A Named-Data Networking Approach to Underwater Monitoring Systems

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ABSTRACT

Scientists take interest in monitoring underwater ecosystems over time because it provides rich data on ecology, pollution, and climate change. We thus envision a searchable monitoring system building on top of the Underwater Sensor Network (UWSN) deployed to collect and deliver data from underwater sensors to globally distributed scientists as they request. In this extended abstract, we explore Named-Data Networking (NDN) as an approach to support data retrieval from this underwater acoustic network. Also, we present a comparative simulation study to investigate several issues relating to the feasibility and performance. These issues are raised due to a couple of choices available as popular research results in terms of how the network can be established.

1. INTRODUCTION

Unlike terrestrial networks which generally rely on distance independent, high-bandwidth radio channels with well-understood, isotropic propagation properties, underwater networks experience severe delay and doppler spread intrinsically due to their adherence to acoustic communication channels. The speed of sound in water is approximately 1500 m/s, which results in channels plagued with remarkably low bandwidth.

With the goal of a searchable monitoring system, we explore the feasibility of using the Named-Data Networking (NDN) communication architecture [2]. NDN transports data based on its name, not on its location like IP networks. NDN seems appropriate for our application scenario because it naturally handles content distribution problems, in which many consumers attempt to access data from distributed sensors. While, the host-to-host communication in IP stack seems inappropriate in this situation since the sensed data are distributed and not associated with any nodes.

NDN does not directly establish connection between two end-hosts, but rather the consumer initiates communication via an *Interest* message. As *Interest* messages are communicated from one node to another, *Pending Interest Table (PIT)* entries are created at each traversed node. This further helps in back tracking the path the message needs to take when it needs to get back to the receiver with the data. Forwarding transmission is based on the *Forward Interest Base (FIB)*, which is populated by name-based routing protocols. A *Content Store* which maps names to data at each node lends NDN a built-in network caching solution. Thus by implementing these data structures at each node, NDN allows a query to be dynamically forwarded towards any node with the desired data, which is particularly important in aquatic environments, where connectivity may be intermittent, or nodes with unstable energy sources may die.

In this extended abstract, our aim is to assess NDN as an underlying network architecture that supports an searchable system and underwater content distribution network. Further, as other network technologies can also be used to retrieve data from the sensor nodes, we study and compare three approaches to support the application, which will be introduced in the following section.

2. THE NETWORK ARCHITECTURES

To construct a searchable eco-info system, three networking models are possible: Named Data Networking, consumer-driven networking and producer-driven networking. In all of them, we consider a master node that behaves as the gateway (also as a consumer) to the underwater sensor networks, receiving requests from scientists and sending them to the sensor nodes, which are the data producers.

In the NDN system, users request Data by sending Interest packets with the name of the data. The application that the scientists use will pass the Interest to the master node that initiates the data search and retrieval process using NDN communication model.

The consumer-driven system represents the current practice by the scientific community when they access the sensor data. Typically, the scientists access the individual sensors via a web portal. The portal may allow them to receive data with a time tag. In this system, the master node, acting as a consumer in our simulation, will relay each request to the intended individual sensor. This model represents an IP-based end-to-end approach. The sensor of interest, upon receiving a request, will reply the needed data.

The producer-driven system represents another popular way of data retrieval from sensor nodes, i.e., the sensors, as data producers, send data directly to a sink (or a master) node at scheduled times. The sink may be connected to a backend database for storage. And the scientists can retrieve the desired data from the web portal of the database. Again,

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this model resembles an IP-based, or an end-to-end (e2e) system.

3. SYSTEM DESIGN

When designing a searchable monitoring system, we consider using the three network architectures as approaches to collect data from underwater sensors and deliver them to satisfy requests from scientists. For NDN model, all data items on the sensor nodes are assigned different name. The master node, as a consumer, broadcasts Interest packets periodically. Only one sensor is able to respond the data with the matching name. The interested data item can only be obtained from the sensor that generates them. It is also possible that the data item can be returned directly from the master node if the Interest is satisfied from its own cache. We use ndnSIM [1], a NS-3 package implementing NDN, to realize this application. In consumer-driven network model, master node sends request packets to all sensor nodes. The sensor node having the data will reply after receiving the request. We implement this e2e application using direct socket in NS-3. The socket is a bare bone socket, unreliable like UDP. For the producer-driven networking, we also use direct socket in NS-3 and sensors send their data to the master periodically all the time.

We experiment with a set of applications. These applications generate Interests to a sequence of data items with different request interval. This setting reasonably mimics the usage patterns of different scientists. We expect that while some requests may request the same data item by different scientists, NDN will have advantage due to the fact that the application with longer interval may request a data item that has been requested by other applications, so that cache in NDN can be used. While for other models, the master node has to acquire the data from the sensor node again.

Due to extremely long delay and heavily packet collision, underwater acoustic transmission needs special-designed MAC protocols to satisfy quality and efficiency of communication. We choose to use CW-MAC that provides a channel-sensing mechanism on the sender side. If there are multiple packets to be sent, MAC layer can enqueue and process them one-by-one. Before sending one packet, it will set up a backoff waiting timer by a pre-defined window size and randomly chosen time slot. If the channel is sensed busy (transmitting or receiving) during waiting, it will pause the timer and resume it when the channel turns to idle. When the waiting timer is up, the packet is sent through physical channel and MAC layer will setup timer for the next packet. During the simulation, we choose the window size as 12, which is the maximum number of sensor nodes, and time slot as 1 second, which is approximate transmission delay for a packet.

4. RESULTS AND DISCUSSION

The goal of this experimental study is to compare performance of three network models as approaches to underwater monitoring system, so we choose to collect metrics related to user satisfaction, response delay and energy cost. Due to page limit, in Figure 1, we only present the results of user satisfaction ratio, which indicates the reliability of network, especially when it is in large-scale (large sensor numbers), or heavy-load (small request intervals). In NDN and consumer-driven networking, the ratio is the number of satisfied requests over the total requests. In producer-driven networking, it is calculated by the number of received solicited data over the total number of data that has been sent.

We can observe from the first sub-figure that the ratio of NDN has always been 100%, which is because master node broadcasts Interest packet to all the sensors and only one of them can reply the data. Other nodes, even though they can receive Interest, will not reply. In consumer-driven model, master node needs to send request to each sensor one-by-one. CW-MAC can control packet collision on sender, but there are still some packet losses while receiving the data. For example, when data from sensor arrives at master node that could be sending request to other sensor at that time, so the data is dropped because the physical channel is busy. In producer-driven model, all sensors send data to master node at scheduled same time, thus the collision happens when master tries to receive multiple data. In addition, it is obvious that the more sensors send data at the same time, the higher probabilities the collisions happen.

Heavy-load has been tested and results are shown in the second sub-figure. We find that NDN has 100% satisfaction ratio unless interval is less than 40 seconds, which is because the interval is smaller than the response delay, thus when the next request is sent out, the previous replied data has not arrived and packet collision happens. For other two models, the ratio is getting lower when there are more requests because MAC layer needs to handle more enqueues.

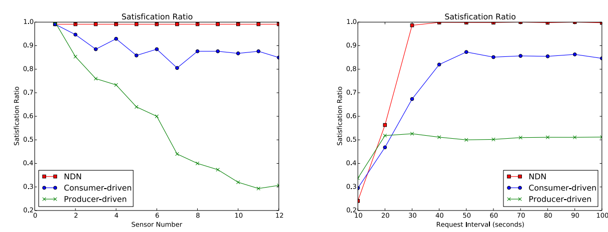

Figure 1: Satisfaction Ratio

5. CONCLUSION

In this extended abstract, we explored NDN as an approach to underwater monitoring systems. Also, we compared performance of three network models and presented the results of user satisfaction, which shows that NDN can achieve higher satisfaction ratio than other two network models, even in large scale and heavy load.

6. REFERENCES

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