Hello everyone. Today I am going to talk about a new scheme for underwater data collection from sensors by using an unmanned ship.

In this talk, I will first introduce some background, and give the brief optimization problem formulation, and talk about how to solve it and give some numerical results.

[page 4] The conventional data collection methods are as follows. We can use cable technologies to transmit data directly from sensors to land. But this method works when the transmission distance is within 1 kilometer. And it is costly to build the cable under the ocean surface; Another approach is to use the satellite communication and sea surface buoys. Here the sensors can transmit their data to buoys, and then the buoys act as relays to forward the data to satellites, and finally the satellites transmit the data to the land. But this approach is costly for buoy development and satellite communication. Another approach is to use multi-hop network transmission by employing both relay nodes under the sea surface and buys. This approach will reduce the satellite communication cost, but it will also incur high network infrastructure deployment and maintenance cost.

[page 5]So our approach is to use an unmanned ship for the data collection task. Specially, this ship equipped with underwater acoustic modems moves from initial to destination, and when it moves close to underwater sensors, the sensor will transmit the data to the ship using acoustic communication technologies. This scheme does not incur network infrastructure cost, and it can be used to collect large amount of data.

[page 6]In this scheme, the limited power of USNs is the first crucial facts we need to consider, since the power is difficult and expansive to recharge. Therefore, our objective is to save the energy consumption for USNs as much as possible, under several constraints. Moreover, the communication loss between the ship and USNs will increase exponentially as the distance increase. Therefore, with the limit of time, we will carefully optimize for the path of the unmanned ship to increase communication efficiency.
Therefore, in this scheme, we should consider the path of the ship, and when and how much power should USNs transmit their data, which means we need to optimize for the wake-up transmission policy and transmission powers of USNs.

[page 9]First, we approximate the transmission rate for underwater acoustic channel based on several assumptions. Assume that the noise for the channel is Gaussian, and the channel is divided into several sub-channels. Therefore, the rate between the k-th USN and the ship, with transmission distance d can be approximated as follows, where p_k denotes the transmission power for the k-th USN.

[page 10]The system model is as follows. The ship wants to collect data from K USNs, and the total time horizon is discreet into M slots. We have three groups of decision variables. The path of the unmanned ship is denoted by q; $x_k[m]$ is a binary number indicating whether the k-th USN is waked up to transmit data or not within the m-th time slot; p_k denotes the transmission power of USNs. The objective is to minimize the maximum energy consumption for these K USNs.

[page 11]The constraints are as follows. Suppose the ship's initial and final locations are fixed. The ship also satisfies the maximum speed constraints. The addition of scheduling variable $x_k[m]$ over all USNs should not exceed 1, which means in each time slot at most one USN is waked up. The system should also be supposed to finish the data collection task, so we have the data load constraint.

[page 12]Therefore, the data collection scheme is formulated as the following optimization problem. Following similar idea of the paper in literature, we could develop an efficient block-coordinate descent method to solve this problem. For example, for fixed p and q, the problem is simply an integer programming, which can be solved efficiently by CVX.

[page 14]One numerical result is also presented, where the ship should be at (0,0) for initial time, and (8000,0) for final time. Within different time limit, the ship have different trajectories plotted in the figure.