

An Energy-Efficient, Cross Layer Approach for Time-Critical Applications in Underwater Sensor Networks

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ABSTRACT: The Ocean remains the least explored frontiers. Many oceanic and marine applications seen relatively slow in exploiting the state of the art info-communication technologies. Acoustic communications is the most promising mode of communication underwater. Because of high error rate and long propagation delay of the acoustic channel, it is difficult to provide energy efficient communication. We proposed a new scheme which guarantees a good balance between the overall energy efficiency, end-to-end packet delay and end-to-end delivery ratio. This scheme smartly combines power-control with multipath routing and packet combining at destination. With carefully designed power-control strategies and since no hop-by-hop retransmission is allowed, multipath transmission introduces much shorter delay than the traditional one-path scheme with retransmission. We conducted extensive simulations to evaluate the performance of multipath power-control transmission. Our result shows that multipath transmission is highly energy-efficient with low end-to-end packet delays.

Keyword: Underwater Sensors, Underwater Environment, Multipath transmission, Packet Combination.

I. INTRODUCTION

Earth is largely covered by water. This is largely unexplored area and recently humans are showing interest towards exploring it. Natural or man-made disasters that have taken place over the last few years have aroused significant interest in monitoring oceanic environments for scientific, environmental, military needs etc. In order to perform these monitoring task industries are showing interest towards deploying sensor nodes underwater. Also advancements in technologies helped in using many novel networking schemes. Sensor network greatly influence different areas of technologies like science, industries and government. This is because of availability of low powered processing, storage units and micro electrical and mechanical systems used in the construction of on board sensing units [2].

Wireless underwater networking is the enabling technology for underwater applications. The sensor networks deployed underwater consists of numerous sensor nodes and underwater vehicles, which helps in monitoring over a given area. But to achieve these objectives sensors and vehicles should have self organizing ability in an autonomous network that can adapt to differing characteristics of underwater environment [1].

II. UNDERWATER NETWORK

We consider multi-sink underwater sensor network with acoustic modems distributed underwater. On the water surface acoustic as well as radio frequency modems are deployed, which receives signal from underwater modems and transmit to the base station.

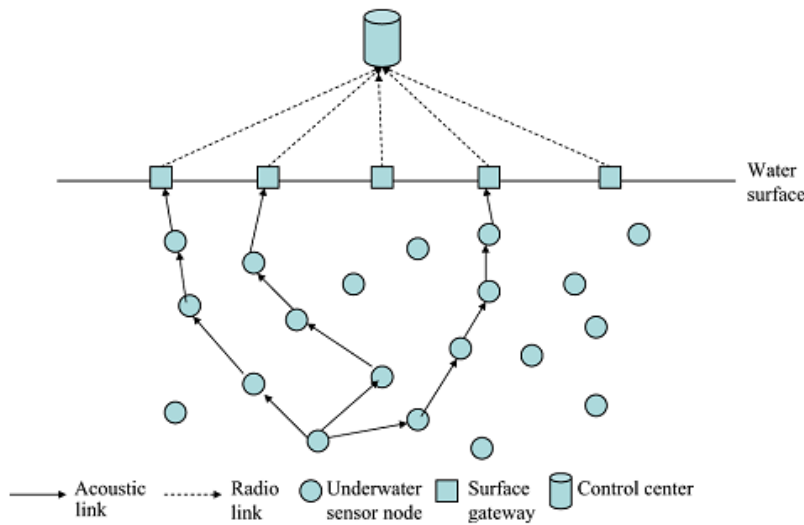


Fig 1: Underwater Network Model.

Network under the water will be as shown in Fig 1. Whenever a node has particular data to send, it distributes it through several paths to the gateways at the surface of the water. These gateways forward the received data using radio frequency link [6].

III. SYSTEM ARCHITECTURE

The system architecture for the simulated system is as shown in Fig 2 and consists of following sub components.

- **Config:** The Config provides a GUI interface to configure the number of nodes and acoustic channel parameters like packet error rate and delay.
- **Acoustic Simulator:** The Acoustic simulator is discrete event simulator. The nodes and sink don't communicate directly instead send packets to the Acoustic simulator. This simulator introduces packet delay and error rate.
- **Node:** This emulates the wireless sensor nodes in the acoustic network. Nodes can generate packets, relay packets.
- **MPT Routing:** Nodes use MPT Routing to know about the routing paths and send across multiple paths.
- **Reporter:** The Acoustic simulator module measure the energy spent by each node and calculate the average energy used by the nodes and provides the values to the Reporter. The Reporter modules store the values and draw the performance graph.
- **Sink:** The sink node combines and restores the packets [5].

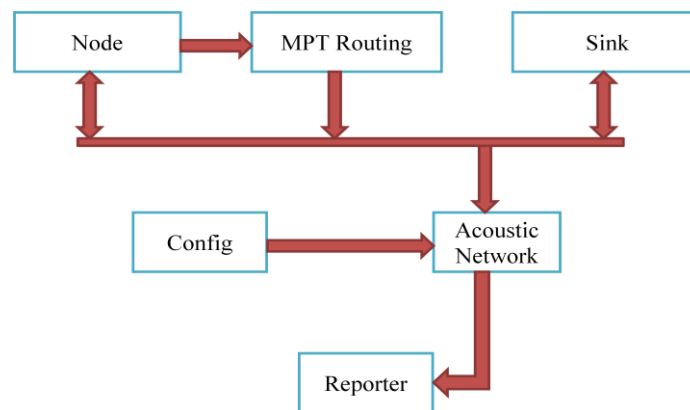


Fig 2: System Architecture.

IV. Design Layout

The design layout of the system is as shown in Fig 3 and the system flow is described below:

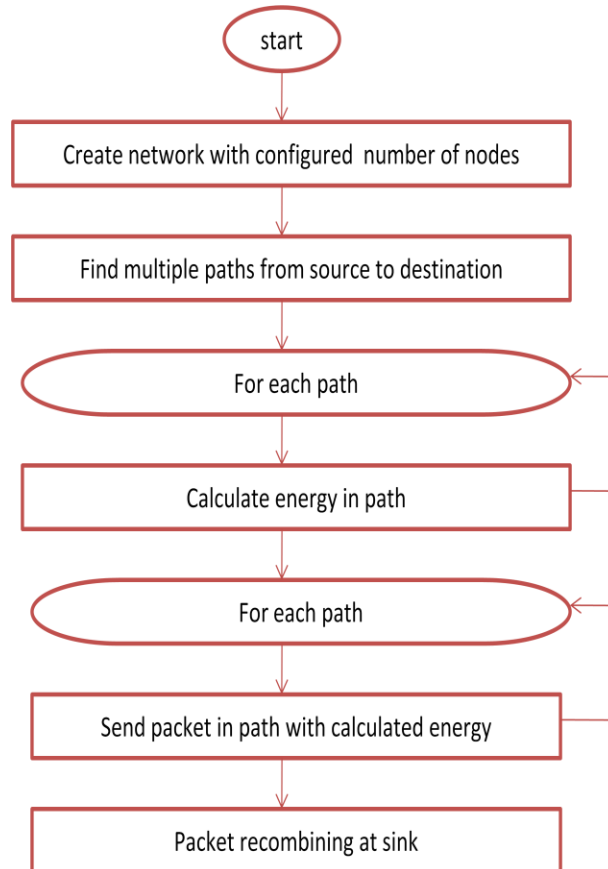


Fig 3: Design Layout.

- Step 1: Create an underwater sensor network with pre configured number of node.
- Step 2: Find multiple path from source to destination.
- Step 3: For each path found, Calculate the energy spent in individual path
- Step 4: Find the path from source to destination which is having minimum energy.
- Step 5: Send packets through paths found in Step 4.
- Step 6: Reassemble all the received packets at the destination.

V. MULTIPATH POWER CONTROL TRANSMISSION

The new scheme, multipath power-control transmission can be seen as a three-fold approach for time-critical application. The three approaches can be classified as:

- Multipath routing
- Source initiated power-control transmission.
- Destination Packet Combining.

A. Multipath Routing

For our system, we will be using modified Ad-hoc on demand distance vector algorithm to support multiple path routing. The basic procedure for multipath routing is as shown in Fig 4.

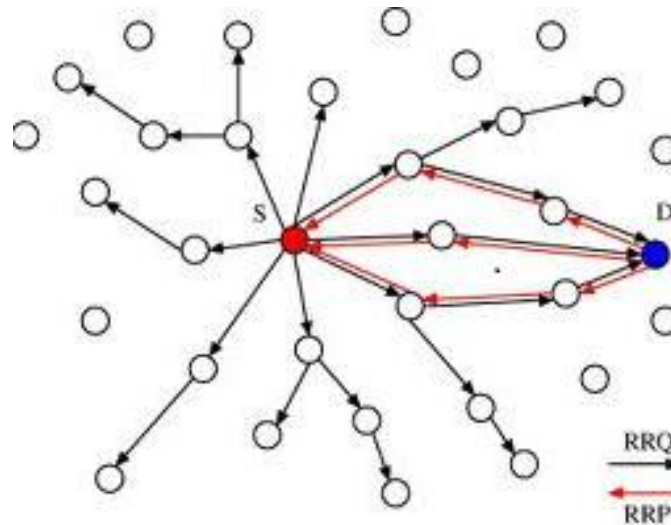


Fig 4: Multi-Path Routing Mechanism.

Whenever the source node has particular information to be sent to destination, it first sends a “Route Request” message through all the nodes to destination. When a particular node receives this message for the first time it forwards the message to destination. Once destination receives this message, it replies with “Route Reply” message through the path through which it had received request message. When source node receives the acknowledgement it sends the packet through the selected multiple paths to destination [4].

B. Source-Initiated Power-Control Transmission

New scheme is said to be Source-initiated because same packets sent by the source node is transmitted through all possible intermediate nodes through the selected nodes. It is a cross layer approach in which functionalities of power management plane, the co-ordination plane and the localization plane are necessary for efficiency.

C. Packet Combining at Destination

The packets sent by source node through multiple paths arrive at the destination. Since no retransmission is allowed, some packets might have been dropped with errors. The technique used is as shown in Fig 5.

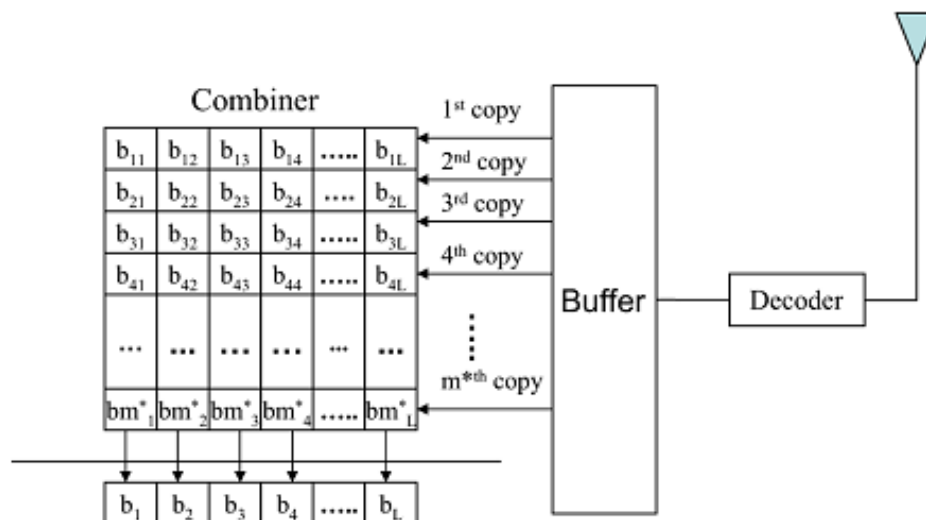


Fig 5: Packet combining technique.

At destination when the message is received, it checks whether this message is correct or not. If it is correct then it has successfully received the message. But if the message is not correct it stores the message in its buffer. When multiple corrupted copy messages are received, it combines them to obtain original message.

VI. ENERGY DISTRIBUTION PROCESS

The energy distribution process can be described as follows:

Step 1: Using source-initiated multipath routing process, the source node get to know all information like available paths, number of hops for each path and per hop distance.

Step 2: At source node, modified AODV is used for multipath distribution.

Step 3: For each selected path, messages are sent along with the calculated energy ‘ E_i ’ and ‘ G_i ’, constant defined by signal frequency, antenna gains and other parameter.

Step 4: For each node ‘ j ’ along path ‘ i ’, transmitting energy is calculated as:

$$E_{ij} = \frac{G_{ij}}{G_i} \times E_i.$$

Then it transmits packet with energy E_{ij}

Step 5: At destination, when it receives a copy of packet it checks for correctness of the packet. If it is correct then message will be sent to base station or else waits for other corrupted copies and combines to form original message [6].

VII. PERFORMANCE EVALUATION

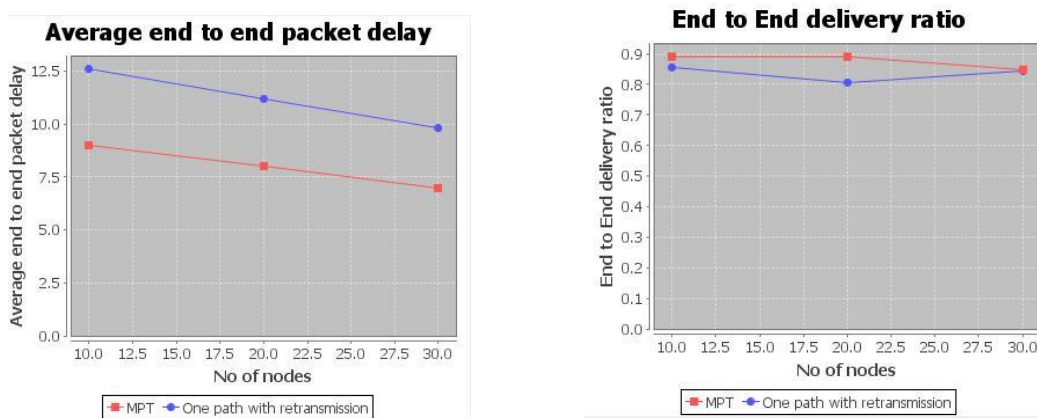
A. Simulation Settings

We used Prowler simulator for simulation with following parameters predefined:

- Number of nodes : More than 10.
- Window size : 400 X 400.
- Transmission Range : 200.
- Broadcast protocol : Vector Based forwarding.
- Routing Protocol : Modified AODV to support multiple paths.
- Each Simulation : 10000s.

B. Result

During simulation we compared new scheme with one-path with retransmission scheme and showed that our new scheme is efficient. During simulation we measured metrics like average and end-to-end packet delay and end-to-end delivery ratio. The comparison graph of the same is shown in Fig 6a and Fig 6b.



(a) Average and end-to end packet delay.

(b) end-to-end delivery ratio.

Fig 6: Simulation Result.

VIII. CONCLUSION AND FUTURE WORK

We proposed a novel multipath power-control transmission scheme, for time-critical applications in underwater sensor networks. This scheme combines the power-control strategies with multipath routing protocols and packet recovery at the destination. Without retransmission at the intermediate nodes, multipath power-control transmission scheme can achieve low end-to-end packet delay. For time-critical applications in energy constrained underwater sensor networks, multipath power-control transmission scheme is a promising transmission scheme for a good balance between packet delay and energy efficiency.

In future we would like to integrate multipath power-control transmission scheme with coding techniques such as erasure codes to further improve the system performance. In networks with high traffic density, interference and collisions among nodes are not negligible anymore. We would like to investigate a new distributed optimization model that takes interference and collisions among nodes into consideration under the framework of multipath power-control transmission scheme. To further improve the energy efficiency, we would like to integrate multipath power-control transmission scheme with more energy-efficient MAC protocols.

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BIOGRAPHY



Rakesh V S completed B.E (CSE) from East Point College of Engineering, Bangalore, Karnataka in 2011 and pursuing M.Tech (CS) in MVJ College of Engineering, Bangalore, Karnataka. My main research interests include Networking and Mobile Computing.



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