DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

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DESERT Underwater

UNWis - Padova (Italy)

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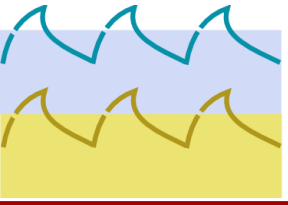
Filippo Campagnaro, Roberto Francescon, Angela Soldà, Michele Zorzi

filippo.campagnaro@unipd.it



DESERT Underwater

DESERT – DESERT stack

DESERT Underwater

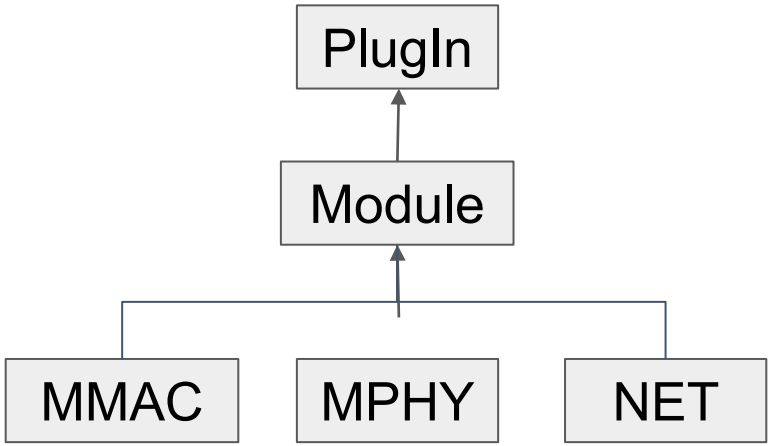
- Open-source framework publicly available to simulate, emulate and realize testbeds of underwater networks
  http://desert-underwater.dei.unipd.it/
- Supports simulation of acoustic, optical and multimodal networks
- Includes many routing and MAC protocols
- Uses different models to simulate the channel
- Allows sea trials with the removal of simulated physical layers and addition of real modems
- Can be cross-compiled for embedded

DESERT Underwater - more

DESERT..

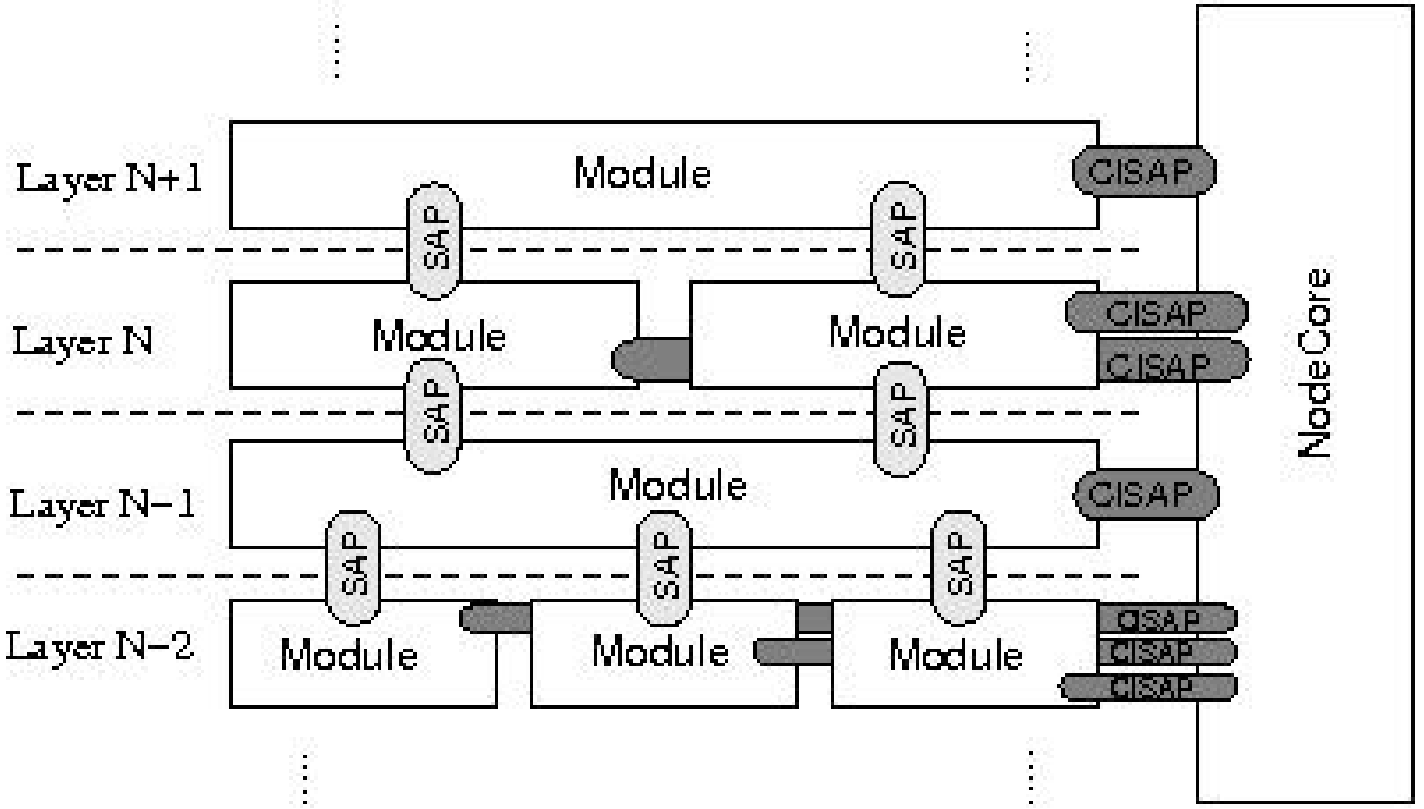
- is an extension of ns2-miracle
  http://telecom.dei.unipd.it/ns/miracle/doxygen/
- can directly use all modules of ns2-miracle
- all DESERT modules have a prefix uw to distinguish them from ns2 and ns2 miracly
  - E.g., uwcbr vs cbr, uwaloha vs aloha
- This looks like a duplication, but it is not
  - All layers have been reimplemented as uw network do not use IP and all protocols need to be customized due to the characteristics of the uw channel

ns2 - Miracle



- each DESERT Module (PHY, NET, etc) extends from the class Module, that extends from the class PlugIn
- they provide basic apis to:
  - receive a Packet and send it to upper/lower layer
  - communicate with other layers of the stack via crosslayer messages
  - configure the layer via tcl script (command and bind)

ns2 - Miracle



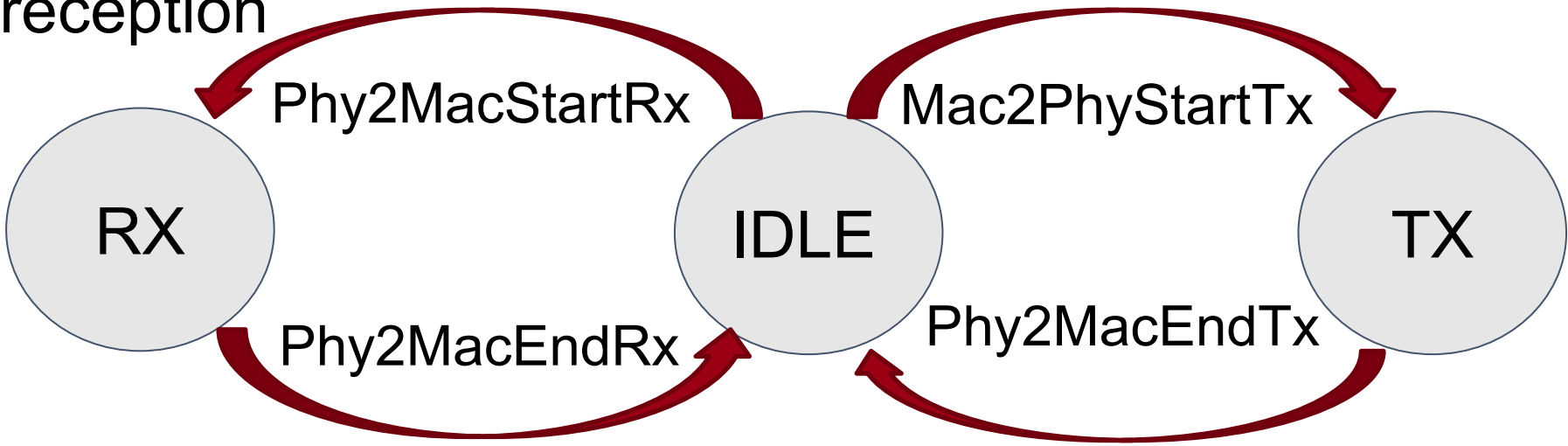
- Service Access Point (SAP) allows communication between adjacent layers
- Cross Layer SAP (CISAP) allows communication between non-adjacent layers using NodeCore as Cross layer bus

ns2 - Miracle MMAC and MPHY

- MMAC is the base module class with MAC layer APIS
  - each MAC extends from MMAC
- MPHY is the base module class with PHY layer APIS
  - each PHY extends from MPHY
- they are strictly connected

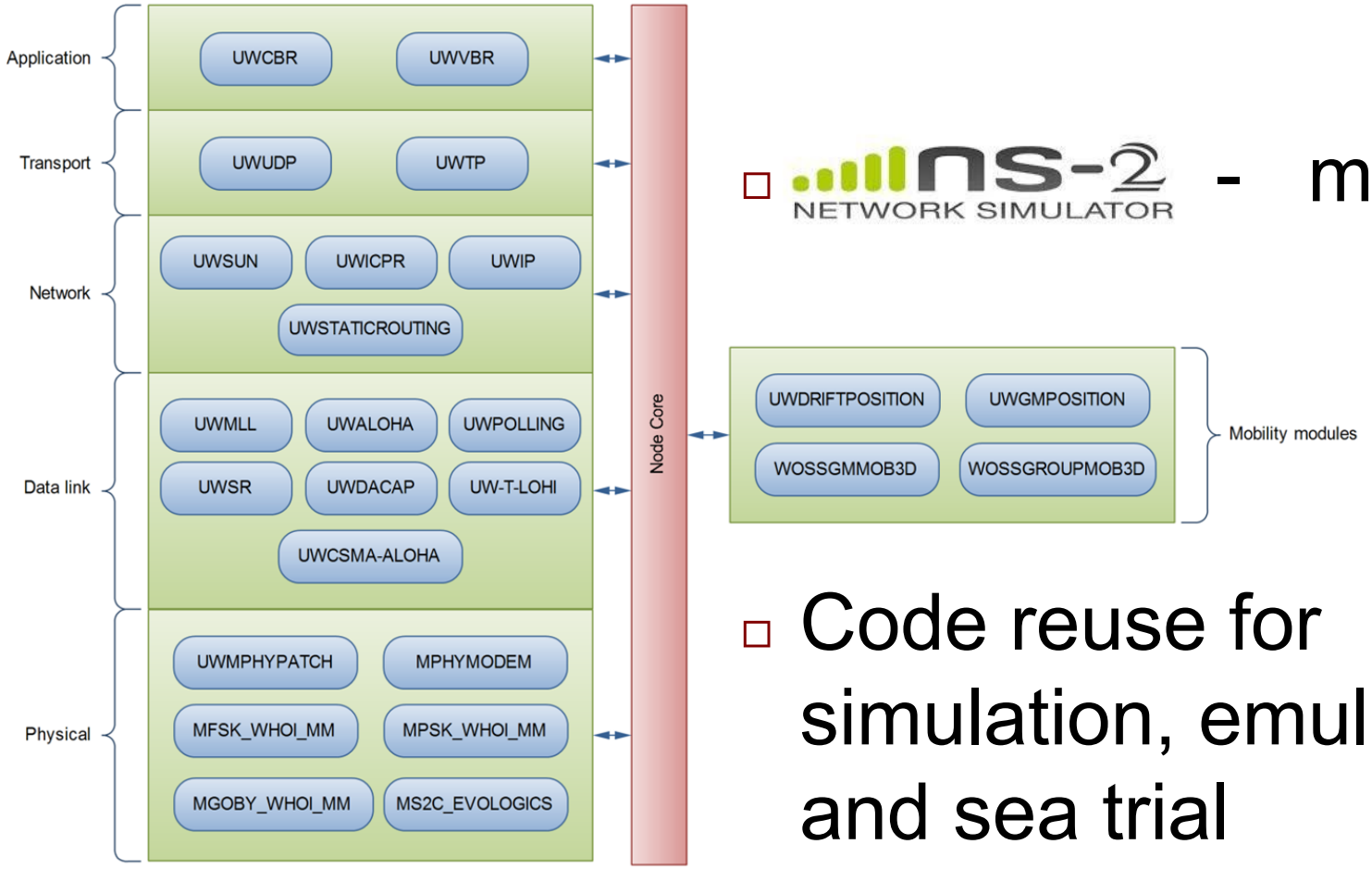
MAC state machine

- MMAC starts the transmission of a packet with the PHY, that notifies when the transmission finishes
- PHY also notifies when a packet starts end finishes to be received
- each MAC should implement a state machine to avoid transmitting when busy for transmission and reception



DESERT Underwater v3

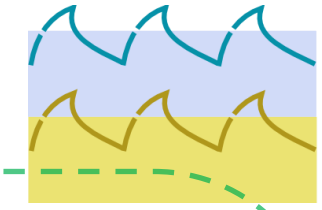
"DEsign, Simulate, Emulate and Realize Test-beds for Underwater network protocols"

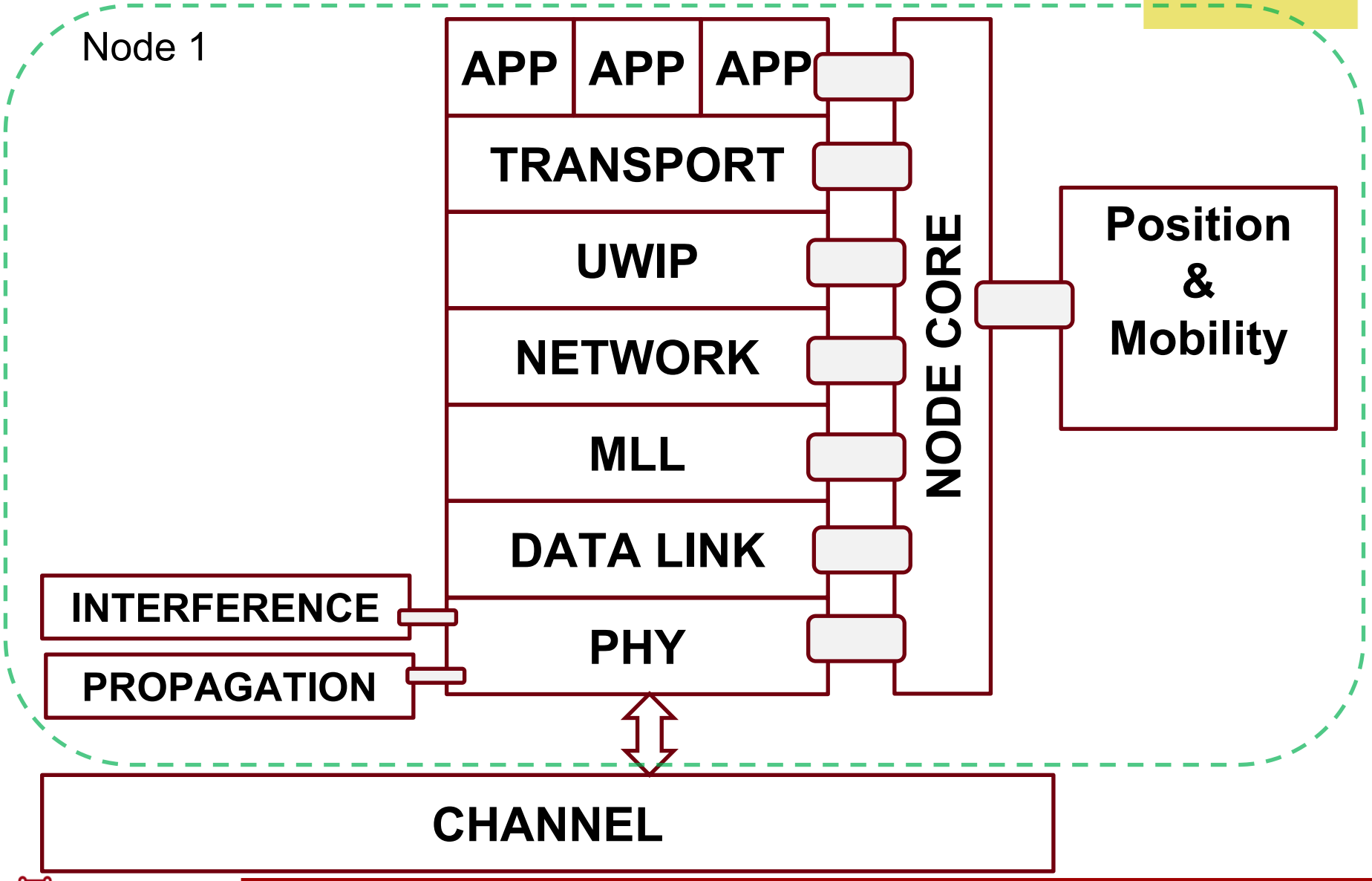


- ns-2 NETWORK SIMULATOR - miracle

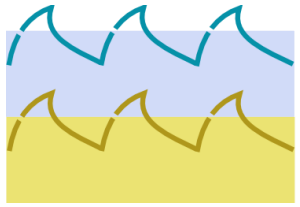
- Code reuse for simulation, emulation and sea trial

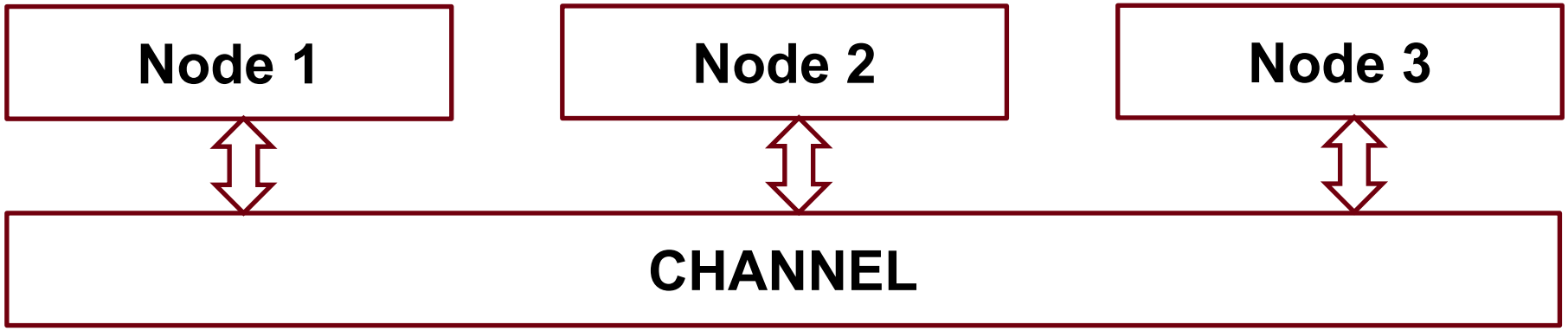
DESERT Underwater stack





DESERT Underwater stack





Application layers

uwapplication - uwcbr - uwvbr

uwcbr

Constant bitrate (cbr) application layer, can:

- generate packet with a fixed size and a **fixed period**
- generate packet with a fixed size according to a **Poisson** r.v. with average λ = the average generation time (time difference between to subsequent packets is an exponential r.v.)
- generate packets at a **determinate moment** set from the configuration script

uwvbr

Variable bitrate (vbr) application layer, can:

- generate packet with a fixed size and a **variable period**
- generate packet with a fixed size according to a **Poisson** r.v. with average λ that varies time to time
- generate packets at a **determinate moment** set from the configuration script

uwApplication

extends uwcbr and can:
- work just as uwcbr
- transmit and receive real data given by the user via socket interface (only in real-time)

Allows DESERT to be used as the stack of a real underwater networks, exchanging real data

More app

More app are available as addons:

- uwrov and uwrov-ctr simulate the traffic of an ROV and of a ROV remote control, respectively
- uwtracker simulates the traffic of a node detecting items with a scanning sonar

Filippo Campagnaro, Paolo Casari, Federico Favaro, Michele Zorzi, "On the Feasibility of Fully Wireless Remote Control for Underwater Vehicles" Asilomar SS&C 2014

Federico Mason, Filippo Campagnaro, Federico Chiariotti, Andrea Zanella, Michele Zorzi, “Automatic Shark Detection via Underwater Acoustic Sensing”, IEEE IoTMag 2022

Transport

uwudp

uwudp

- UDP, with port number
  - Does not perform any retransmission or reordering
  - Best effort
  - Just delivers the packet to the proper application

Routing

uwip uwstatic-routing uwflooding uwicrp uwsun uwposition-based-routing

uwip and addressing

- there is not IP address underwater
  - Usually we have small (compared to internet) local networks, IP is not required
  - IP gives high overhead, specially in low-rate networks
  - In uwip we use sequential number, starting from 1
  - 0 is broadcast address
  - No actual distinction between MAC address and “UWIP” address (uwmll matches them)

Classic routing schemes

- uwstatic routing
  - Classical static routing
  - Fixed route
  - Allows to set the next hop given the final destination
  - Uses a routing table
- uwflooding (our main **benchmark** protocol)
  - Epidemic flooding,
  - Every node forwards the packets to all other nodes
  - No re-forwarding of the same packet
  - Time to live = number of times a packet is forwarded, usually set to 2 or 3

Geographical Routing protocols

- Position-based routing
  - Assumes to know the position of all static nodes and about itself
  - Information about position of mobile nodes is updated thanks to information sent in pigback
  - Each node selects the next hop according its closest neighbor to destination

Alberto Signori, Filippo Campagnaro, Michele Zorzi, "Multi-Hop Range Extension of a Wireless Remote Control for Underwater Vehicles" MTS/IEEE Oceans18 Kobe

Advanced routing schemes

- uwsun
  - From nodes to a unique sink
  - Dynamic source routing
  - Route determination on hop-count, obtained with a route discovery phase
- uwicrp
  - Simple dynamic routing protocol
  - Update of routing table based on update messages
  - Uses the first route that it discovers: if a shorter one is discovered, it uses this one

Beatrice Tomasi, Giovanni Toso, Paolo Casari, Michele Zorzi, On the Impact of Time-varying Acoustic Channels on Routing Protocols for Underwater Networks, UCOMMS 2012

Data link

uwaloha uwcsma-aloha uwcsma-ca uwtdma uwtdma-frame uwcsma-aloha-trigger uwpolling uw-t-lohi uwdacap uwmll

MLL (ARP) and addressing

- uwmll
  - Layer for “ARP” between MAC and routing address
  - Needed only to support miracle mac layers (from which DESERT mac layers inherit)

Contention-based MAC

- uwaloha
  - Classical aloha MAC
- uwcsma-aloha (contention-based **benchmark** MAC)
  - Carrier sense mac layer, with optional re-transmissions and out of order reordering
- uwcsma-ca
  - Collision avoidance csma with RTS/CTS

Contention-free MAC

- uwtdma (contention-free **benchmark** MAC)
  - Classical TDMA MAC
  - Possible to have fair or unbalanced slots, with different size, to give more chance to transmit to nodes with high traffic
  - possibile traffic prioritization
- uwtdma-frame
  - extends uwtdma
  - schedule defined from file
  - allows nodes to transmit simultaneously (super TDMA)
  - allows nodes to transmit multiple times within a frame

MAC for data muling (from AUV)

- uwcsmaaloha-trigger
  - all nodes that receive a trigger from an AUV can transmit some packets according to csma-aloha MAC
- uwpolling
  - polling based scheme
  - neighbor discovery phase and polling phase
  - AUV decides which node can transmit according to a fair schedule
- uwUFetch
  - a cluster-head retrieves data from all nodes in a cluster
  - AUV (final destination) takes the data from cluster-heads

Federico Favaro, Paolo Casari, Federico Guerra, Michele Zorzi, “Data Upload from a Static Underwater Network to an AUV: Polling or Random Access?”, Oceans 2012 Yeosu

Other MAC

- uwsr
  - selective repeat MAC
- uw-t-lohi
  - single wake-up tone for channel reservation
  - data using all bandwidth
- uwdacap
  - handshake RTS-CTS-DATA
  - exploits the knowledge of distance between neighbors
  - leverages on near-far to allows simultaneous handshakes and data transmissions

Federico Guerra, Paolo Casari, Michele Zorzi , "A Performance Comparison of MAC Protocols for Underwater Networks using a Realistic Channel Simulator", Oceans 2009

Physical layers

MODEL: uwphysical, uwoptical_phy, uwhmmphysical, uwphysicalrogermodel;
LUT: uwphysicaldb, uwphysicalfromdb, uwhermesphy, uwahoi_phy, uwopticalbeampattern;
SEA TRIAL: uw-al, uwmodem, uwmodemca, uwahoimodem, ms2c_evologics, ms2c_evologics_lowlevel

Model-based PHYs

- uwphysical
  - Urick-Thorp formula
- uwoptical-channel
  - Beer law formula
- uwhmmphysical
  - Time variability based on 2 and 3 state HMM
- uwphysicalrogersmodel
  - Better characterization of horizontal transmissions

P. H. Rogers, Onboard Prediction of Propagation Loss in Shallow Water. Washington, DC: Naval Research Lab Defense Technical Information Center, Washington, DC, 1981.

LUT-based PHYs

- uwphysicaldb, uwphysicalfromdb,
  - Generic for SNR and SINR vs BER from LUT
  - They just use a different LUT format
- uwhermesphy, uwahoi_phy,
  - Performance figures of FAU Hermes and TUHH AHOI modem
- uwopticalbeampattern
  - Includes LUT of optical modem beam pattern

Sea-trial PHYs

- uwal
  - Commute simulated packets to binary bitstreams to be transmitted and performs segmentation
- uwmodem
  - Abstract class with for interfacing DESERT to modems
- uwmodemca
  - Drivers for Ethernet transparent modems (e.g., Bluecomm)
- uwahoimodem, uwevologicss2cmodem
  - Drivers for AHOI (TUHH) and EvoLogics modems

R. Francescon, F. Campagnaro, E. Coccolo, A. Signori, F. Guerra, F. Favaro, M. Zorzi, "An Event-Based Stack For Data Transmission Through Underwater Multimodal Networks", IEEE Ucomms 2021

Channel

uwoptical-channel underwater-channel

Channels

- The channel only sets the propagation delay between nodes
  - After the delay, that depends on nodes position and speed of media (sound/light), the packet starts to be received by the PHY of the receiving node
- uwoptical-channel
  - Simulates the optical channel
  - It is an EM channel
- underwater-channel
  - Simulates the acoustic channel
  - It is a ns2-miracle module

Mobility

uwdriftposition uwgmposition uwsmposition

Mobility

- uwdriftposition
  - A node drifts according to a certain current speed
  - Some randomness considered
- uwgmposition
  - 3D Gauss Markov mobility model
- uwsmposition
  - Fixed speed towards a waypoint
  - A new waypoint aborts the previous one

DESERT Installation

Installation procedure

DESERT Framework Installation

- DESERT Framework installation procedure permits to install with one script:
  - ns engine and all its necessary dependencies
  - DESERT libraries
  - WOSS
  - Acoustic Toolbox

DESERT Framework Installation

- `cd DESERT_Underwater/DESERT_Framework`
- `./install.sh --wizard`

- Wizard guides you throughout all the installation process and setting your preferences
  - **TARGET**: target of the installation (local system or cross-compile for available target systems?)
  - **INSTALLATION MODE**: "`development`" (copy also code source) or "`release`" (only bin and lib folders).
    In case of cross-compilation (TARGET is not LOCAL), it is strongly advised to use "release" mode
  - **DESTINATION FOLDER**: where to put lib and bin (in case of cross-compilation, this folder can be secure-copied to the target)
  - **WOSS:** Do we want WOSS installed?
  - **ADDITIONAL PARAMS:** Do you have some additional parameters for an additional installer?
  - **ADDONs** we want to be installed.

And after installation?

- You shall setup your PATH and LD_LIBRARY_PATH env variables
- In your destination folder chosen during installation process:
  - `source environment` (if you chose “development” installation mode)
  - `./make_environment.sh && source environment` (if you chose “release” installation mode)
  - You can copy and paste this in the file .bashrc (with complete path) in you home, so all new terminals will run it automatically

Installation documentation

- More info about installation, dependencies and details can be found at https://signetlabdei.github.io/DESERT_Underwater_doc/html/INSTALL1.html

More

add-ons

More..

- multimodal addons
  - Technology switch (acoustic LF, HF and optical)
- packer
  - Serialization of packer headers
  - One per layer that need to be serialized