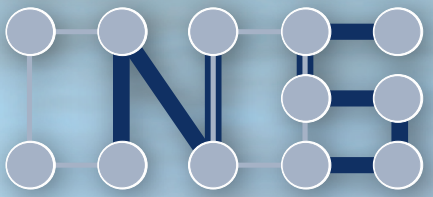

AquaTools: An Underwater Acoustic Networking Simulation Toolkit

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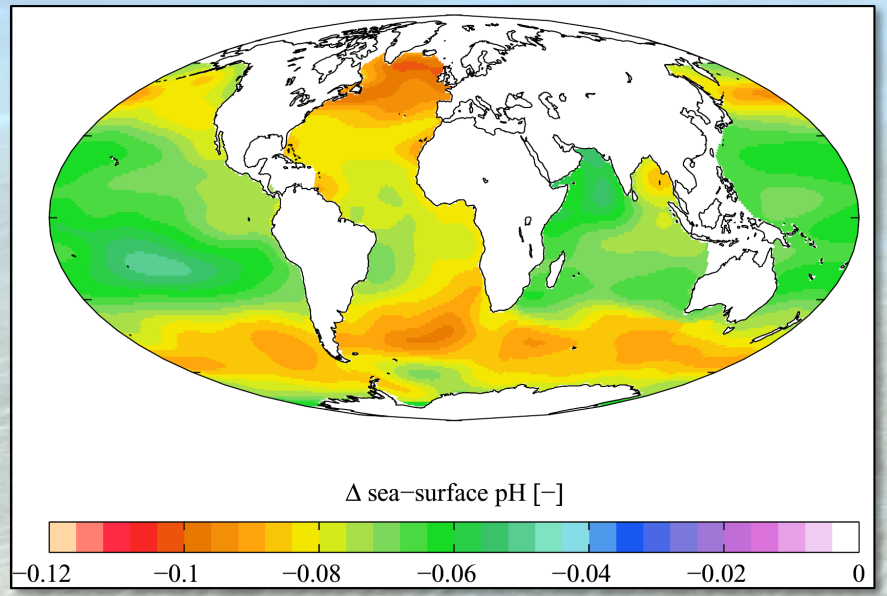
Motivation

- Radio and optical communication channels are not efficient
  - Radio requires very low frequencies (30-300 Hz)
  - High attenuation
- Fabrication and off-shore testing is extremely expensive
  - Several thousands for a dependable modem
  - Thousands per day in off-shore deployment costs



- Channel performance is dependent on ambient conditions
  - Change in temperature, acidity and salinity changes system performance
- No dependable simulators exist to simulate underwater networks
  - MATLAB simulations provide channel modeling capabilities
  - Networks also need routing, MAC, application layer simulations

Related Work

- *Nsmiracle* based underwater channel simulation module *(Harris et al)*
  - Nsmiracle is an extension of ns2
  - Only MAC and PHY layer supported
  - Not possible to test a full scale network
- Underwater LAN designed in OPNET *(Sozer et al)*
  - Task specific simulation
  - Static environmental parameters
  - Node mobility not accounted for
- MATLAB based simulations
  - Plenty in number and easy to set up
  - No possibility to define topologies, packet losses/collisions, routing and transport layer

Mathematical Model

- Ainslie & McColm Model (Attenuation by Absorption)

$$\alpha = 0.106\frac{f_1 f^2}{f_1^2 + f^2}e^{\frac{pH-8}{0.56}} + 0.52\left(1+\frac{T}{43}\right)\left(\frac{S}{35}\right)\frac{f_2 f^2}{f_2^2 + f^2}e^{\frac{-D}{6}} + 4.9\times 10^{-4} f^2 e^{-\left(\frac{T}{27}+\frac{D}{17}\right)}$$

- Ambient noise

$$10\log N_t(f) = 17 - 30\log f$$

$$10\log N_{th}(f) = -15 + 20\log f$$

$$10\log N_w(f) = 50 + 7.5w^{\frac{1}{2}} + 20\log f - 40(f + 0.4)$$

$$10\log N_s(f) = 40 + 20(s - 0.5) + 20\log f - 60(f + 0.03)$$

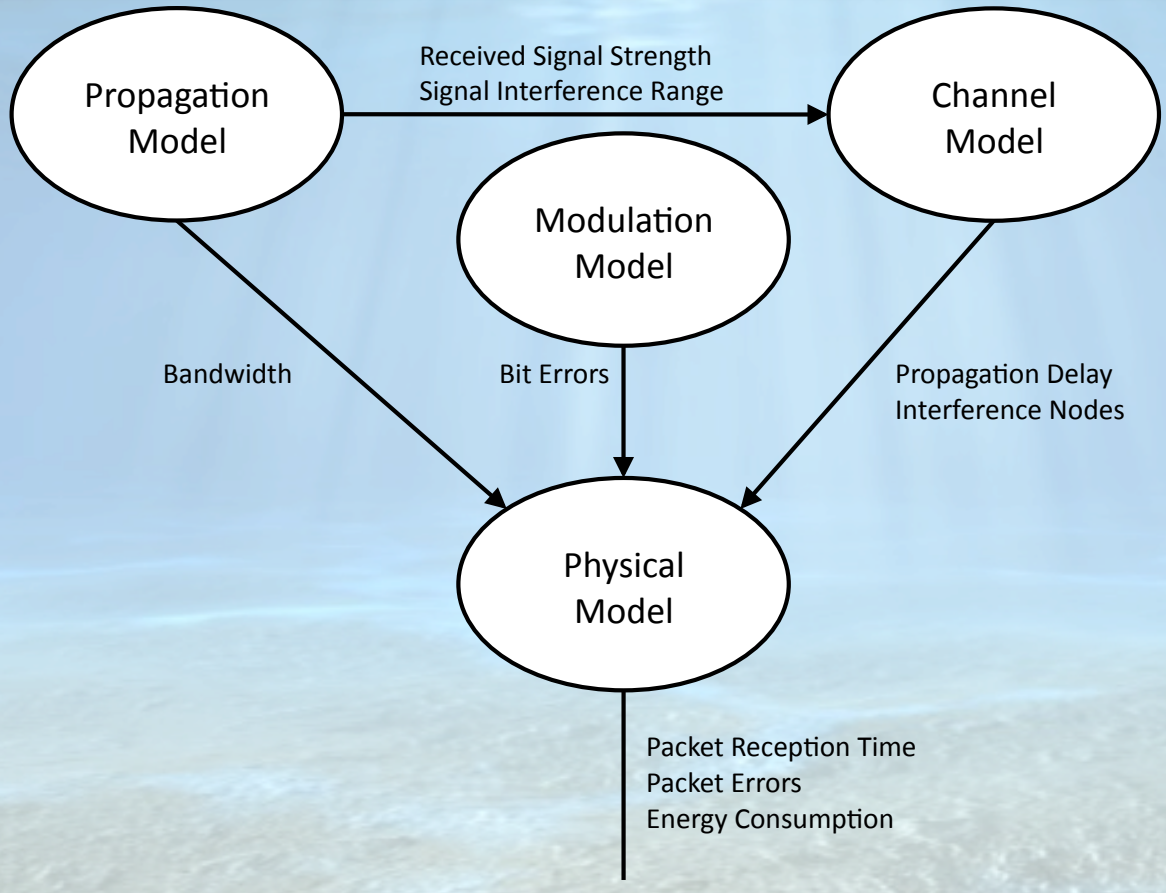
- Transmission Loss

$$10\log A(l,f) = k\cdot 10\log l + l\cdot \log\alpha$$

- Signal-to-noise Ratio (SNR)

$$SNR(l,f) = \frac{P}{A(l,f)N(f)\Delta f}$$

Simulation Toolkit



- AquaTools provides an implementation for the components of the ns2 functional model – enabling usage of any existing ns2 modules.
- The Propagation, Channel and Physical Layer models are implemented. Modulation model is adopted from ns2 itself.

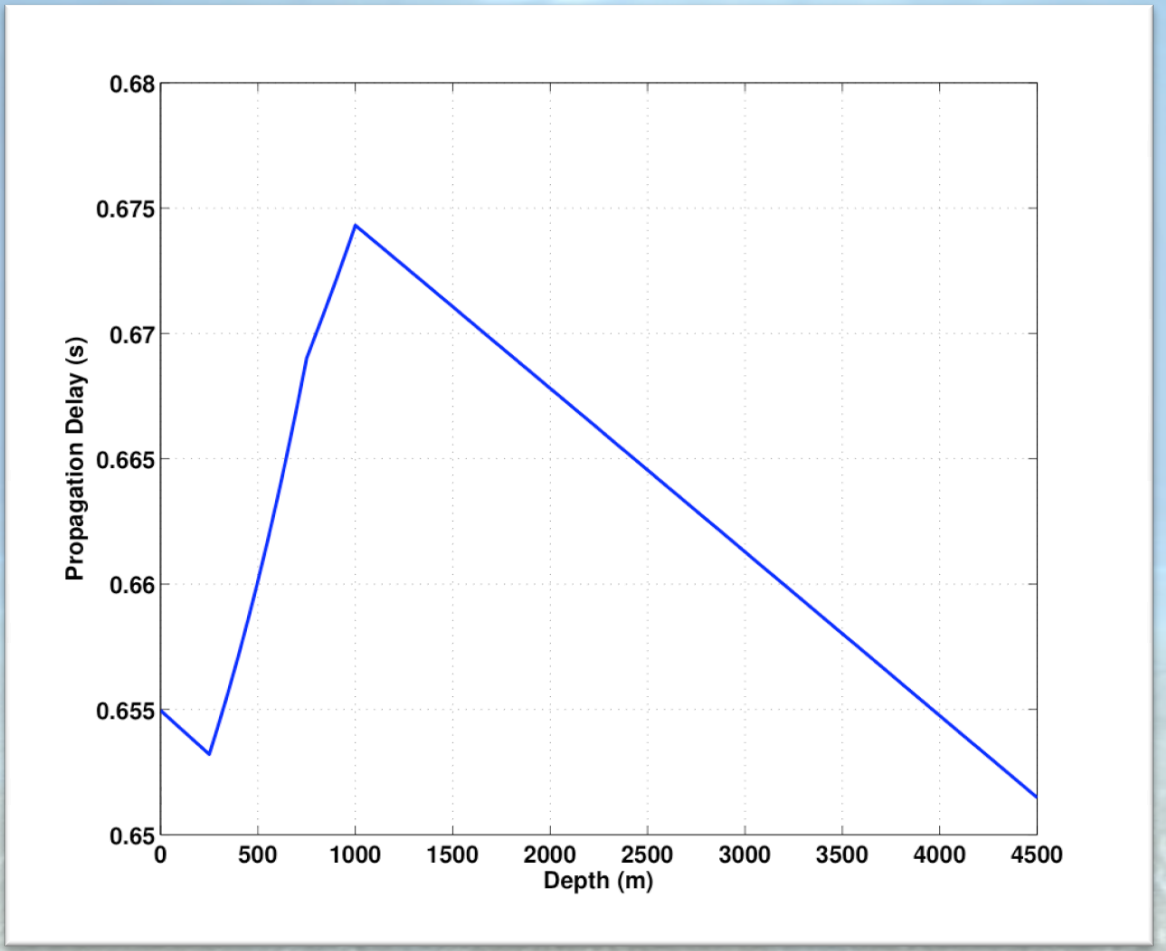
Simulations Setup

```
# ==================================================
# Define channel and modem options
# ==================================================
set val(chan)           Channel/UnderwaterChannel
set val(prop)           Propagation/UnderwaterThorp
set val(netif)          Phy/UnderwaterPhy
set val(ifq)            CMUPriQueue
set val(rp)             DSR

Phy/UnderwaterPhy set CPThresh_ 10.0;
Phy/UnderwaterPhy set CSThresh_ 0.284;
Phy/UnderwaterPhy set RXThresh_ 4.0;
Phy/UnderwaterPhy set Pt_ 97;
Phy/UnderwaterPhy set freq_ 30;
Phy/UnderwaterPhy set L_ 1.0;

# ==================================================
# Set Node Mobility
# ==================================================
$ns_ at 0.10 "$node_(0) setdest 5.0 5.0 0.50"
$ns_ at 0.10 "$node_(1) setdest 6.0 5.0 0.50"
$ns_ at 0.10 "$node_(2) setdest 5.5 5.0 0.50"
```

```
# ==================================================
# Setup Traffic Flows
# ==================================================
set udp [new Agent/UDP]
$udp set fid_ 1
set sink [new Agent/LossMonitor]

$ns_ attach-agent $node_(0) $udp
$ns_ attach-agent $node_(1) $sink

$ns_ connect $udp $sink

# Creating CBR Traffic
set cbr [new Application/Traffic/CBR]
$cbr set packetSize_ 1
$cbr set interval_ 10.0
$cbr attach-agent $udp
$ns_ at 0.0 "$cbr start"
```

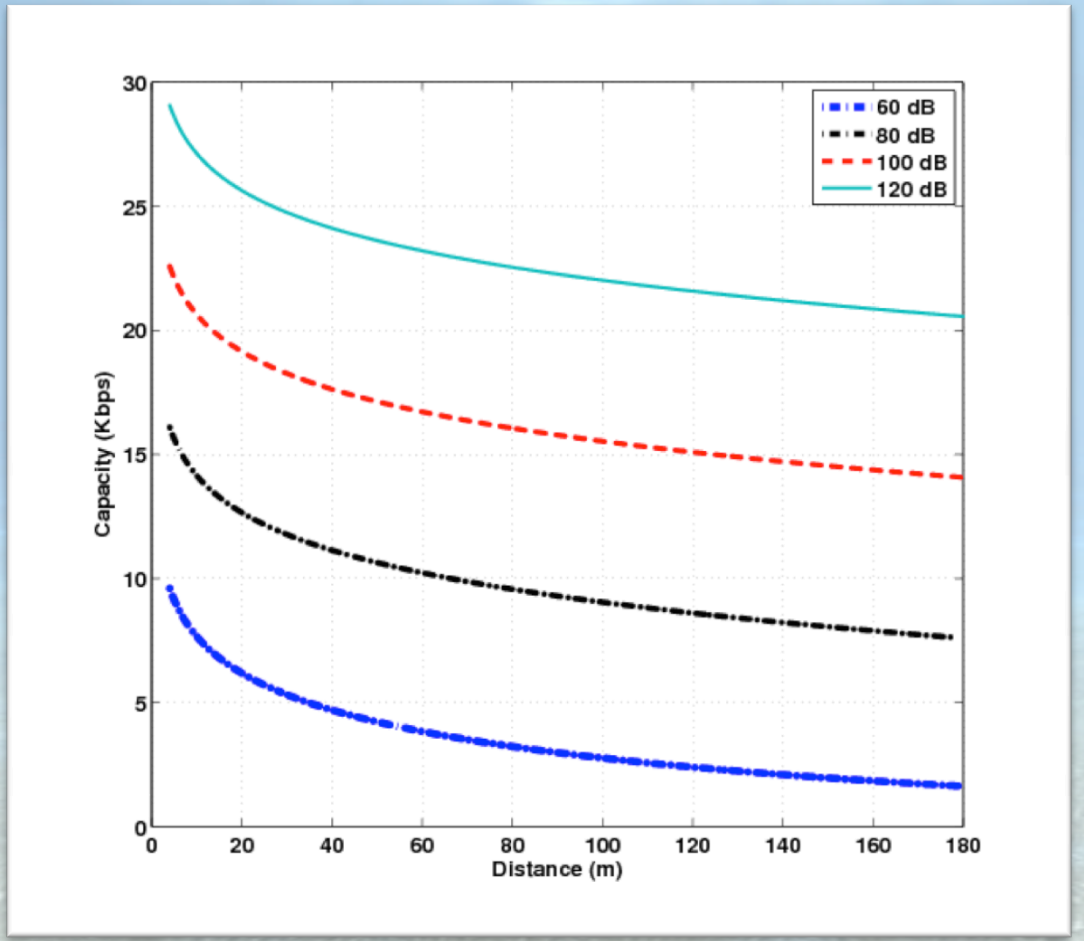
- Simulation setup can be done by defining modem characteristics, node mobility and traffic flows.
- Important channel parameters can be setup simply by setting values for appropriate *Tcl* variables.

Results – Propagation Delay



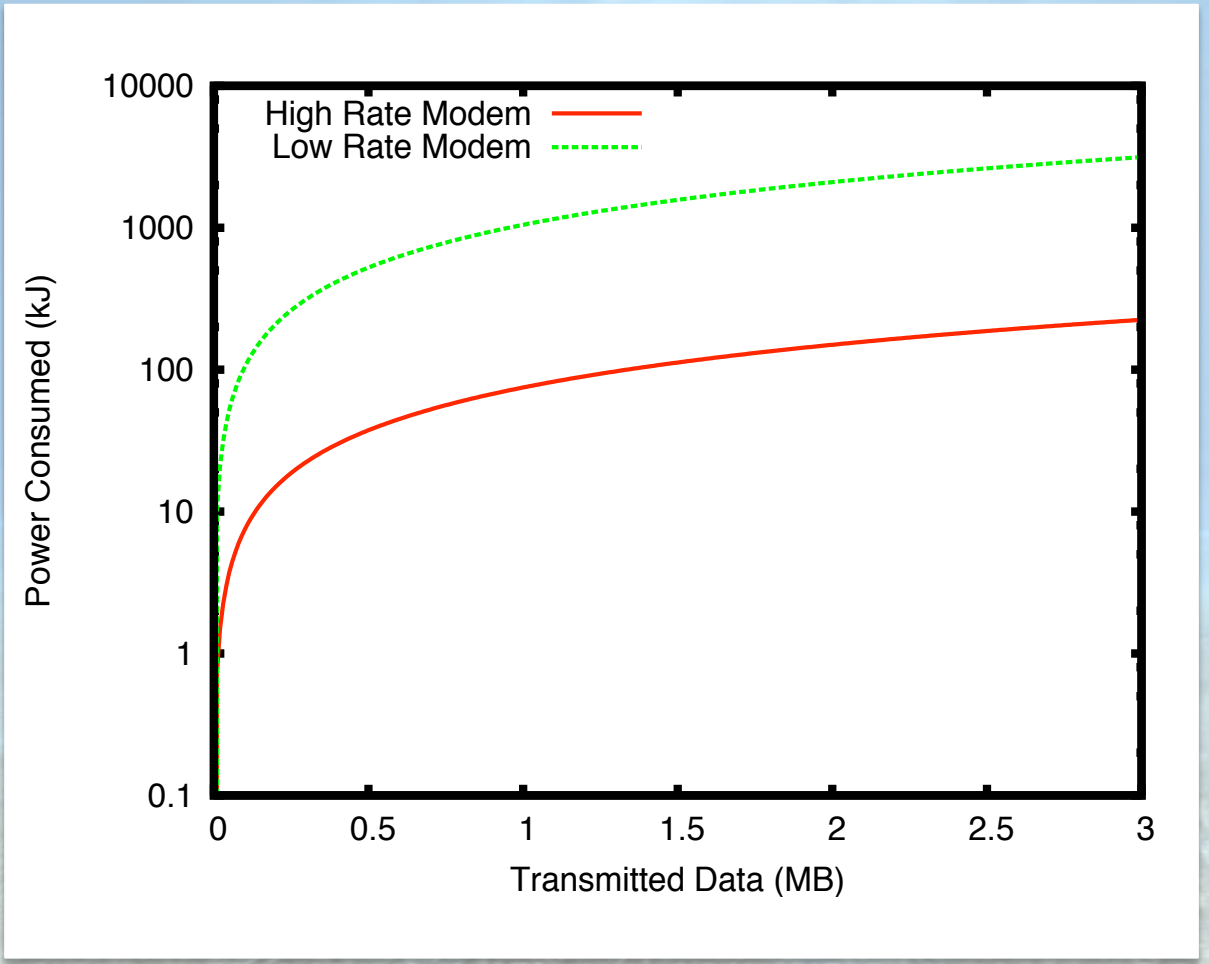
- Propagation delay results mimic the shape of the sound velocity profile used – indicating an accurate performance.

Results – Channel Capacity



- As expected, the channel capacity predicted reduces logarithmically with distance and increases with transmission strength.

Results – Energy Consumption



- Studies performed using AquaTools have confirmed that using a high power high-data rate modem for transmitting data over shorter hops can save energy.

Conclusions & Future Work

- The AquaTools simulation toolkit is based on the ns2 simulator.
  - Widely used simulator.
  - Easy to write Tcl scripts.
- The obtained results are within bounds of numerical evaluations.
  - Numerically correct results.
  - Need to be compared to real world deployments
- The simulator provides a method for developing and testing routing, transport and application layer protocols as well.

Relevant References

- A. F. Harris and M. Zorzi, “Modeling the underwater acoustic channel in ns2,” in ValueTools ’07, ICST, Brussels, Belgium, 2007, pp. 1–8.

- E. M. Sozer, M. Stojanovic, and J. G. Proakis, “Design and simulation of an underwater acoustic local area network,” in Proc. Opnetwork 99,1999.