TELKOMNIKA, Vol. 11, No. 4, April 2013, pp. 1757~ 1768
ISSN: 2302-4046

Micro-ANP Network Protocol Architecture and Simulation Implementation

DU Xiujuan*[1], LAN Shenglin[2], LIU Fan[3], FENG Zhenxing[4]
[1,2,3,4]School of Computer Science and Technology, Qinghai Normal University, China No.38, Wusi Xi road, Xining city, Qinghai province, China, 810008, 13519784233
Corresponding author, e-mail: 124111397@qq.com, dxj@qhnu.edu.cn

Abstract

Due to the unique characteristics of underwater sensor network (UWSN), conventional network protocols for terrestrial WSN are unable to satisfy the performance of UWSN. In addition, the limits of energy, CPU and memory of UWSN nodes demand the protocol stack running on them should be simple and efficient. The paper proposed a Micro-ANP protocol architecture model for UWSN, which are three layered including application layer, network-transport layer and physical layer, optimized packet size using three objective functions: packet throughput, energy consumption and resource consumption under Micro-ANP architecture by means of MATLAB, designed and implemented UWSN simulation platform based on Micro-ANP and QualNet software, lay a solid foundation for further research on underwater sensor network.

Keywords*: UWSN, micro-ANP, green network, simulation, QualNet*

1. Introduction

Research on Underwater Sensor Network (UWSN) which applies sensor network in underwater environments has attracted significant attention [1-7] recently. UWSN adopts acoustic communication; acoustic channel is characterized by high bit error of 10^{-3}-10^{-7}, long propagation delay in the order of second and low bandwidth of scores of kbps, resulting in terrestrial-based WSN protocols inapplicable for UWSN. Compared with conventional modems, acoustic modems in UWSN are more energy-consuming. However, nodes are battery-powered and harder to recharge and replace in harsh underwater environments. Furthermore, due to the high cost of underwater devices, underwater nodes are usually deployed more sparsely, and most nodes in UWSN can move passively with water currents or other underwater activity, lead to highly dynamic network topology and significant challenges to the protocol design for UWSN.

Current researches on UWSN focus mostly on routing protocol and MAC mechanism, and the whole architecture of protocol stack for UWSN is less investigated. The resources of UWSN sensor nodes such as energy, computing and storage are severely limited, so the protocol stack running on them should be simple and efficient. However, all researches on underwater networking so far are based on traditional five-layered model which is bloated and inefficient for UWSN node with scarce resource, and network efficiency can be obtained only with cross-layer design which will cause lots of hard issues in wireless community, especially in harsh environments such as dynamic topology, seriously impaired channel and scarce node's resources.

With the development of network technology and its application, green network which aims at reducing energy-consumption has become hot spot recently. Green network involves the core scientific issues such as network architecture, network protocols of each layer, innovation of network device structure, algorithm design and optimization etc. Most researches are concerned with only one (or some) aspect of energy saving, such as energy-consumption for the routing protocol or MAC layer mechanisms, and what is needed now is rethinking energy-saving strategy from the global perspective of the whole network .

In this paper, we analyzed UWSN communication characteristics and the limitations of conventional five-layer protocol architecture for UWSN, presented Micro-ANP, a green network protocol architecture for UWSN, realized the packet size optimization in UWSN based on Micro-

Received December 26, 2012; Revised February 6, 2013; Accepted February 18, 2013

ANP and MATLAB. In addition, following the Micro-ANP architecture, we designed and implemented UWSN simulation platform based on QualNet software system, lay a solid foundation for further research on underwater sensor network.

The reminder of the paper was organized as follows. Section 2 analyzed characteristics of UWSN communication and inapplicability of conventional five-layered protocol architecture for UWSN. Section 3 gave Micro-ANP protocol architecture in detail. The packet size optimization was presented in Section 4. UWSN simulation platform was designed based on Micro-ANP and QualNet system in Section 5. Finally, Section 6 concludes the paper and discusses some future work.

2. Limitations of Traditional Protocol Architecture for UWSN

Traditional network communications are interactive and address-centric, the communication protocols are divided into five layers: application, transport, network, data link and physical layer. In contrast, UWSN is data-centric and noninteractive, the perceived data require position information enclosed; UWSN messages are usually summarized into control message, multimedia data, and attribute data composed of quadruples including time, location, attribute name and the attribute values as <time, location, temperature, 23> and the data field in UWSN package are usually short, so the excessive address fields with traditional protocol stack will lead to additional protocol overhead involving source and destination ports, network addresses and node IDs of source and destination, and of previous and next hop and so on.

There are two technologies of data aggregation currently, AIDA (application independent data aggregation) and ADDA (application dependent data aggregation). AIDA is implemented as an independent protocol layer by merging multiple frames into one frame without understanding the semantics of application data and unable to eliminate redundancy and error. In contrast, ADDA is a reliable aggregation technology which is implemented at network layer, and the network layer protocol needs to understand the semantics of application layer data by cross-layer which is a difficult issue for traditional five-layer protocol architecture.

The transport layer of UWSN is a totally unexplored area. The window-based flow-control relies on an accurate estimate of the round trip time (RTT) which is high and variable in UWSN. For the same reason, the feedback control which relies on feedback messages is also instable. Furthermore, due to high bit error rate of acoustic channel, packets being dropped caused by the impairments of the channel are more than those by network congestion. From above analysis, conventional end-to-end reliability solutions will lead to waste of scarce resources and inapplicable for UWSN, and the unique characteristics of UWSN bring about great challenges to UWSN reliable communication. Thus, the UWSN requires completely new strategies to achieve reliability.

UWSN uses acoustic communication of more energy-consuming, and the nodes are battery-powered and harder to recharge and replace in harsh underwater environments. Acoustic channel is characterized by high bit error of 10^{-3}-10^{-7}, long propagation delay in the order of second and low bandwidth of scores of kbps. In addition, underwater nodes are usually deployed more sparsely, and most nodes can move passively with water currents or other underwater activity, resulting in highly dynamic network topology and great challenges to routing protocol and MAC mechanism for energy-restricted UWSN. So, terrestrial-based network protocols are inefficient for UWSN. UWSN calls for adaptive, robust and energy-aware routing and MAC protocol [8].

Physical layer solutions contain mainly such designs specifically tailored to UWSN as inexpensive transmitter/receiver modems, low-complexity sub-optimal filters to enable real-time communications with decreased energy expenditure.

3. Micro-ANP Protocol Architecture

3.1. Layer Structure of Micro-ANP

In order to solve that the network protocol stack running on node with limited resource shouldn't be too complex, and the network efficiency based on the traditional five-layered protocol architecture can be obtained only with a cross-layer design in environments of dynamic topology, seriously impaired channel and scarce resources. Having analyzed the characteristics of application and communication in UWSN and inapplicability of traditional five-layered architecture for UWSN, we propose a simple and efficient network protocol architecture model tailored for UWSN called as Micro-ANP, which is three-layered structure including application, network-transport, physical layer and an integrated management platform as Figure 1. The functions of each layer and the platform are as followings.

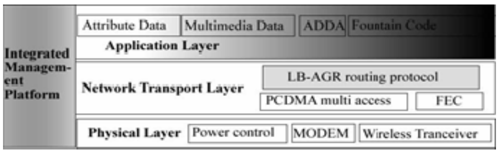

Figure 1. Micro-ANP Protocol Architecture

Application layer: Application layer is mainly responsible for processing application data such as multimedia and attribute data, performing ADDA data aggregation and reliable mechanism based on fountain coding.

As we know the conventional mechanisms of window-based flow control and acknowledgement-based reliability solutions in five-layered protocol architecture are inapplicable for real-time transmission of multimedia in UWSN with signal channel of impaired, high and high variance delay and will lead to waste of scarce resources. Here, we employ digital fountain coding techniques to implement reliable transmission at the application layer in UWSN paradigm.

Network-transport layer: Network-transport layer is mainly responsible for routing and forwarding, multiple access, and reliable transmission hop-by-hop. In Micro-ANP, we employ LB-AGR (Level-Based Adaptive Geo-routing) routing protocol [9], which can handle dynamic networks with fair energy-consuming so as to prolong the network lifetime while shortening end-to-end delay, probabilistic code division multiple access (PCDMA) technology which is robust to frequency selective fading and can distinguish simultaneous signals transmitted by means of pseudo-noise codes so as to reduce the number of packet retransmissions, decrease energy consumption and increase network throughput, and Forward Error Coding (FEC) technology to increase transferring reliability hop-by-hop.

Physical layer: Physical layer is mainly responsible for modulation & demodulation of signal and wireless transceiver.

Integrated management platform: Integrated management platform is responsible for comprehensive treatment of node's available energy, location and other control information as parameter basis of routing, forwarding and adjusting the transmit power. The node's location information is essential. Besides as one of 4-tuple of the attribute data, the node's location information is also as an important parameters of geographic routing. Moreover, the integrated management platform can dominate the sensor node's action based on the control massage from the sink node.

As aforementioned, Micro-ANP is a three-layered architecture which facilitates the intermediate nodes to perform ADDA data aggregate at the application layer and allows more efficient use of the scarce available resources without cross-layer design. Moreover, Micro-ANP architecture eliminates completely incapable layer and excessive, repeated fields such as address, ID, length and FCS etc., and reduces the node's overhead and energy consumption by employing micro and efficient protocols tailored for UWSN while increasing the reliability of the network.

3.2. Packet Format of Network-transport Layer

bits：1	8	8	16	1	16	8	6	8	variable	16
direction 0:downstream 1:upstream	Sink ID	level	Node ID	(sender/ target) 0:position 1:node ID	Position or ID (sender/target) Full “1” for broadcast	Packet ID	Application priority	Load length	data	FCS
		previous node		Target for downstream /sender for upstream						
Head									load	tail

Figure 2. The Format of Packet

Different from traditional network, UWSN communication is like the way of hub and spokes, the sink node acts as a hub, either the source of downstream traffic or the destination of upstream while the sensor nodes as spokes. The nodes around sink are responsible for relaying packet from or to the sink besides perceiving data, and have great impact on the operation of UWSN, The closer to the sink, the greater impact on the network. So each node is designated a level on behalf of its degree of importance as in LB-AGR [9] routing decisions.

UWSN is data-centric network; however, without location information attached, the perceived data is meaningless for any application. So it is imperative for the sensor node to obtain its location information, and this can be done through a localization process initiated by the sink. The sink broadcasts periodically a kind of control packet with position or other piggyback information in it. The control packet can be used by the sensor nodes to obtain or update their positions based on some location algorithm which is not detailed here. In Figure 2, the level field is filled with the forwarder's level which is initialized to zero by the sink and the data field is filled with the information of position, available power, one-hop neighbor and other piggyback information of the forwarder, and the fields of level, node ID and data are changed hop-by-hop.

The first bit in the packet indicates the direction of traffic, "1" means upstream to the sink and "0" means downstairs from the sink node. Except the data field, the packet length is 11 bytes while the length of protocol fields in TCP/IP architecture is about 80 bytes.

4. Packet Size Optimization based on Micro-ANP

The packet size directly affects the reliability of the communication since longer packet sizes are susceptible to wireless channel errors given a certain level of link quality [10]. We formalize packet size optimization for UWSN based on Micro-ANP architecture by using three different objective functions: packet throughput as formula (1), energy consumption per data bit as formula (2) and resource consumption per data bit as formula (3) [13].

$$TPUT = \frac{\ell_{appdata}(1 - PER_{e2e})}{T_{flow}} \tag{1}$$

$$ENG_{bit} = \frac{E_{flow}}{\ell_{appdata}(1 - PER_{e2e})} \tag{2}$$

$$RES_{bit} = \frac{E_{flow}T_{flow}}{\ell_{appdata}(1 - PER_{e2e})} \tag{3}$$

where $\ell_{appdata}$ is the payload length, i.e., length of application data in the packet, PER_{e2e} is the end-to-end packet error rate, which is derivational by formula (4), and T_{flow} is the end-to-end latency, which is the time spent between a packet is generated at a sensor and received at the sink through the multi-hop route. The packet throughput function considers the end-to-end packet success rate and the end-to-end delay to transmit a packet.

$$PER_{e2e} = 1 - \prod_{i=1}^{n_{hop}}(1 - PER_i) \tag{4}$$

$$PER_i^{FEC}(n, k, t, \ell_{appdata}) = 1 - (1 - ERR_{block}(n, k, t))^{\frac{\ell_{appdata}}{k}} \tag{5}$$

$$ERR_{block}(n, k, t) = \sum_{i=t+1}^{n}\binom{n}{i}p_b{}^i(1 - p_b)^{n-i} \tag{6}$$

$$P_b^{FSK} = \frac{1}{2} e^{-\frac{E_b / N_0}{2}} \tag{7}$$

$$E_b / N_0 = \psi \frac{B_N}{R_{bit}} \tag{8}$$

Where PER_i is the packet error rate of the i_{th} hop which is derivational by formula (5) for FEC codes, we consider block codes which is represented by(n, k, t), where n is the block length, k is the payload length, and t is the error correcting capability in bits. $ERR_{block}(n, k, t)$ is block error rate, i.e., the probability of the number of error bit in a block greater than t and can be derivational by formula (6). P_b^{FSK} expresses the bit error rate with non-coherent FSK modulation scheme which is given by formula (7) and (8).

$$T_{flow} = T_{sensor} + T_{propagation} + T_{transaction} \tag{9}$$

$$T_{sensor} = \frac{\ell_{appdata}}{R_{produce}} \tag{10}$$

$$\mathrm{E}[n_{hop}(D)] = L_{sour-node} \cong \frac{D - Radius_{trans}}{\mathrm{E}[d_{hop}]} + 1 \tag{11}$$

$$\mathrm{E}[d_{hop}] \cong \frac{D - Radius_{trans}}{L_{sour-node} - 1} \tag{12}$$

$$T_{propagation} = \mathrm{E}[n_{hop}(D)] \cdot \frac{\mathrm{E}[d_{hop}]}{\upsilon} = L_{sour-node} \cdot \frac{D - Radius_{trans}}{(L_{sour-node} - 1) \cdot \upsilon} \tag{13}$$

$$\begin{aligned} T_{transaction} &= T_{recv} + T_{forw} = 2\mathrm{E}[n_{hop}(D)] \cdot (\frac{\ell_{total}}{R_{bit}} + T_{dec}) \\ &= 2L_{sour-node} \cdot (\frac{\ell_{total}}{R_{bit}} + T_{dec}) \cong 2L_{sour-node} \cdot \frac{\ell_{total}}{R_{bit}} \end{aligned} \tag{14}$$

where T_{flow} consists of three parts as formula (9) where T_{sensor} is the generating latency of the packet at the sensor as formula (10) in which $R_{produce}$ is the generating rate of data bit and about 1-5bps for underwater sensor.

$\mathrm{E}[n_{hop}(D)]$ in formula (11) point out the expected value of number of hops via from the sensor node which is D away to the sink node and approximate to the level of source sensor node $L_{sour-node}$ if LB-AGR routing applicable [9]. $\mathrm{E}[d_{hop}]$ in formula (12) presents expected distance of one hop and $Radius_{trans}$ presents the transmission range. υ in formula (13) is acoustic speed under water. $T_{transaction}$ in formula (14) is the transaction latency at each intermediate node containing two latency of receiving and forwarding, T_{dec} is the decoding latency of FEC which is negligible relative to the transaction latency.

$$\ell_{total} = \ell_{appdata} + \ell_{redundancy} + \ell_{control} \tag{15}$$

$$\ell_{redundancy} = (n-k)\cdot\left(\frac{\ell_{appdata}}{k}\right) \tag{16}$$

$$E_{flow} = E_{forw} + E_{recv} \tag{17}$$

$$E_{forw} = \left(E_{dec} + \frac{\ell_{total}}{R_{bit}}\cdot P_{forw}\right)\cdot \mathrm{E}[n_{hop}(D) \cong \frac{\ell_{total}}{R_{bit}}\cdot P_{forw}\cdot L_{sour-node} \tag{18}$$

$$E_{recv} = \left(E_{dec} + \frac{\ell_{total}}{R_{bit}}\cdot P_{recv}\right)\cdot \mathrm{E}[n_{hop}(D)] \cong \frac{\ell_{total}}{R_{bit}}\cdot P_{recv}\cdot L_{sour-node} \tag{19}$$

In formula (17), E_{flow} is the energy consumption of transporting one packet from source node to the sink containing two parts of receiving and forwarding. In formula (18), E_{dec} presents energy consumption for decoding which can be negligible relative to the transport energy consumption. R_{bit} presents the number of bits per second send by node, P_{forw} presents sending power and P_{recv} for receiving power.

We investigate the effect of length of payload of packet in terms of PER, energy consumption and end-to-end latency based on Micro-ANP protocol architecture in a multi-hop network via numerical evaluations in MATLAB which is shown in Figure 3-Figure 12. Unless otherwise noted, the parameters in Table 1 are used for the numerical results.

Figure 3–Figure 12 show that the throughput and energy consumption in UWSN tend to a steady optimal value respectively when the length of packet payload is greater than 50Byte based on Micro-ANP, but with the increasing of the payload of packet, the end-to-end latency of the packet increases dramatically because attribute data are generated very slowly by the sensor. However, it is not the case for multimedia data which are generated at high speed at the source node.

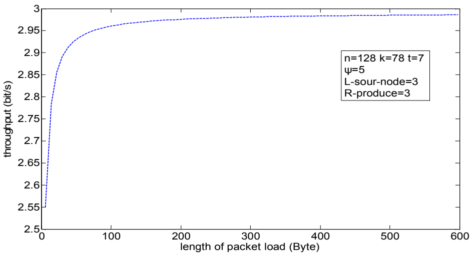

Figure 3. Throughput vs Length of Payload

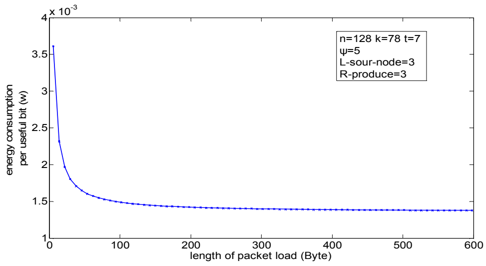

Figure 4. Energy Consumption vs Length of Payload

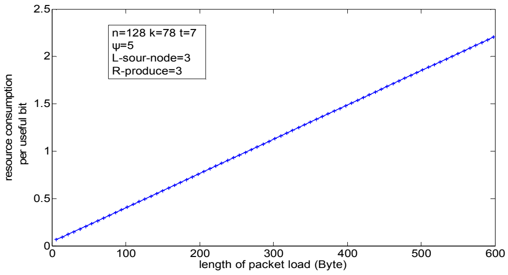

Figure 5. Resource Consumption vs Payload

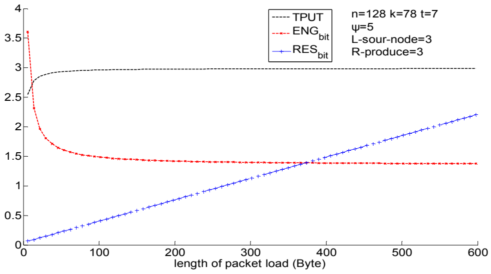

Figure 6. Objective Functions vs Payload

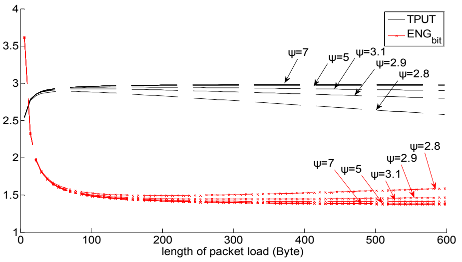

Figure 7. Throughput & Energy vs Payload

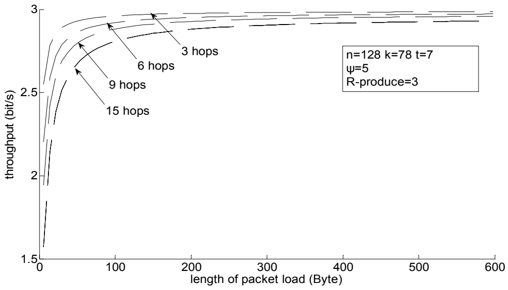

Figure 8. Throughput vs Payload for Different n_{hop}

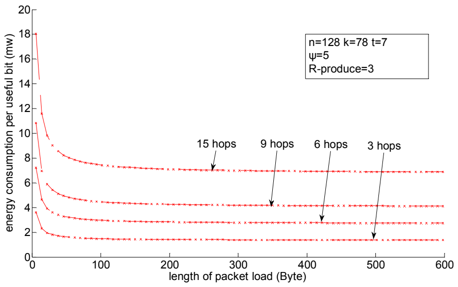

Figure 9 Energy vs Payload for Different n_{hop}

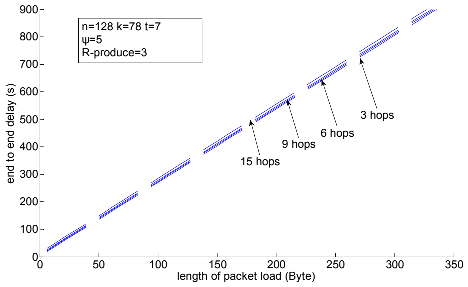

Figure 10. Delay vs Payload for Different n_{hop}

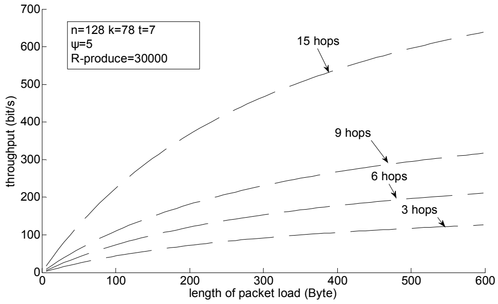

Figure 11. Throughput vs Multimedia Payload

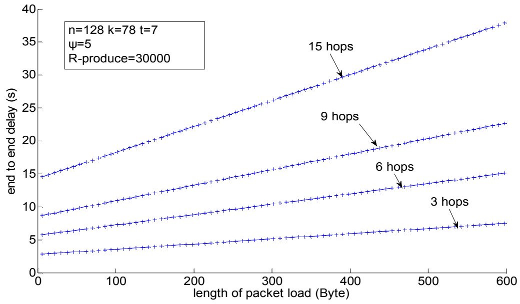

Figure 12. Delay vs Multimedia Payload

Table 1. Parameters in MATLAB

Parameter	value	Parameter	value
B_N	25KHz	$Radius_{trans}$	1500m
R_{bit}	10Kbps	n	128
P_{forw}	2w	k	78
P_{recv}	0.75w	t	7
υ	1500m/s	$\ell_{control}$	10Byte

5. Micro-ANP Simulation Implementation

5.1. Simulation Software Selection

Researches on network usually require simulation experiments to validate the proposed protocol. Currently, the mainstream simulation soft wares include NS2, NS3, QualNet and OPNET. OPNET is used to analyze the flow of enterprise network, solve business configuration of ISP, design new protocols and devices etc. and unsuitable for developing new protocol architecture.

At present, the only underwater sensor network simulator is Aqua-Sim, an underwater sensor network simulation package in NS2 software system based on traditional five-layer network architecture. With the characteristic of split object model, NS2 can be used to add or modify network protocol easily. However, the complex structure makes NS2 unfeasible for developing new or modifying existed protocol architecture or model. Updating the five-layer Aqua-Sim simulation package to version with Micro-ANP architecture will be a tremendous workload which is prone to error. Moreover, Bi-language system (C++/Tcl) makes debugging complex. NS3 is an open source network simulator based on discrete event. NS3 is not an upgrade version of NS2 but a new simulator, which is developed in C++ and the script language in C++ (optional Python) too, while NS2 cores in C++ and the script in OTcl. NS3 does not support API of NS2, and most modules of NS2 have been ported to NS3.

Although the source code files of NS3 add up to more than 1400，the structure of NS3 is simple and hierarchy is clear, each protocol layer has standard interface. So, it is feasible to implement UWSN simulation platform based on Micro-ANP architecture using NS3 software. Nevertheless, many NS3 source codes such as Callback Object system, Attribute system, Object system, aggregation template library etc. employ large numbers of advanced C++ techniques, make them complex and hard to understand which brings great challenges to set up UWSN simulation platform based on Micro-ANP architecture and NS3 software for involving modifying the NS3 kernel.

QualNet is written in C++ without complex C++ technologies, compared with other network simulation software, the source codes in QualNet are simple and protocol modules are more independent and modularized which can be easy to increase delete and modify. QualNet supports the standard interface between layers of TCP/IP protocol stack, users can develop the corresponding protocol by following these standard interface. Furthermore, QualNet also supports non-standard protocol stack, namely cross-layer interaction, through calling the standard interface function between different layers. Based on above analysis, we choose QualNet as the software platform to implement UWSN simulation module based on Micro-ANP architecture.

5.2. UWSN Simulation Implementation based on Micro-ANP and QualNet

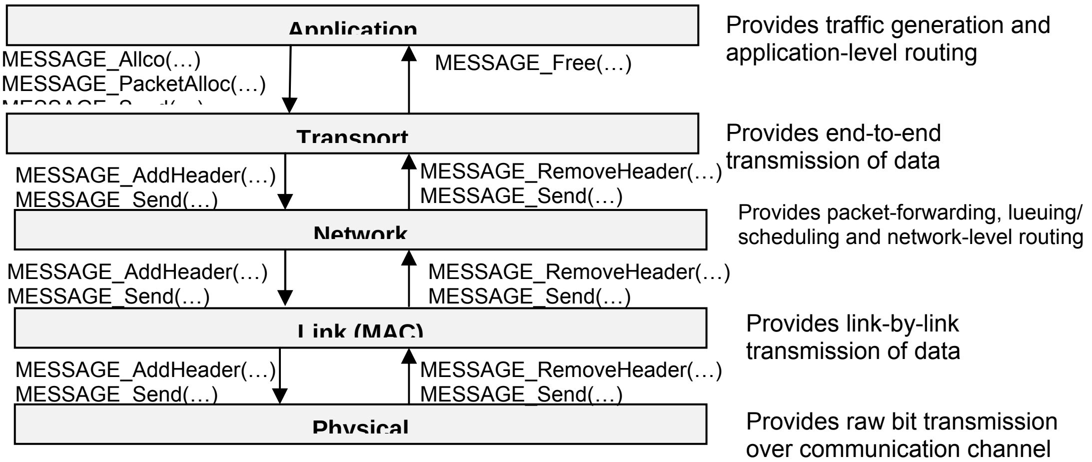

Figure 13. QualNet Protocol Stack and Adjacent Layers Communication

QualNet uses a layered architecture similar to that of the TCP/IP network protocol stack. Within the architecture, data moves between adjacent layers. From top to bottom, QualNet's protocol stack consists of application, transport, network, link (MAC) and physical layers. Generally, layer communication occurs only between adjacent layers, and adjacent layers in the protocol stack communicate via well-defined APIs as Figure 13. For example, transport layer protocols can get and pass data to and from application and network layer protocols, but cannot do so with link (MAC) layer protocols or physical layer protocols, this rule concerning communication only between adjacent layers may be circumvented by the programmer.

Each protocol in QualNet has three components: Initialization, Event Handling, and Finalization. Each of these functions is performed hierarchically: first at the node level, then at the layer level, and finally at the protocol level. Figure14 describes the hierarchy of these three functions.

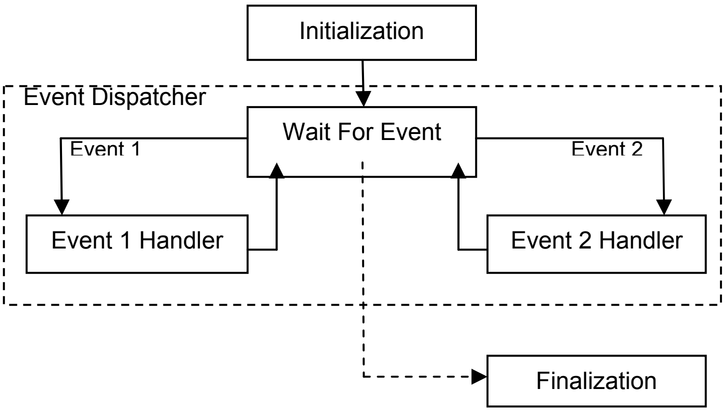

Figure14 QualNet Major Components

Initialization: At the beginning of simulation, the simulator calls the function of PARTITION_InitializeNodes in the source file of QUALNET_HOME/main/partition.cpp to initialize all nodes in the network. Then, the function of PARTITION_InitializeNodes calls the initialization function of each layer from bottom to top to initialize the protocol of each layer.

Event Handling: When generating an event, QualNet will place it into the scheduling queue waiting for the kernel to implement it later. When implementing, the kernel will adjust the simulator clock, and call a dispatcher function of NODE_ProcessEvent, defined in QUALNET_HOME/main/node.cpp. If the event is for the Application Layer, NODE_ProcessEvent calls the Application Layer event dispatcher function which is APP_ProcessEvent. The event dispatcher function for a layer determines the protocol for which the event has occurred, and calls the event handler for that protocol. Last, the event dispatcher function for a protocol determines which event has occurred, and calls the event handler for that event.

Finalization: At the end of simulation, the simulator will call the function of PARTITION_Finalize in QUALNET_HOME/main/partition.cpp file to print the statistical information. Then the function PARTITION_Finalizecalls will further call the finalization function of each layers to print the statistical information of each layer protocol.

In order to set up UWSN simulator platform based on Micro-ANP and QualNet, the functions of interface, initialization, event handing and finalization should be designed firstly for physical layer, network-transport layer and application layer. Part data structure in Micro-ANP is as followings.

```
struct Header_microanp_trans
{       UInt32 type;
        UInt8  ah_flow;  //flow direction
        UInt32 ah_level; //the sending node level
        NodeAddress   ah_sid; // thesending node ID
        NodeAddress   ah_nid;  //the next hop nodeID
        UInt8          ah_addtype; //address type  0: node position  1： node ID
    Address    ah_did;  //node address(position or ID, source for upstream, destination
for downstream)
        double         ah_sid_X;//the coordinates of the sending node
        double         ah_sid_Y;
        double         ah_sid_Z;
        double         ah_did_X;// the coordinates of the destination node
        double         ah_did_Y;
        double         ah_did_Z;
        ..........
```

```
};
/*    micro_anp Neighbor route table    */
class microAnp_Neighbor
{       friend class Micro_Anp;
        friend class microAnp_rtable;
 public:
        microAnp_Neighbor();
        ~microAnp_Neighbor();
        microAnp_Neighbor(UInt32 a) { neighbor_node_id_ = a; }
        NodeAddress & id() { return neighbor_node_id_; }
        UInt8 & neighbor_node_level() { return neighbor_node_level_; }
        double& neighbor_engery() { return neighbor_node_engery_; }
        double& neighbor_position_X() { return neighbor_position_X_; }
        double& neighbor_position_Y() { return neighbor_position_Y_; }
        double& neighbor_position_Z() { return neighbor_position_Z_; }
        UInt8 & hop() { return hop_; }
        double& neighbor_expire() { return neighbor_expire_; }
protected:
        LIST_ENTRY(microAnp_Neighbor) rt_link;
        NodeAddress neighbor_node_id_;         //node ID
        UInt8  neighbor_node_level_;  //level
        double neighbor_node_engery_;       //available power
        double neighbor_position_X_;         //position
        double neighbor_position_Y_;
        double neighbor_position_Z_;
        UInt8  hop_;
        Address nexthop_;
    double neighbor_expire_;      // lifetime ALLOWED_HELLO_LOSS * HELLO_INTERVAL };
```

Three-layer Micro-ANP architecture is implemented by modifying the original message parameters accordingly convenient for desired protocol function to handle further when calling the function of MESSAGE_Send. So, we modified the protocol of application layer, transmitted the CBR message stream directly to protocol of network-transport layer bypassing the UDP protocol which is shown in Figure15.

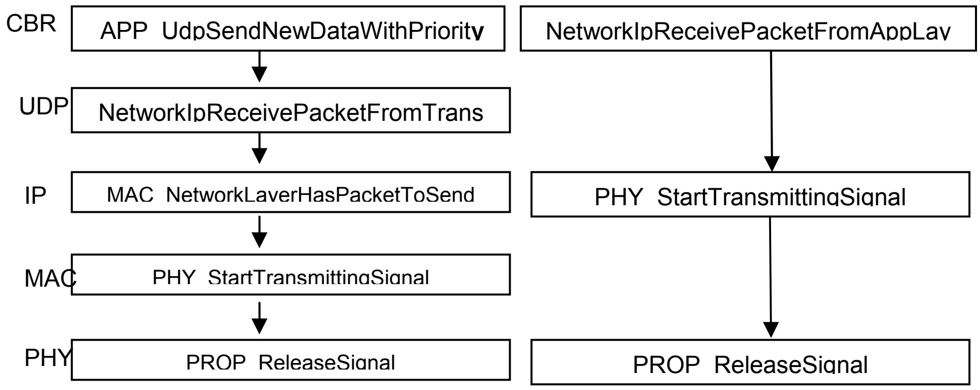

Figure 15. Micro-ANP Implementation

Parts of source codes of protocol communication from network-transport layer to application layer:

```
void SendToMicro-ANP-APP(...)
{
    Message *msg;
    ActionData acnData;
    msg = MESSAGE_Alloc(
           node,
           APPLICATION_LAYER,
           ApplicationProtocol_Micro-ANP-APP,
           MSG_Application_FromNetwrokReceive);
           ...
           //Trace Information
```

```
          acnData.actionType = RECEIVE;
          acnData.actionComment = NO_COMMENT;
          TRACE_PrintTrace(node, msg, TRACE_NETWORK_LAYER,
              PACKET_OUT, &acnData);
          MESSAGE_Send(node, msg, delay);}
```

Parts of source codes of protocol communication from physical layer to network-transport layer:

```
void PhySignalEndFromChannel(...)
{
    ...
    MESSAGE_SetInstanceId(newMsg, (short) phyIndex);

    //This Function send the packet from Physical layer to Network Layer
  NETWORK_ReceivePacketFromPhyLayer(…);
       ...
}
void NETWORK_ReceivePacketFromPhyLayer (...)
{
    Message *msg;
    ActionData acnData;
    msg = MESSAGE_Alloc(
           node,
           NETWORK_LAYER,
           NetwrokProtocol_Micro-ANP-APP,
           MSG_Network_FromPhyReceive);
           ...
           //Trace Information
           acnData.actionType = RECEIVE;
           acnData.actionComment = NO_COMMENT;
           TRACE_PrintTrace(node, msg, TRACE_PHY_LAYER,
               PACKET_OUT, &acnData);
           MESSAGE_Send(node, msg, delay); }
}
```

6. Conclusion

In this paper, we analyzed the characteristics of application and communication in UWSN and inapplicability of traditional protocol architecture for UWSN, proposed a three-layered Micro-ANP protocol architecture model tailored for UWSN, and optimized packet size under Micro-ANP architecture, designed UWSN simulation platform based on Micro-ANP and QualNet software. Micro-ANP protocol architecture and packet size optimization improve the energy efficiency of UWSN, prolong the network lifetime and achieve green network while meeting the requirement of QoS with the constraints of limited resource. UWSN simulation platform based on Micro-ANP and QualNet software laid a solid foundation for further research and experiment on underwater sensor network.

As future work, we plan to investigate PCDMA (Probabilistic Code Division Multiple Access multiplexing) multiple access technology and digital fountain coding-based reliability mechanism and realize them and LB-AGR routing protocol under the Micro-ANP framework further.

Acknowledgements

This work is supported by the Program for New Century Excellent Talents in University of China(NCET-11-1025), the National Natural Science Foundation of China（No. 61162003, 61163050）, Qinghai office of science and technology (No. 2012-Z-902, 2010-J-728), 973 Program of China (No. 2011CB311809).

References

[1] Kota Kinabalu, Borneo, Malaysia. *Analyzing The Performance of Acoustic Channel in Underwater Wireless Sensor Networks(UWSN).* 2010 Fourth Asia International Conference on Mathematical Analytical Modelling and Computer Simulation. 2010: 550-555.

[2] Dario Pompili, Akyildiz IF. A Multimedia Cross-Layer Protocol for Underwater Acoustic Sensor Networks. *IEEE Transactions On Wireless Communications*. 2010; 9(9): 2924-2934.

[3] Pompili D, Melodia T, Akyildiz IF. A Distributed CDMA Medium Access Control for Underwater Acoustic Sensor Networks. *IEEE Transactions on Wireless Communications*. 2009; 8(4): 1899-1909.

[4] Dario Pompili, Tommaso Melodia, Akyildiz IF. Distributed Routing Algorithms for Underwater Acoustic Sensor Networks. *IEEE Transactions On Wireless Communications.* 2010; 9(9): 2934-2944.

[5] Chenn-Jung Huang, Yu-Wu Wang, Hsiu-Hui Liao. A power-efficient routing protocol for underwater wireless sensor networks. *Applied Soft Computing*. 2011; 11(2): 2348–2355.

[6] Tiansi Hu, Yunsi Fei. *An Adaptive and Energy-efficient Routing Protocol based on Machine Learning for Underwater Delay Tolerant Networks*. 2010 18th Annual IEEE/ACM International Symposium on Modeling, Analysis and Simulation of Computer and Telecommunication Systems. 2010: 381-384.

[7] Zhong Zhou, Zheng Pengt, Jun-Hong Cui etc. Handling Triple Hidden Terminal Problems for Multi-Channel MAC in Long-Delay Underwater Sensor Networks. *INFOCOM.* 2010: 1-5.

[8] Akyildiz IF, D Pompili, T Melodia. Underwater acoustic sensor networks: research challenges. *Ad Hoc Networks.* 2005; 3(1): 257-279.

[9] DU Xiujuan, HUANG Kejun, LAN Shenglin. LB-AGR: Level-Based Adaptive Geo-routing for Underwater Sensor Networks. *Journal of IEEE Communication Letters*. 2012.

[10] Mehmet C. Vuran, Akyildiz IF. Cross-Layer Packet Size Optimization for Wireless Terrestrial, Underwater, and Underground Sensor Networks. *INFOCOM*. 2008: 780-788.

[11] D Pompili, Akyildiz IF. Overview of networking protocols for underwater wireless communications. *IEEE Communications Magazine.* 2009; 97-102.

[12] GA Shah. *A survey on medium access control in underwater acoustic sensor networks*. Proc. of WAINA '09. 2009; 1178-1183.

[13] DU Xiujuan, HUANG Kejun, LIU Fan. Micro-ANP：A Novel Network Protocol Architecture for Underwater Sensor Network. *Applied Mechanics and Materials*. 2012; 12.

[14] Bo Wei, Yong-mei Luo, Zhigang Jin. *ES-VBF: An Energy Saving Routing Protocol*. Proceedings of the 2012 International Conference on Information Technology and Software Engineering Lecture Notes in Electrical Engineering. 2012; 87-97.