routing focuses on reducing the overhead added by routing messages while at the same time finding the best path, which are two conflicting requirements. In a recent paper [19], the authors compared four ad hoc network routing protocols presented in the literature:

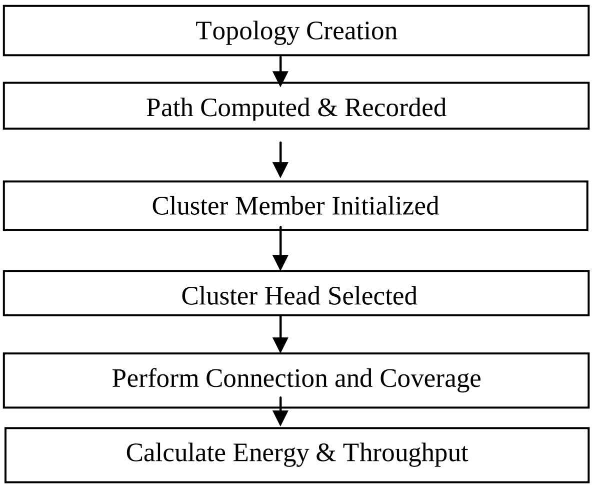
- Destination Sequence Distance Vector (DSDV)
- Temporally Ordered Routing Algorithm (TORA)
- Dynamic Source Routing (DSR)
- Ad hoc On-demand Distance Vector (AODV)

DSDV maintains a list of next hops for each destination node which goes to the shortest distance route. The protocol requires each node to periodically broadcast routing updates to maintain routing tables. TORA is a distributed routing algorithm. The routes are discovered on demand. This protocol can provide multiple routes to a destination very quickly. The route optimality is considered as a second priority and the routing overhead is reduced. DSR employs source routing, that is, the route of each packet is included in its header. Each intermediate node that receives the packet checks the header for the next hop and forwards the packet. This eliminates the need for intermediate nodes to maintain the best routing information to route the packets. AODV uses the on-demand route discovery as in TORA and has the maintenance characteristic of DSR, and employs them in a hop-by-hop routing scheme instead of source routing. Also, periodic updates are used in this protocol. In a mobile radio environment, DSR provides the best performance in terms of reliability, routing overhead, and path optimality. The effect of long propagation delays and channel asymmetries caused by power control are issues that need to be addressed when considering application of these network routing protocols to UWA channels.

V. ALGORITHMS

- Topology Control Algorithm (TCA)
  TCA consist of two phases
- First phase, applied to the Edge Constructed Model (ECM), which can obtain an initial topology Creation.
- Second phase, Distributed algorithm that extracts a double clustering structure from the initial topology.

A. *Algorithm Dataflow*



B. *Network Model*

We consider a static large-scale WSN with high node density. A set of ***N*** nods, ***V= {v_1, v_2... v_N}***, are uniformly distributed in a two-dimensional plane ***S***. We have the following assumptions:

- Each node has a unique ID.
- The wireless channel is symmetric and obstacle-free.
- There exists an underlying MAC layer resolving interference, and we do not take into account the interference outside the transmission range.

C. *TCA*

A scale-free structure is recognized with the development of the initial topology from ECM, TCA is then proposed to construct a double clustering structure topology. TCA is executed round by round, and at every round TCA selects some cluster-heads or determines some nodes radii. The details of TCA are as follows.

Step1: The initial topology is generated from ECM, and all the edges from set *E*.

- ECM – The ECM is designed to form an initial topology where all possible edges should be calculated based on the assumption that all nodes use the maximum communication radius.

Step2: A Cluster-head *H*→*S* is defined and initialized.
Step3: At current round, any adjusting node V_i calculated
Step4: Communication Radius *(RC(i))* should be computed.
Step5: Repeat Steps 3 and 4 until all nodes have determined their roles and radius.
Step6:Any node *Vi* senses with Sensing radius *(RS(i))* and communicates with *RC(i)* Ordinary nodes turn off the radio when the UASN enters the SLEEP state.

VI. ANALYSIS

A. *Energy Consumption and Propagation Delay*

Maximum energy consumption is produced when all nodes adopt the maximum sensing or communication radius. The energy consumption is composed of three parts: the sensing consumption from Coverage, the communication consumption from Connection, and the communication consumption from ordinary nodes in AWAKE state.
To calculate energy for each node is given by
Consume energy= Initial energy – final energy
Maximum energy = consume energy
Average energy=total energy/n

B. *Throughput*

Throughput or network throughput is the average rate of successful message delivery over a communication channel. The system throughput or aggregate throughput is the sum of the data rates that are delivered to all terminals in a network
Calculate aggregate throughput is given by
Throughput = Received Packet / (stop time-start time)

C. *Neighbor Node*

Number of neighbors connected
Depends upon distance from a node

$$D = sqrt((x_1 - x_2)^2 + (y_1 - y_2)^2) \quad (1)$$

Where *(x_1, y_1)*→ co-ordinate of one node
(x_2, y_2)→co-ordinate of another node
Maximum the neighbor, the network will be denser.

D. *Distance Calculation*

Distance can be calculated by

$$D = sqrt((x_1 - x_2)^2 + (y_1 - y_2)^2) \quad (2)$$

Where *(x_1, y_1)*→ co-ordinate of BS
(x_2, y_2)→co-ordinate of a particular node

VII. SIMULATION EVALUATION

We used Network Simulator-2 (ns2) as simulation tool to analyze the performances of the Cluster head selection algorithm. This includes connection and coverage and increase the throughput of the network. TCA is estimated by observing the performance variation of different model parameters and by comparing TCA with other algorithms. The transmission delay from the algorithm calculation and energy consumption from the receiving messages are neglected in the simulations. Table 1 shows the values of the parameters.

TABLE 1: SIMULATION PARAMETERS

Parameters	**Specification**
Simulation tools Used	NS2 Network Simulator (NS 2.35)
Simulation Time	60 sec
Number of Nodes	100
Transmission Range	250 m
Maximum Speed	0-22 m/sec
Application Traffic	CBR(Constant Bit Rate)

Packet Size	512 Bytes
R_{uw}	1500m/s
Initial Energy	100 J
Protocol	AODV

A. Simulation Set Up and Network Scenario

NS2 Simulator generates a TCL (Tool Command Language) file. Running the tcl file results into two files, first file stands the trace file which contains all the data regarding the network and second file is the NAM (Network Animator) file which is a visual aid presentation how packets flow beside the network and displays the Virtualization of the network corresponding to the trace file. All routing protocols in NS2 are growing in the directory of “ns-2.35”.

VIII. SIMULATION RESULTS

A. Nam Window

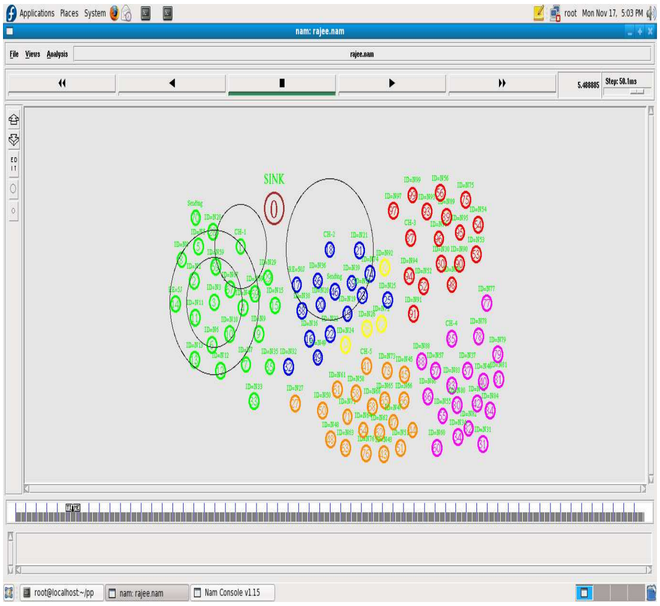


Fig-2. Cluster Formation in Nam Window Using 100 nodes

B. Packet Delivery Ratio

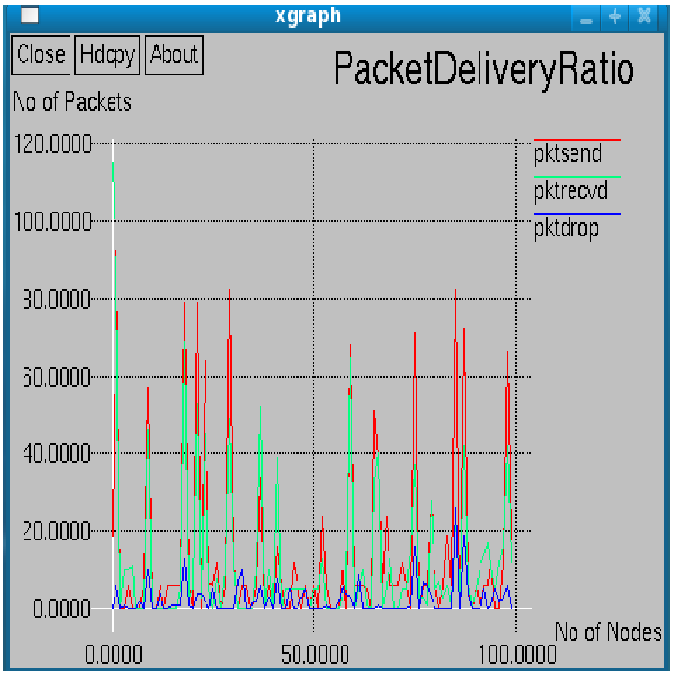


Fig-3. Packet Ratio with 100 nodes

C. Throughput of the Network

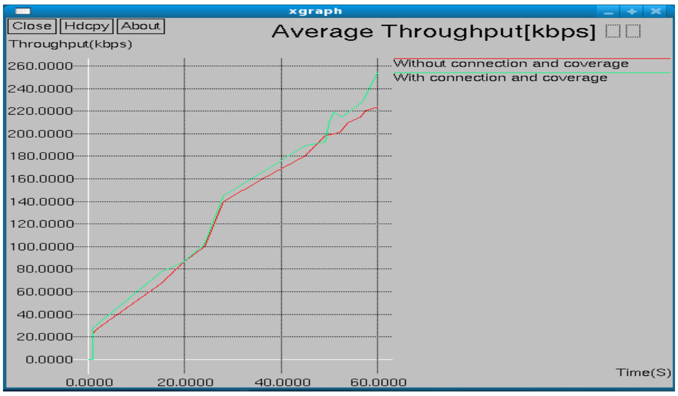


Fig- 4. Throughput of the network (100 Nodes)

Here, the normal network throughput is 243 Kbps
With Connection and Coverage of the Network throughput is 245 Kbps. So, the Throughput is slightly varied in this algorithm.

IX. CONCLUSION

The problem of energy conservation and delay reduction has been implemented in Coverage and Connectivity for UASNs. Cluster based routing protocol in UASNs which improves the throughput of the network by maintain the connectivity and coverage.

In our work, we simulated the connection and coverage in the Wireless networks using AODV routing protocol and examine its influence. Similarly, other routing protocols could be simulated as well. Simulation results for different routing protocols are likely to present varied, interesting and thought provoking conclusions. Here, the throughput slightly varying but future work to increase the throughput to a considerable value by implementing other suitable technique for Cluster Head selection and connection and coverage algorithm.

ACKNOWLEDGMENT

The authors would like to thank the unidentified reviewers for their constructive comments and suggestions which improved the paper significantly. The authors would also like to thank Dr.V.Rajendran, Former NIOT Chairman, India, for his valuable comments and careful reading of the drafts of the paper.

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