OMNeT++ Community Summit, 2014

A Unified, Scalable, and Extensible Physical Layer Design for INET

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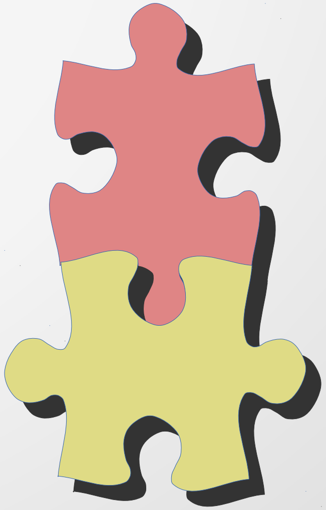
Motivation

- Incompatibility
- Scalability
- Extensibility
- Maintainability
- Duplicated functionality
- Missing functionality
- Parallel hardware support



Goals

- Unify existing INET and MiXiM physical layer functionality into a new physical layer model
- Make the new model scalable in terms of level of detail with respect to signal representation and signal processing
- Make the new model extensible with alternative implementations for meaningful sub-components
- Port existing MiXiM and INET higher layer functionality to use the new physical layer
- Support optimistic parallel execution on multiple CPUs and on highly parallel GPUs

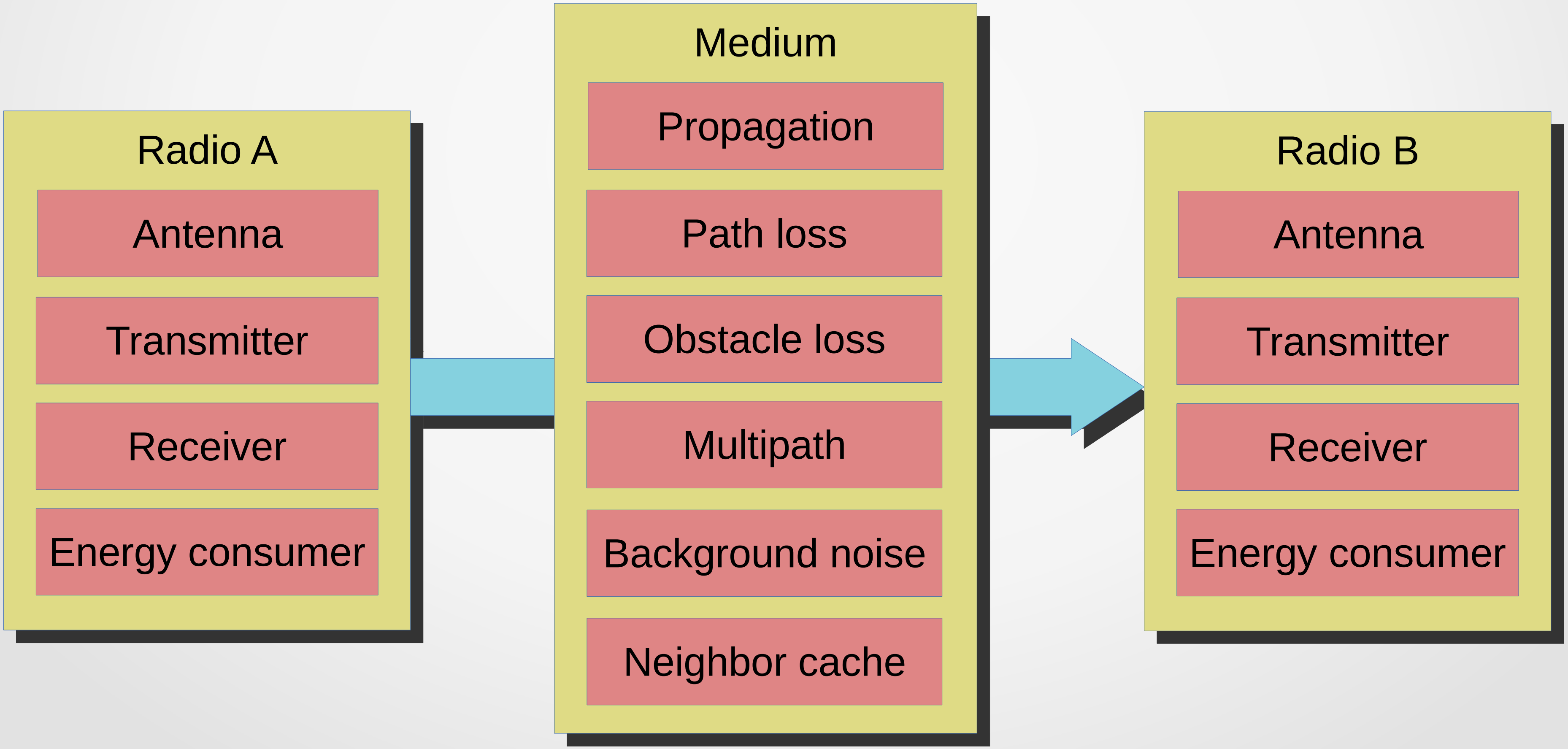
Scaling the Level of Detail

Performance — versus — Accuracy

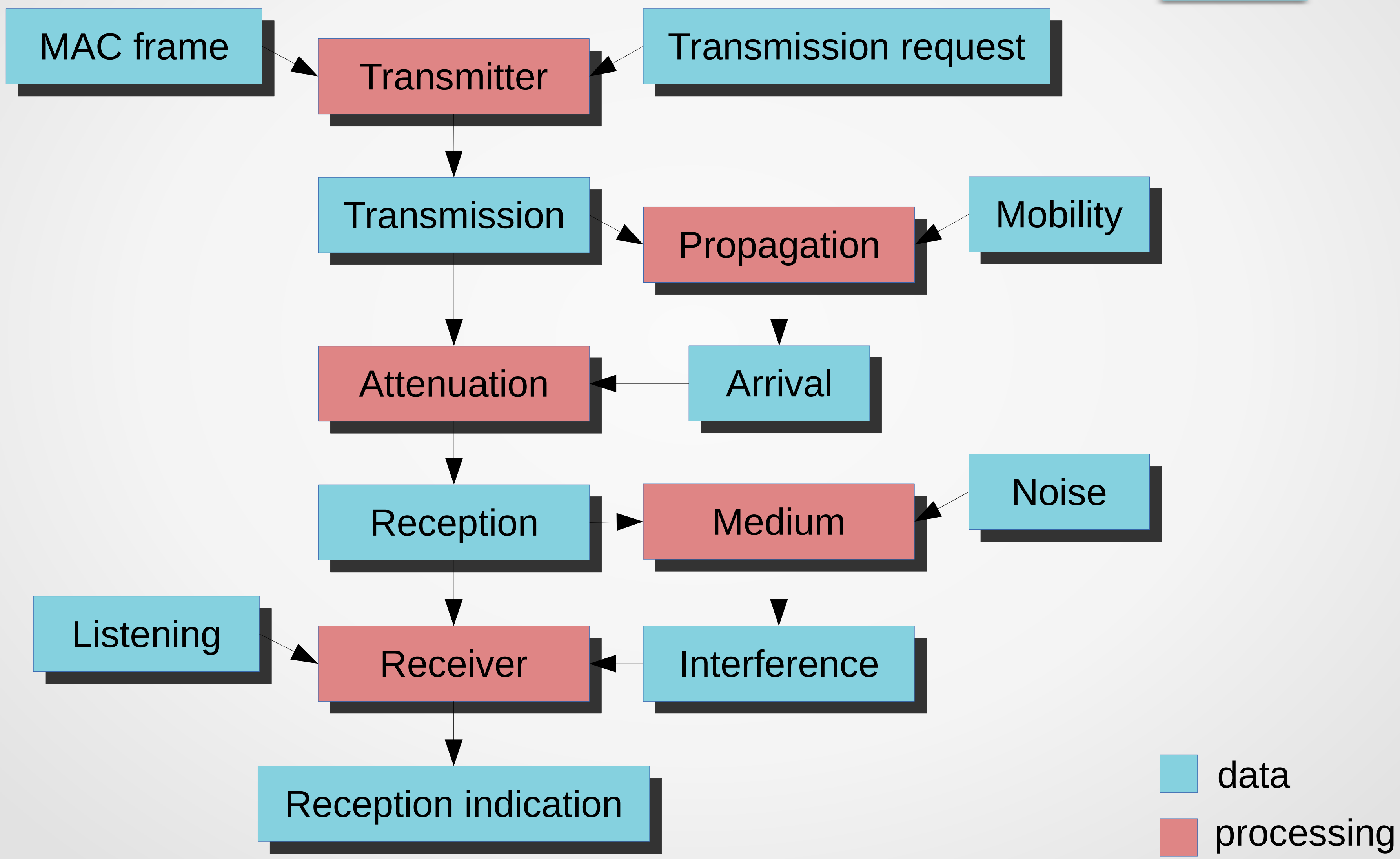
Statistical	Model	Emulation
Flat	Architecture	Layered
Scalar	Data	Dimensional
Some	Message	All

Extensible Modules

- Split up radio and medium modules into submodules
- Avoid mixing parameters of different implementations



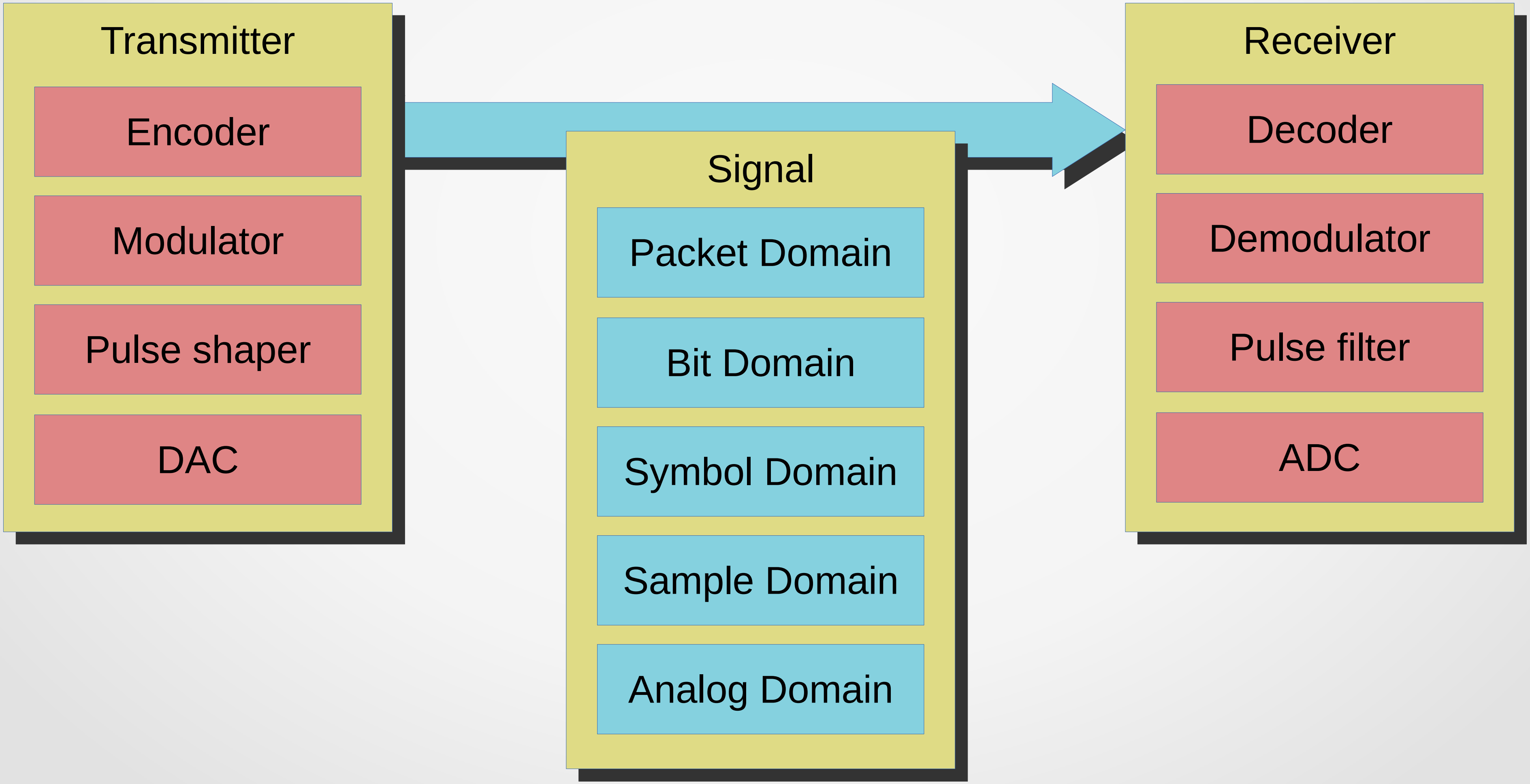
Data Flow



MAC frame
Transmitter
Transmission request
Transmission
Propagation
Mobility
Attenuation
Arrival
Reception
Medium
Noise
Listening
Receiver
Interference
Reception indication
data
processing

Layered Data and Processing Architecture

- Further split up transmitter and receiver modules

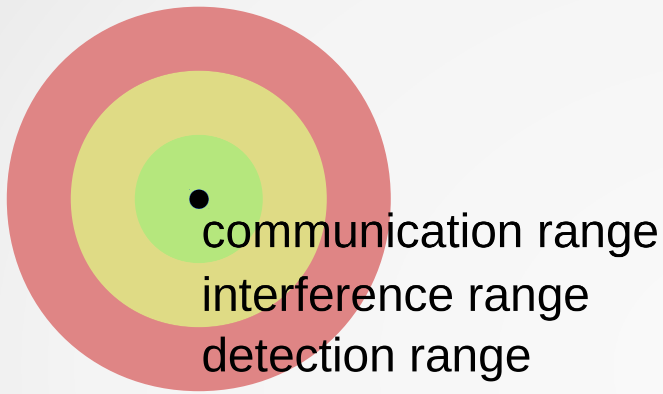


Domain Specific Signal Representations

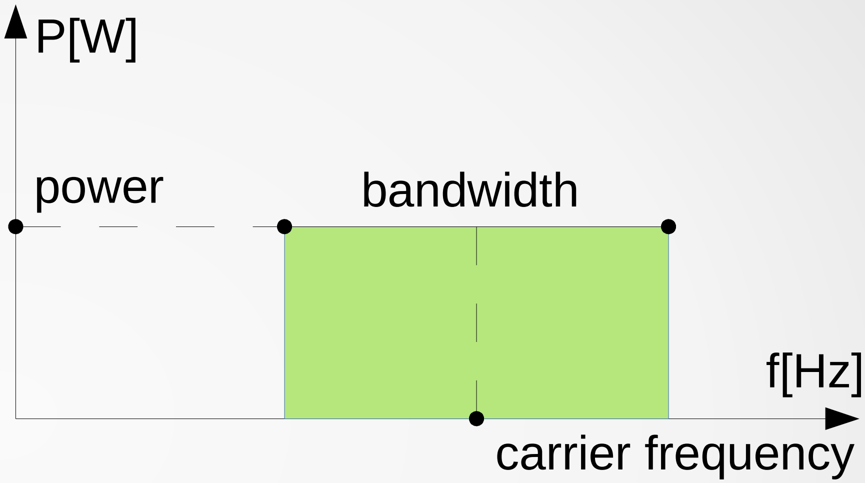
- Packet domain
  - packet, packet error rate, packet error
- Bit domain
  - bit length, actual bits, bit rate, FEC, CRC, bit error rate, bit error count, erroneous bits
- Symbol domain
  - number of symbols, symbol rate, actual symbols, modulation, symbol error rate, symbol error count, erroneous symbols
- Sample domain
  - number of samples, sampling rate, actual samples
- Analog domain
  - space-time coordinates, ranges, scalar, dimensional, RSSI, SNIR

Analog Domain Signal Representations

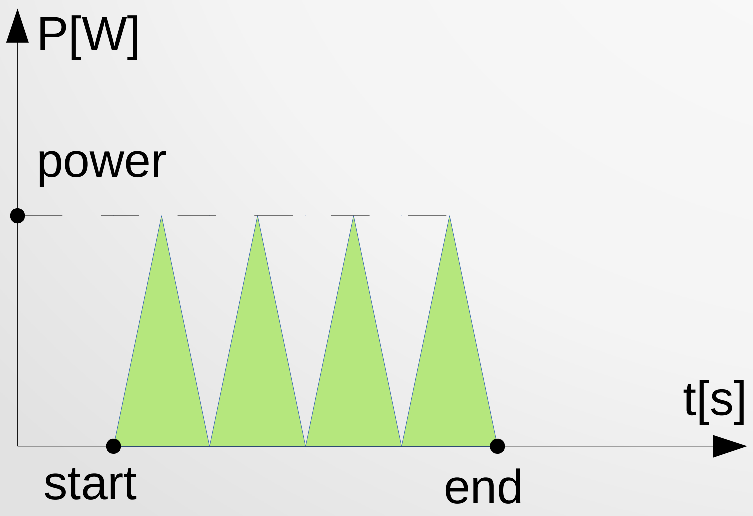
range-based



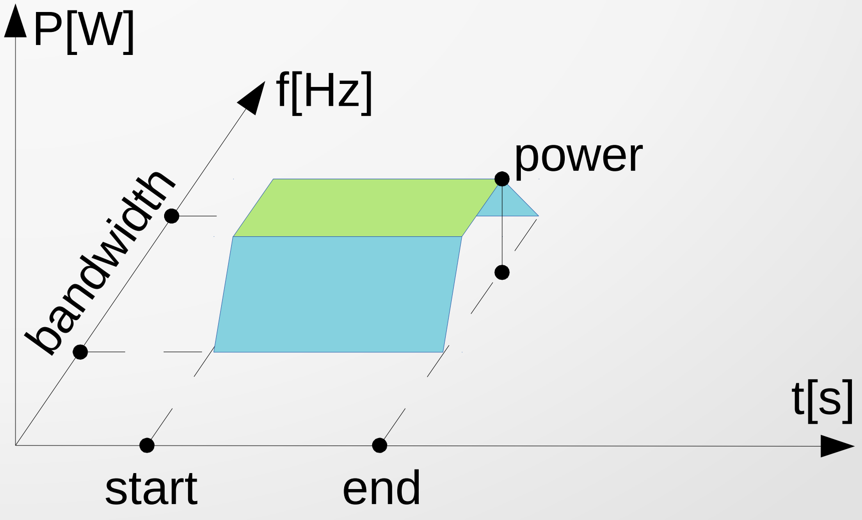
scalar



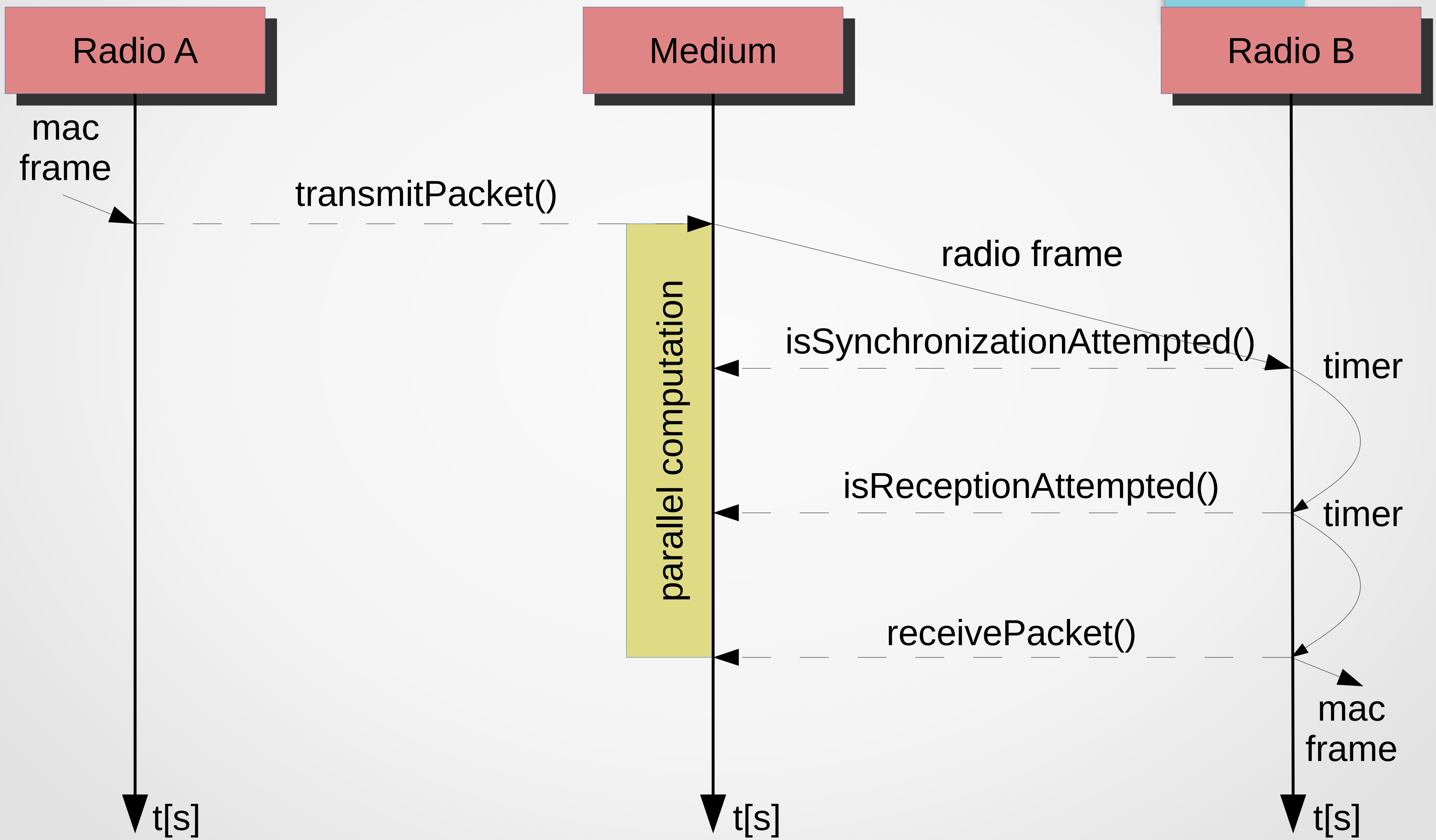
single dimensional



multi dimensional

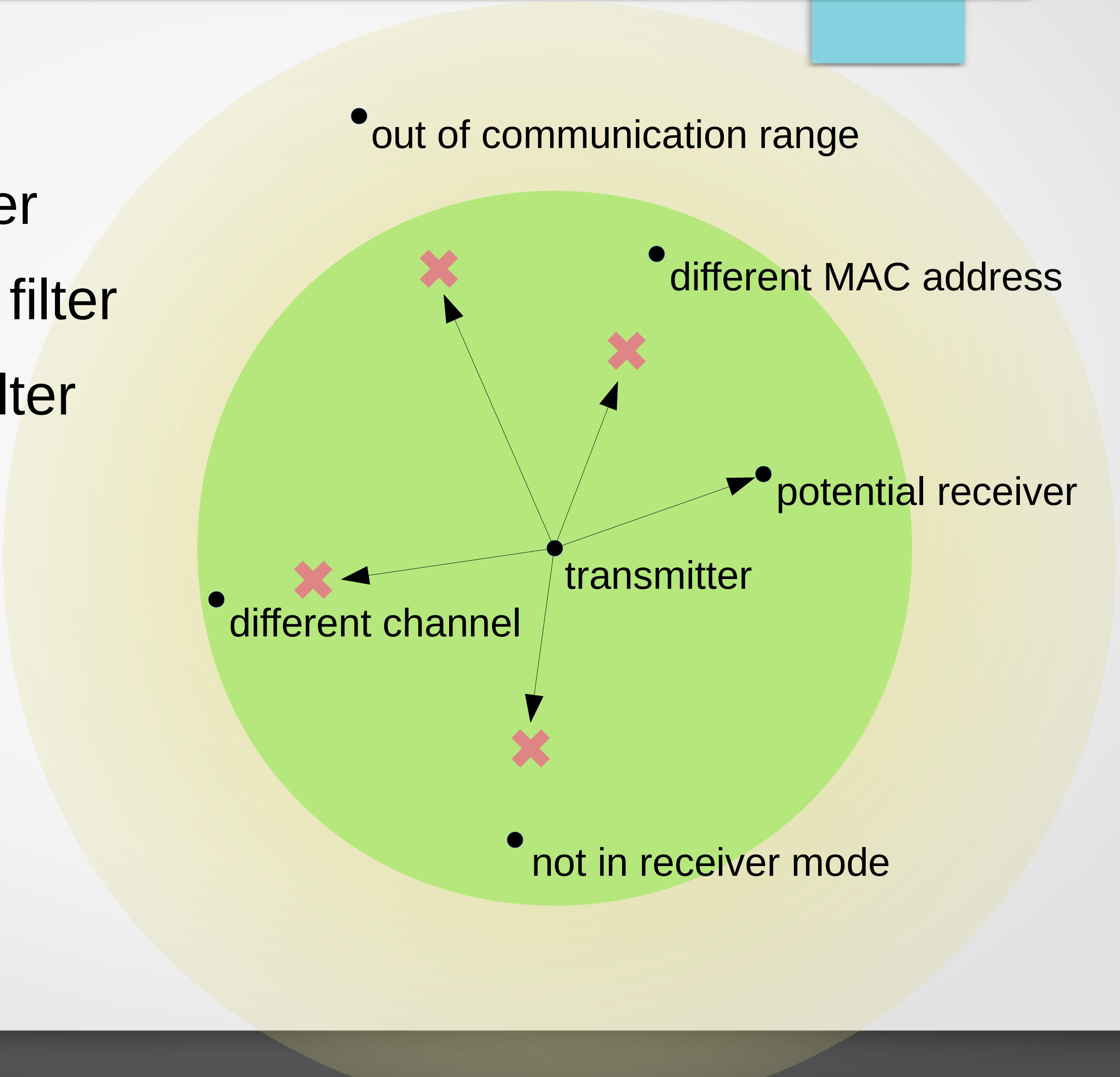


Message Processing



Optimizing Message Sends

- Range filter
- Radio mode filter
- Listening mode filter
- MAC address filter

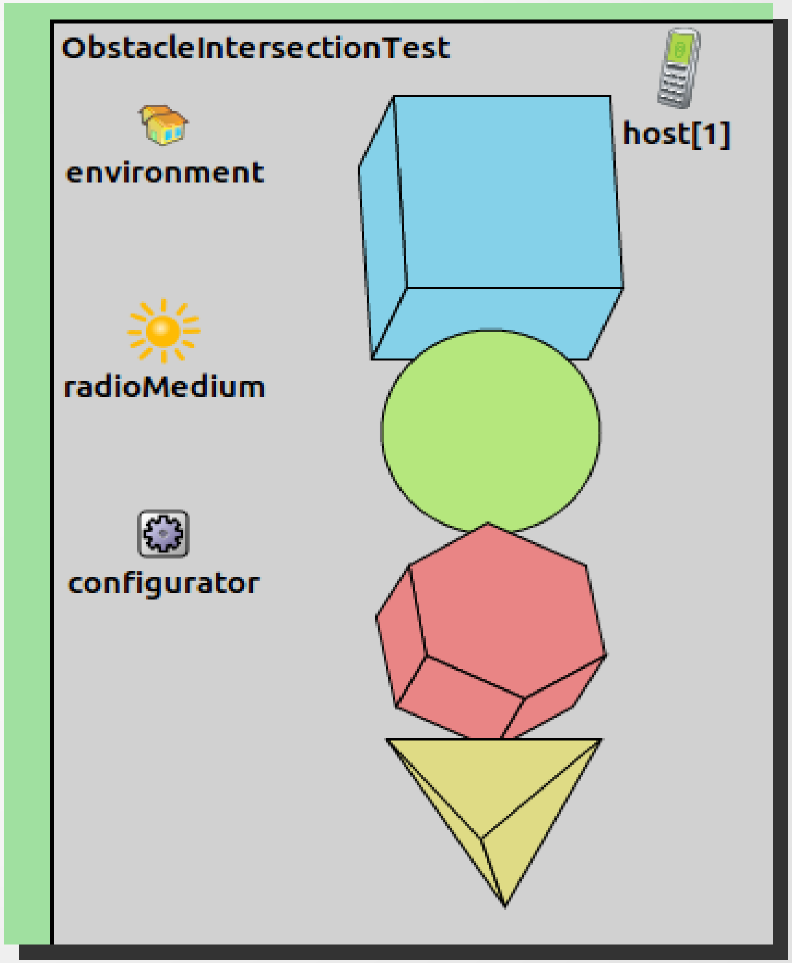


Parallel Execution

- Parallelization opportunity: computing receptions
  - they dominate performance
  - they are independent of each other
- Parallel hardware: multi-core, vector instructions, GPU
- Optimistic parallel computing in background threads
- Minimize blocking of main simulation thread
- Efficient only if upcoming receptions are mostly cached
- Discard cached results upon changes on the medium
- Optionally compute arrivals on GPU in main thread

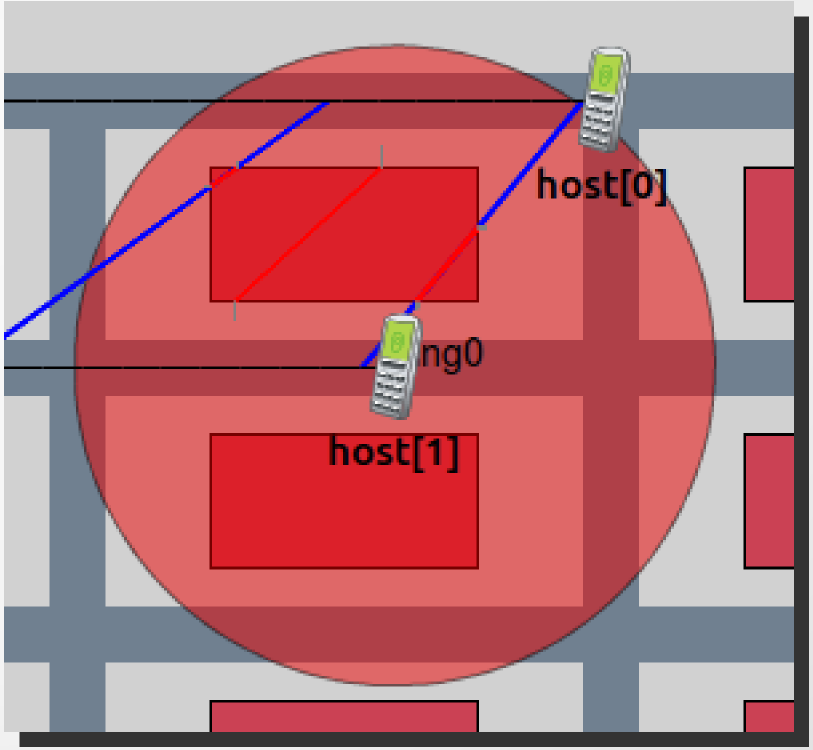
Physical Environment

- 3D geometry
- Physical properties
- Physical objects
- Materials
- Graphical properties
- Initialized from XML
- Efficient object cache
- Used by ostacle loss



Visualization

- Physical objects
- Movement trajectory
- Ongoing transmissions
- Successful receptions
- Obstacle intersections
- Reflection normal vectors



Notable Changes in C++ Source Code

- Extensible classes and data structures
  - polymorphism using subclassing and virtual functions
- Physical quantities have compile-time verified SI units
  - base units, prefixes, operators, arithmetic expressions
  - m, s, mps, W, mW, Hz, MHz, etc.
- Parallel execution needs
  - immutable data structures
  - purely functional code that is free of side effects

Implemented Functionality: Radio

- Radio modes
  - off, sleep, receiver, transmitter, transceiver, switching
- Antenna
  - isotropic, constant gain, dipole, interpolating
- Transceiver
  - range-based, flat statistical scalar and dimensional
- Power consumer
  - based on radio mode, transmitter state and receiver state
- Ported standards
  - IEEE 802.11 from INET
  - IEEE 802.15.4a UWBIR from MiXiM

Implemented Functionality: Medium

- Propagation
  - constant time, constant speed
- Path loss
  - free space, breakpoint, log normal, two-ray ground, Nakagami, Rayleigh, SUI, UWB stochastic
- Obstacle loss
  - straight path based dielectric and reflection loss
- Background noise
  - isotropic
- Neighbor cache
  - neighbor list, spatial grid, quad tree

Implemented Functionality: Geometry

- 3D sets
  - line segment, axis aligned box, polygon, plane
- 3D shapes
  - sphere, cuboid, convex prism, convex polyhedron
- 3D orientation
  - Euler angles, rotation matrix, quaternion
- Caches
  - spatial grid, quad tree, BVH tree
- Algorithms
  - bounding box, faces and normal vectors, intersection, visible faces, convex hull, 2D projection

Other Implemented Functionality

- Mobility
  - stationary orientation, constant speed rotation
- Power source
  - ideal power source, voltage regulated battery
- Physical environment
  - environment, object, material
- Physical object cache
  - spatial grid, BVH tree

Higher Layer Functionality

- Link layers
  - ported IEEE 802.11 from INET
  - ported IEEE 802.15.4a from MiXiM
  - ported CMSA, BMAC, LMAC from MiXiM
  - added Ideal mac
- Network layers
  - ported Flood, Probabilistic Broadcast, Wireless Sensor Network from MiXiM
  - untouched INET network layers

Functionality under Development

- Radio
  - layered bit precise, GNU software-defined radio
- Medium
  - multi-threaded, GPU based scalar, acoustic wireless, wired
- Propagation
  - GPU based, receiver movement approximating
- Path loss
  - Weibull, Jakes from MiXiM
- Stochastic obstacle loss
- Multipath fading
  - UWB stochastic from MiXiM, ray tracing for reflections

Tests and Examples

- All existing wireless fingerprint tests pass in INET
- New tests for reception and interference corner cases
- New examples for
  - various MAC and physical layer combinations
  - indoor and outdoor scenarios with obstacles
  - scaling for parallel execution
  - neighbor cache comparison
  - object cache comparison

Questions and Answers

Thank you for your attention!