A Study On Under Water Network Simulators

Monika M, Dr. Shanta Rangaswamy

Department of Computer Science & Engineering, CIT, Gubbi, India;
Department of Computer Science & Engineering, R.V. College of Engineering, Bangalore, India.
Email: monika.m@cittumkur.org, shantharangaswamy@rvce.edu.in

ABSTRACT: In the recent years, a technology for communication in underwater has been rapidly progressed. Underwater communication methods include radio wave, optical and acoustic communication. Acoustic communication is considered as the ideal communication and is used in aqua applications monitoring of severe weather events, anthropogenic disturbances. So it is necessary to develop the network protocols for UAN's, development, testing and validation of these protocols rely on simulations, as real sea experiments requires huge infrastructure investments. So study of open source simulators, emulator such as SUNSET, DESERT, Aqua Net Mate, and Aqua-Sim has gained importance. In this paper we survey the characteristics of these simulators and also carry out comparison between them.

Keywords: Underwater Acoustic Networks, SUNSET, DESERT, Aqua-Sim, Aqua-net mate, NS-2, NS2-miracle.

1 INTRODUCTION

71% of the earth's surface is covered by oceans and lakes. More than 90% of water world goes unexplored. Man's curiosity towards exploring unknown things made him to explore the depths of ocean. Under water communications via radio waves results in high attenuation. In optical communication, optical waves suffer from high absorption and high scattering. Acoustic communication under water poses many challenges like, acoustic signals propagate with the speed five times lower than speed of electromagnetic waves in terrestrial network, path loss, ambient noises [10]. In spite of these challenges acoustic communication is considered as ideal communication, because acoustic propagation supports low frequencies and available total band width may be low for instance acoustic system may operate at frequency ranges 10-15 KHz, even though total communication available bandwidth is very low say 5 KHz. The system is wide band that is bandwidth is not negligible with respect to centre frequency [7].This made researchers develop new protocols for under water acoustic communication; new protocols have to be tested against real sea experiments. Conduction of open sea experiments requires more man power, huge infrastructure investment. Therefore, development and testing of new protocols relies on simulators and emulators [1].In this paper, authors discuss the architecture, working, similarities and differences between simulators such as DESERT, SUNSET, Aqua Net mate, Aqua-Sim.

2 DESERT (DESIGN, SIMULATE, EMULATE AND REALIZE TEST-BEDS)

DESERT is a simulation / emulation tool developed at the Padova University based on NS-Miracle. NS-Miracle is a simulator which has C++ for developing modules and tcl or otcl for setting the parameters. Tcl is a scripting language provides set of library functions, otcl is extended version with object oriented facility. Thus DESERT provides public libraries of C/C++ needed for the development of new protocols, and also provides underwater protocol stacks. For reliable communication between multiple nodes, DESERT implements the communication and network architecture. Same architecture can be used for simulation, emulation and test-beds. NS-Miracle extends NS-2 which enables co-existence between several modules within the layer and handles the cross layer messages [2].

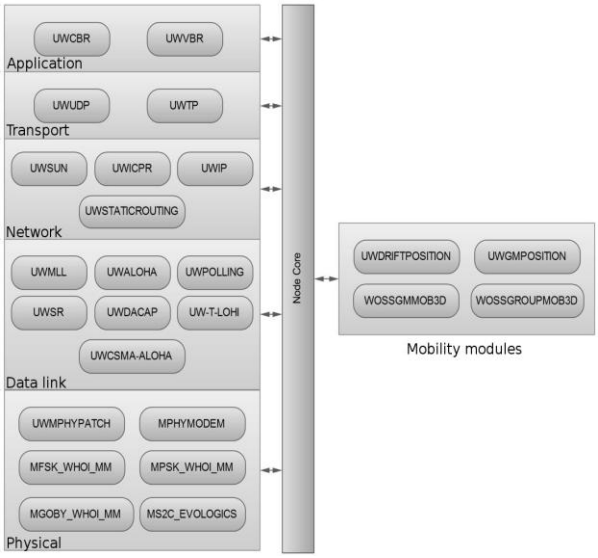

Fig1. *DESERT Architecture as presented in [3]*

A brief description of DESERT modules in each of the OSI layer[3]:

- **Physical layer**: uwphy_modem which defines and implements interface between acoustic modem and NS-Miracle, it manages the cross layer messages between Physical layer and MAC layer. mfsk_whoi_mm and mpsk_whoi_mm modules implements interface between NS-Miracle and FSK micromodem and PSK micromodem correspondingly. Mgoby_whoi_mm and MS2C_Evologics modules implements the interface between NS-Miracle and micromodems which uses goby software.

Data link layer: MAC layer governs the acess to communication channel and is the core of data link layer. DESERT gives MAC techinques with six different modules, uwaloha directly sends the data packets without prior reservation of the channel,uw-csma-aloha,uwdacap are enhancement to basic aloha protocol,uwpolling is based on centralised polling scheme, uw-t-lohi is a MAC protocol uses tones to reserve channel and uwsr error control CSMA aloha.uwmll to map IP address to MAC address.

Network layer: This layer is responsible for providing network addresses and techniques for routing the data. uwstaticrouting testing traffic in predetermined routes.uwsun dynamic routing based on hop count or minimum signal to noise ratio.uwicrp implements routing based on simple flooding.uwip to assign address to nodes and provides TTL functions.

Transport layer: Two modules for transport protocol uwudp and uwtp implements multiplexing, demultiplexing, latter support error and flow control.

Application layer: Two modules for transport layer uwcbr and uwvbr implements constant bit rate traffic and variable bit rate traffic between sender and reciver.

Along with these modules it also provides mobility models for 2D and 3D senarios, that is uwgm position informs node speed and direction, wossgmmob3D incorporates geographical coordinate system to depict node movements, wossgroupmob3D supports 3D mobility where leader node moves in predetermined path and follwer nodes follows the same route [3].

3 SUNSET(SIMULATION, EMULATION AND REAL-LIFE TESTING)

Sapienza University developed a framework to simulate/emulate communication Protocols based on the open source ns2-Miracle.Researchers can run check changing the selected MAC or routing protocol parameters without changing external device codes. SUNSET provides additional functionalities for event scheduling, memory management, data conversion as required by devices, to calculate packet sizes and timeouts. Bellhop ray tracing and empirical formulas are different acoustic channel models that can be selected during simulations. Fig 2 shows SUNSET modules in simulation mode.

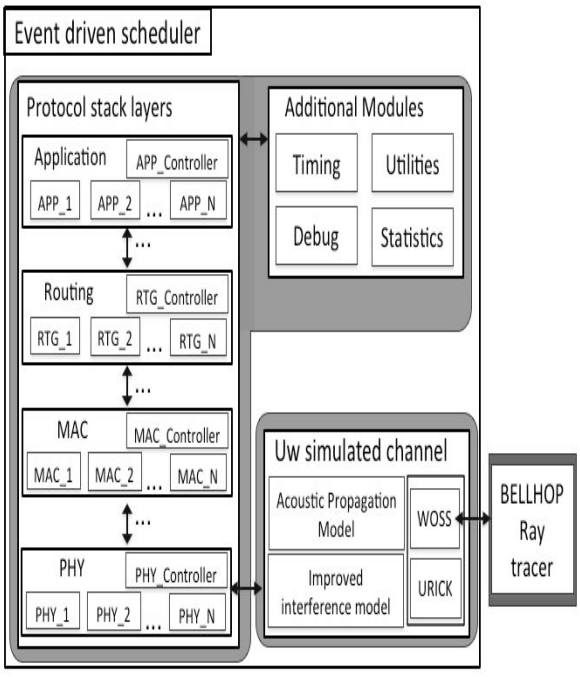

Fig 2. *SUNSET Architecture as presented in [4]*

A brief description of SUNSET modules, Additional modules such as timing, uitility, debuging and statistics.

Timing module: It computes delays such as computational, operational, internal communication delays between various hardware components within the same node. This module returns user defined simulated values.

Utilities module: It uses event driven scheduler in simulation mode to schedule events and updates timing information according to the used scheduler. The utilities module is also does memory management.

Debug module: It allows users to log the debugging information flexibly and prioritize debugging levels during development and testing of new protocols.

Statistics module: This module gathers the statistical information such as number of packets delivered, throughput of the network, additional delays and energy used to evaluate the performance of the protocol.

4 AQUA-NET MATE

Aqua-net mate is a real time virtual channel simulator for aqua-net. Aqua-Net is appropriate for embedded systems but it doesn't provide a simulation mode, so some changes has to be made for its architecture resulted in Aqua-net mate can link to Aqua-net through sockets which provides simulation functions. Major Features of Aqua- net mate are, it is very extensible, highly configurable and friendly to the user, real time scheduling is supported, provides unified configurable interface. Practical Teledyne benthos acoustic modems are implemented by physical module of aqua-net mate.

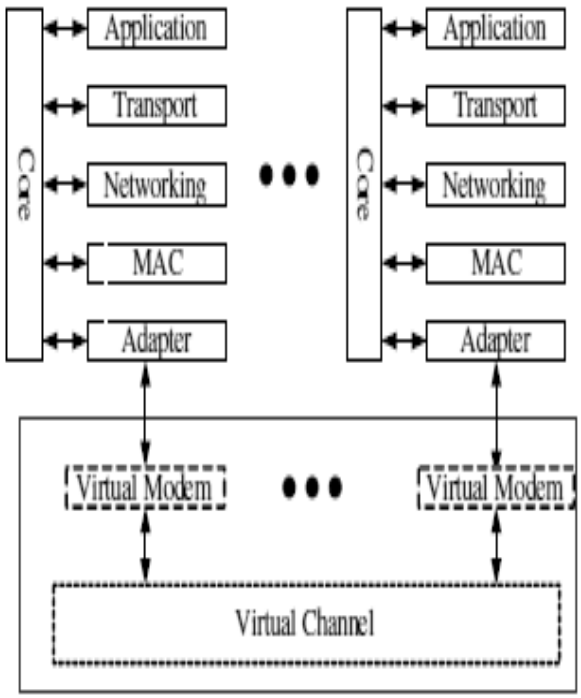

Fig 3. *Aqua-Netmate Architecture as presented in [5]*

A brief description of Aqua-Net Mate modules is given below:

Aqua-Net Mate Adapter:
Aqua–Net Mate adapter is a driver in aqua-net mate package, adapter converts packets in aqua net format to aqua net mate format, and virtual modem module implements this function in Aqua net mate.

Virtual Modem Module:
The base class of virtual modem module is class am_ phy, the basic functions of physical layer device is defined by this class. It forms the interface between virtual channel and virtual modem for receiving and sending packets to adapter. class am _ phy _ benthos implements the behavior of benthos acoustic modem.

Virtual Channel Module:
An interface to virtual modem modules is implemented in the class class _am _channel combines the attenuation and propagation module. Attenuation and propagation modules are the sub modules of virtual channel module former calculates the path loss using throp's approximation, latter computes propagation delay to affected nodes. Aqua-Net Mate simulates the harsh and changeable channel conditions. Aqua-Net Mate supports both Cartesian and geographic coordinate predict test results. A scheduler triggers the events scheduled in time. The scheduler in Aqua-Net Mate is a real-time scheduler.

5 Similarities and differences between SUNSET, DESERT, and AQUA-NET MATE

SUNSET and DESERT are compatible with both open source network simulators ns-2 and extended ns2- Miracle. Both uses event schedulers rather than real time schedulers in simulation mode. Both can support different acoustic channel models. Mobility modules used by DESERT can also be used by SUNSET. In simulation communication protocols used by DESERT can also be used by SUNSET because of information dispatcher module in SUNSET. SUNSET and DESERT differs in efficiency and flexibility when they run in emulation mode, the major differences lies in use of schedulers in real time, data conversion techniques used to convert packets in to bytes for transmission [3]. DESERT cannot move simulations efficiently to real field experiments. Each node runs a NS-2 instance in SUNSET. In embedded system resources are limited so running NS-2 instance on each node results in more overhead. SUNSET protocols do not run in parallel, which weaken the real-time feature of systems. Aqua-Net all protocols run as a separate individual process and they interact with each other through the core. Aqua-net mate can link to Aqua-net through sockets to provide simulation functions [5].

6 AQUA-SIM

Aqua –Sim is an open source most widely used NS-2 based simulator. Aqua- Sim efficiently simulates collision behaviors in long delay acoustic networks and also attenuation of underwater acoustic channels. Aqua-Sim supports 3D deployment in the acoustic network, provides wide range of basic and advanced protocols, it uses otcl to tune the protocol parameters implemented through C++ algorithms. Aqua-Sim incorporates the object oriented paradigm all its modules are implemented as C++ classes.

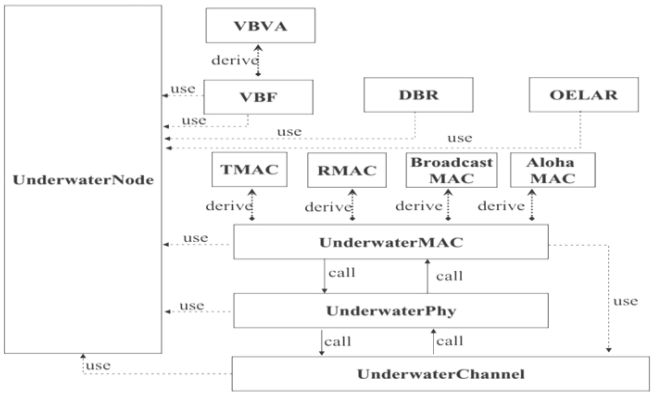

Fig 4. *Architecture of Aqua –Sim as presented in [6]*

Aqua- Sim is structured into four modules such as uw _common, uw _mac, uw _routing and uw _tcl. Underwater-Node is a global object and is the notion of the underwater sensor node. It encapsulates node's location and speed information. UnderwaterChannel implements acoustic channel uw_common constitutes code for implementing sensor nodes and the traffic, uw_mac constitutes code for implementing channels and MAC protocols, uw _routing constitutes various routing protocols, uw _tcl constitutes otcl scripts for validation. Aqua-Sim consists of three major classes such as network entity, Interface and common class, network entity class represents network entities. Underwater Phy, Broadcast- MAC objects represent physical layer and mac layer of the node respectively. Interface class is implemented as virtual class without instantiation, Underwater MAC provides common interface to broadcast MAC and RMAC. Common function class provides common functions to other classes. As it is known that simulations do not produce accurate results, to make results near accurate to sea experiments following changes were made.

Physical layer implements attenuation model and collision model, attenuation model adopts existing attenuation model [6] given by the equation ,

$$A(l, f) = l^k * \left(10^{\frac{\alpha(f)}{10}}\right)^l$$

Where A(l,f) is the average signal attenuation, l is the distance, f is the frequency, k is the spreading factor α(f) is the absorption co efficient and is given by the equation,

$$\alpha(f) = \frac{0.11 * f^2}{1 + f^2} + \frac{44 * f^2}{4100 + f^2} + 2.75 * 10^{-4} * f^2 + 0.003$$

An improved attenuation model is proposed to get accurate results[1] given by the equation,

$$TL = 15\log_{10} R + AR + B + CR^2$$

where TL represents transmission loss, R is the range, A,B,C are the coefficients.

Noise models were introduced which considers the shipping , wind and thermal noise. Different sediment types were taken into consideration. Collision model incorporates packet collision on every node due to long propagation delay during the transmission. Incomingchannel class simulates the collision behaviour. According to the model proposed in [1] physical layer is divided into three sub layers such as environmental sub layer, channel sublayer and modulation sub layer. Environment sub layer considers the physical factors and their effects in the oceanic environment. Channel sub layer to produce the realistic transmission loss it takes sediment type into account, th output of the channel sub layer is taken to calculate SNR and this becomes the input to modulation layer, modulation layer checks this SNR against the packet error rate to determine to decode the packet or not. These changes helps in producing more realistic results. **MAC layer umac module** includes the MAC layer protocols such as Broadcast MAC, Aloha, Tu MAC and R-MAC. When sender has the packets to send Broadcast MAC senses the channel if it is free it sends the packets or else it will not, no acknowledgement will be sent back by reciever on reciving packet.If aloha protocol is used it does not sense the channel directtly sends the packet uses timer if it recives ACK from reciever within time doesnot retransmitt the packet or else it performe retransmission then get redy for sending subsequent packets. In TuMAC RTS/CTS method is used when the sender recieves the CTS from particular reciever sender will not send packets until CTS is transimmited through entire transmission range. Research went on for improved mac protocols,because long delay in the propagation of signal in acoustic network has greater impact on MAC protocol design, then reaschers came up COPE-MAC protocol which has two modules parallel reservation to handle the long delays in the propogation through concurrent transmission, and another is contention based researvation approch to achieve higher efficiency by avoiding collisions. COPE – MAC acheives high throughput in underwater networks with multi hops which has high network traffic[8]. Pure reservation based protocols did not meet demands of many ad-hoc underwater applications, so dynamic adhoc protocol like MACA is needed. Monitoring of data packets during contention and analytical models for high throughput and service time expected are proposed, it is analyzed that batch size increases the throughput of MACA protocols [9]. **Network layer uw _ routing** module consists of all classes of routing protocol. Three routing Protocols include VBF, DBR, QLEAR protocol.VBF routing protocol is a geographical routing protocol which maintains a forwarding vector consists of information about source, target and forwarder positions in the header of the packet. When packet is received distance is calculated to forwarding vector. DBR uses greedy method each time when the packet is received reducing the depth information will be recorded in the packet, each time it greed towards jumping to the next hop with reduced depth. QLEAR is a energy aware and life time aware protocol, which collects the information from the underwater to make routing decisions.

7 CONCLUSION

Following conclusions are drawn from the study of network simulators: DESERT, SUNSET performance is same in the simulation mode but different approaches has to be applied when they move to field experiments. When they run in emulation mode SUNSET performs better than DESERT. In the existing under water systems, embedded systems are widely used and these systems have limited resources, DESERT SUNSET emulation requires huge amount of resources which is again a overhead .Aqua-Net mate is one of the solution, but still simulator results are not so accurate. Researchers are thinking about standardization of existing simulator so that in reduced cost with limited resources to achieve near accurate results matching with open sea experiment. One such step is taken by Aqua-Sim, an open source network simulator.

REFERENCES

[1] Michael Zuba, Zaihan Jiang , T.C. Yang, Yishan Su, and Jun-Hong Cui, “An Advanced Channel Framework for Improved Underwater Acoustic Network Simulations”, in MTS 2013.

[2] R. Masiero, S. Azad, F. Favaro, M. Petrani, G. Toso, F. Guerra, P. Casari, and M. Zorzi, “DESERT underwater: an NSmiracle-based framework to DEsign, simulate, emulate and realize test-beds for underwater network protocols,” in Proceedings of MTS/IEEE OCEANS 2012, Yeosu, Korea, May, 21–24 2012.

[3] Roberto Petroccia, and Daniele Spaccini, “Comparing the SUNSET and DESERT Frameworks for In Field Experiments in Underwater Acoustic Networks”in proceedings of MTS/IEEE oceans 2013.

[4] C. Petrioli and R. Petroccia, “SUNSET: Simulation, Emulation and Real life Testing of Underwater Wireless Sensor Networks,” in Proc. of IEEE UComms, September 2012.

[5] Yibo Zhu, Son Le, Lina Pu, Xiaoyan Lu, Zheng Peng, Jun-Hong Cui and Michael Zuba, “Aqua-Net Mate: a Real-time Virtual Channel/Modem Simulator for Aqua-Net” IEEE 2013.

[6] Z. Peng, Z. Zhou, J.-H. Cui, and A. Shi, “Aqua-Net: An underwater sensor network architecture: Design,implementation, and initial testing,” in Proceedings of MTS/IEEE OCEANS 2009, Biloxi, Mississippi,USA,October,26–29,2009.

[7] Milica Stojanovic, Northeastern University, James Preisig, Woods Hole Oceanographic Institution,“Underwater Acoustic Communication Channels: Propagation Models and Statistical Characterization” in IEEE communication magazine 2009.

[8] Zheng Peng, Yibo Zhu, Zhong Zhou, Zheng Guo and Jun-Hong Cui,” COPE-MAC: A Contention-based Medium Access Control Protocol with Parallel Reservation for Underwater Acoustic Networks” in IEEE 2010.

[9] Shiraz Shahabudeen, MehulMotani, and Mandar Chitre,” Analysis of a High-Performance MAC Protocol for Underwater Acoustic Networks”, IEEE JOURNAL OF OCEANIC ENGINEERING, Vol. 39, No. 1, JAN 2014.

[10] ”UComms: A Conference and Workshop on Underwater Communications, Channel Modeling, and Validation” IEEE Journal of Oceanic Engineering, Vol. 38, No. 4, October 2013.