EKT433 cabling and network components

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- Physical layer modeling
- Physical layer components
  - Bit domain
  - Symbol domain
  - Sample and waveform domain
- Accurate simulation of physical layer
- Physical Layer Modeling for Network Simulations

Physical layer modeling

- Physical layer:
  - describes the media that interconnects networking devices
- Wired
  - Coaxial cable
  - Twisted pair cable
  - Fiber optic
- Wireless

Wired networks

- EIA/TIA 568-A standard
  - minimum requirements for the interconnecting
  - LANS
  - Buildings
- EIA/TIA 568-B (2000)
  - EIA/TIA-568-B.1: Commercial Cabling Standard, Master Document
  - EIA/TIA-568-B.2: Twisted-pair Media
  - EIA/TIA-568-B.3: Optical Fiber Cabling Standard

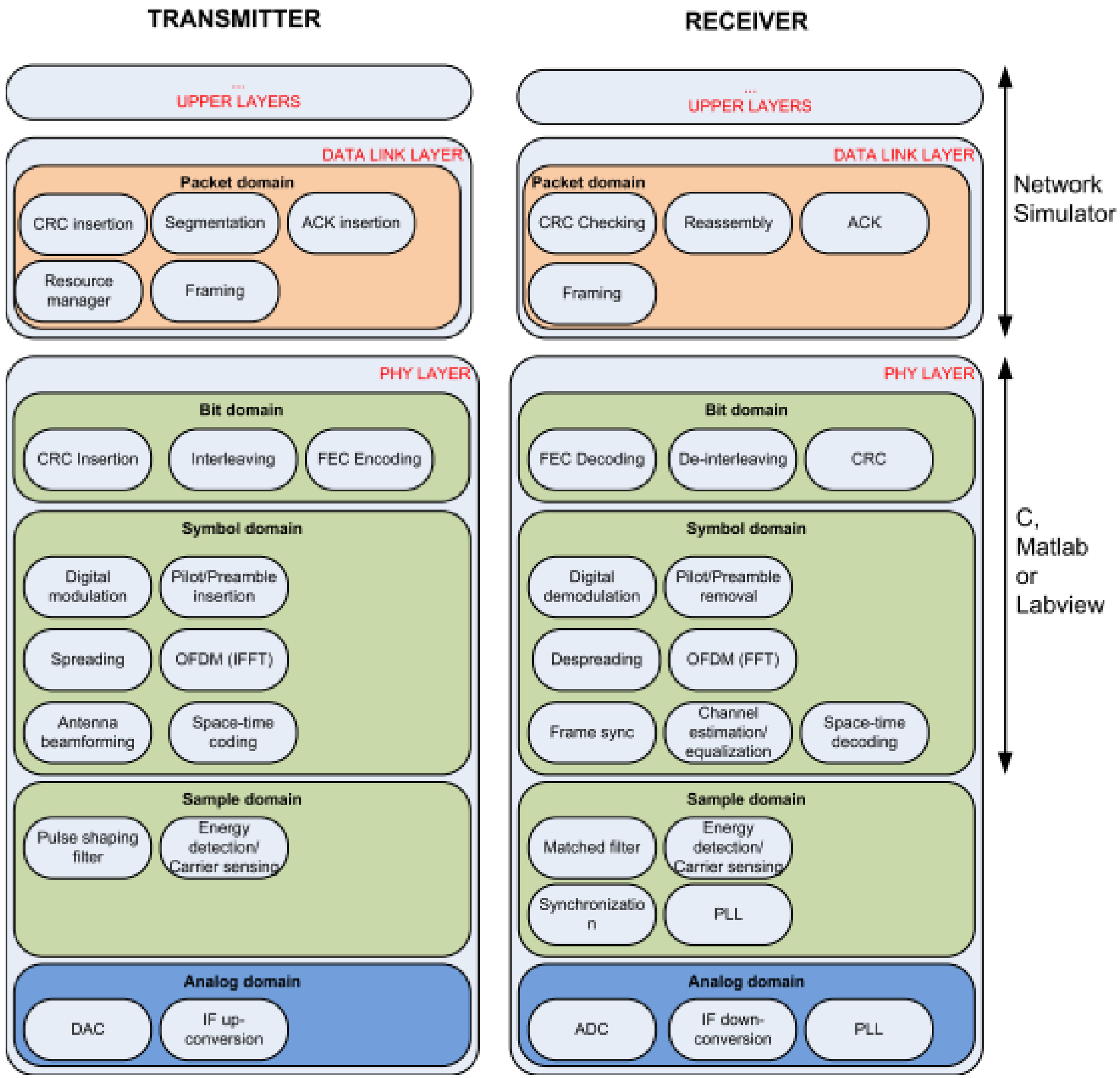
UTP

TABLE 2-1 Different Categories for Twisted-pair Cable, Based on TIA568B

Category	Description	Bandwidth/Data Rate
Category 3 (CAT3)	Telephone installations Class C	Up to 16 Mbps
Category 5 (CAT5)	Computer networks Class D	Up to 100 MHz/100 Mbps 100-m length
Enhanced CAT5 (CAT5e)	Computer networks	100 MHz/1000 Mbps applications with improved noise performance in a full duplex mode
Category 6 (CAT6)	Higher-speed computer	Up to 250 MHz networks Class E/1000Mbps CAT6 supports 10 Gbps but at distances less than 100 meters
Category 6a (CAT6a)	Increased bandwidth	Up to 500 MHz networks Class Ea/10 Gbps
Category 7 (CAT7)	Proposed standard	Up to 600 MHz speed computer networks Class F/10 Gbps
Category 7a (CAT7a)		

Wireless physical layer

- Divided into four domains:
  - Bit domain
  - Symbol domain
  - Sample domain
  - Wave/analog domain


TRANSMITTER
RECEIVER
UPPER LAYERS
UPPER LAYERS
DATA LINK LAYER
Packet domain
CRC insertion
Segmentation
ACK insertion
Resource manager
Framing
DATA LINK LAYER
Packet domain
CRC Checking
Reassembly
ACK
Framing
Network Simulator
PHY LAYER
Bit domain
CRC Insertion
Interleaving
FEC Encoding
Symbol domain
Digital modulation
Pilot/Preamble insertion
Spreading
OFDM (IFFT)
Antenna beamforming
Space-time coding
Sample domain
Pulse shaping filter
Energy detection/ Carrier sensing
Analog domain
DAC
IF up-conversion
PHY LAYER
Bit domain
FEC Decoding
De-interleaving
CRC
Symbol domain
Digital demodulation
Pilot/Preamble removal
Despreading
OFDM (FFT)
Frame sync
Channel estimation/ equalization
Space-time decoding
Sample domain
Matched filter
Energy detection/ Carrier sensing
Synchronizatio n
PLL
Analog domain
ADC
IF down-conversion
PLL
C, Matlab or Labview

Bit domain

- Connect physical layer to DLL
- Three main functions:
  - Cyclic Redundancy Check (CRC)
    - CRC bits are added to the packet bits
    - Transmission error detection (no correction)
  - Forward Error Correction (FEC)
    - Correct eventual transmission error
    - Convolutional codes are used for (noisy link)
    - Turbo-codes
    - Low-Density-Parity-Check
  - Interleaving
    - To reduce bits error

Symbol Domain

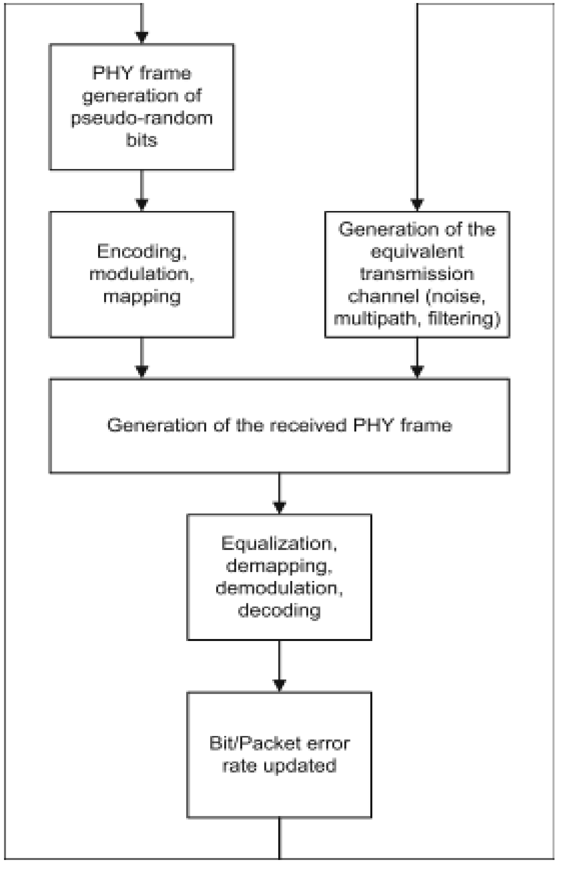
- Intermediate step
- Converts bits into symbol
- Amplitude Shift Keying (ASK)
  - symbol value represents the amplitude of the waveform
- Frequency Shift Keying (FSK)
  - symbol value corresponds to a specific frequency
- Today's technology more complex
  - bit-to-symbol mapping schemes
    - Gaussian Minimum Shift keying (GMSK) in (GSM)
    - Quadrature Amplitude Modulation (QAM) for (IEEE802.11)
    - Differential Quadrature Phase Shift Keying (DQPSK) in DAB/DVB

Sample and Waveform Domain

- Frame/Packet Synchronization.
- Channel Estimation and Equalization
- Pulse Shaping Filter/Matched Filter.
- Carrier Sensing/Energy Detection.
  - Received Signal Strength Indication (RSSI).
- DA/AD Conversion and IF Up/Down Conversion.

Simulation of Physical Layers

- Elementry operation are in:
  - Vector of bits, symbol, and samples
  - Scientific programming language is required
    - Scilab, matlab, labview, C++.



Scientific language limitation

- Slow execution speed
  - Ok with bit and symbol domains
  - Not OK with sample domain
  - determine an equivalent transmission model in symbol domain
    - Usually done
    - Less accurate
- No discrete-event support
  - Higher layers
  - implemented from scratch (NO libraries)
- Lack of interaction with network simulators

Physical Layer Modeling for Network Simulations

- Abstract from the many details of the physical layer
- physical layer impact on the transmission of frames or packets:
  - throughput,
  - Error probability
  - And delay
  - Assuming:
    - Perfect synchronization
- Simulation models accounts for:
  - FEC coding
  - Digital modulation
  - Advance transmission scheme
  - Carrier sensing
  - Other physical components (function) are assumed to be perfect
  - Packet error process (along with delay and throughput)

- Two main component:
  - Channel quality between transmitter and corresponding receiver
    - path loss,
    - shadowing,
    - fading,
    - noise
    - and interference
  - channel quality accountancy
    - average or if an instantaneous channel
    - multiple values per transmitted packet.
  - translate the channel quality into an error rate

Link-to-System Interface

- Mapping of channel state to bit-error probability
- Two types:
  - Fixed channel state (constant)
  - Dynamic channel state

- Example of fixed
  - Channel state is measured in terms of SNR
  - Bit-error is driven according to
    - modulation scheme
    - Transmitted power
  - Packet error is calculated based on the bit error
  - SNR:

$$\gamma = \frac{P_{\mathrm{tx}} \cdot h^2}{\sigma^2}$$

  - Where P_{tx} is the transmit power,
  - h^2 is the channel gain
  - And σ^2 is the equivalent background noise power of the transmission

Equivalent Channel Quality Models

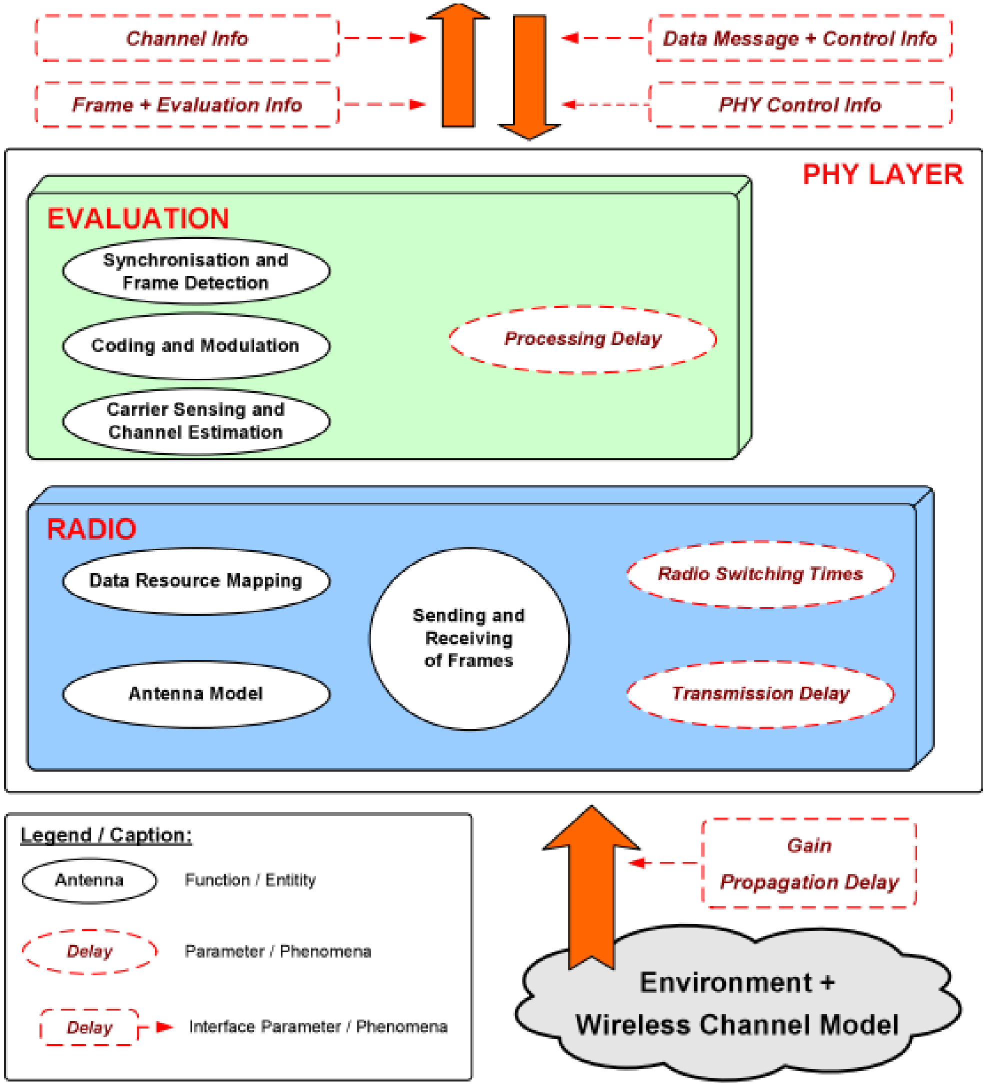
- Channel quality during a packet transmission:
  - Static or dynamic
  - Static
    - Packet error -> bit error -> SNR
  - Dynamic
    - Due to
      - Fading , interference
      - SINR is used (interference case)

$$\gamma = \frac{P_{\mathrm{tx}} \cdot h^2}{\sum_{\forall j} P_j^I \cdot h_j^2 + \sigma^2}$$

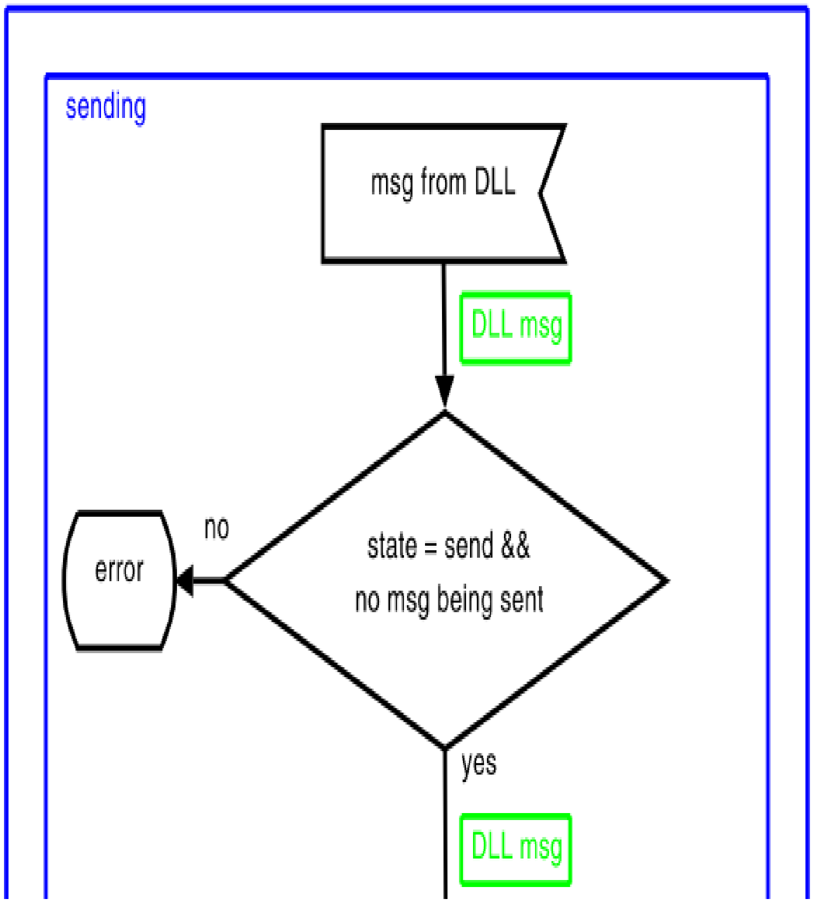
Modeling Advanced Transmission Systems

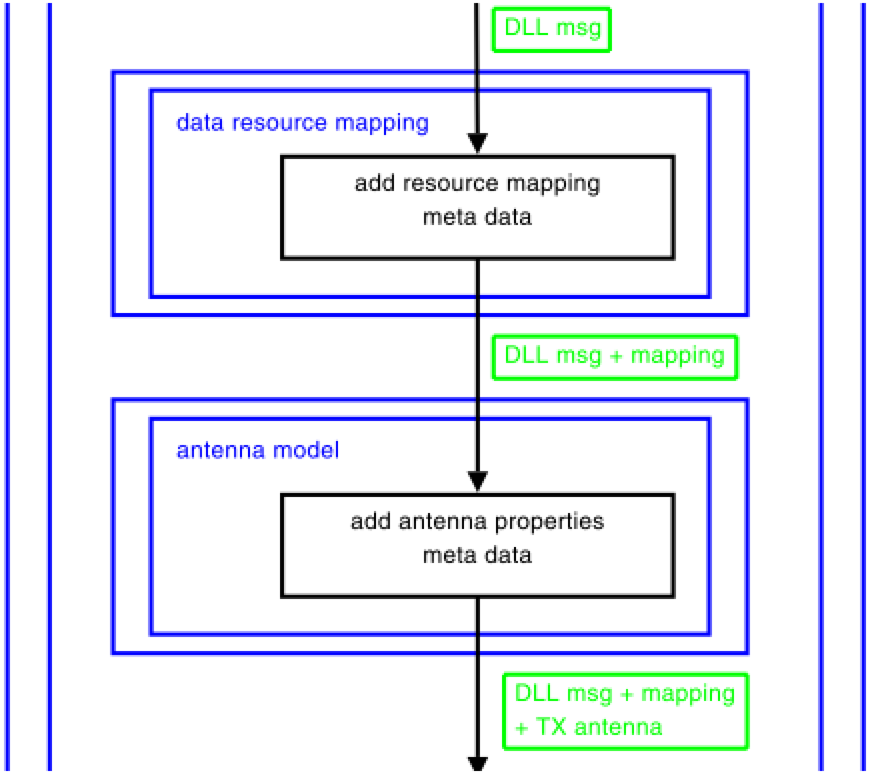
- Interaction between the channel and advanced transmission schemes
- Multi-parameter dependency
- Advanced coding schemes on top of advanced transmission schemes
- Adaptation and channel feedback

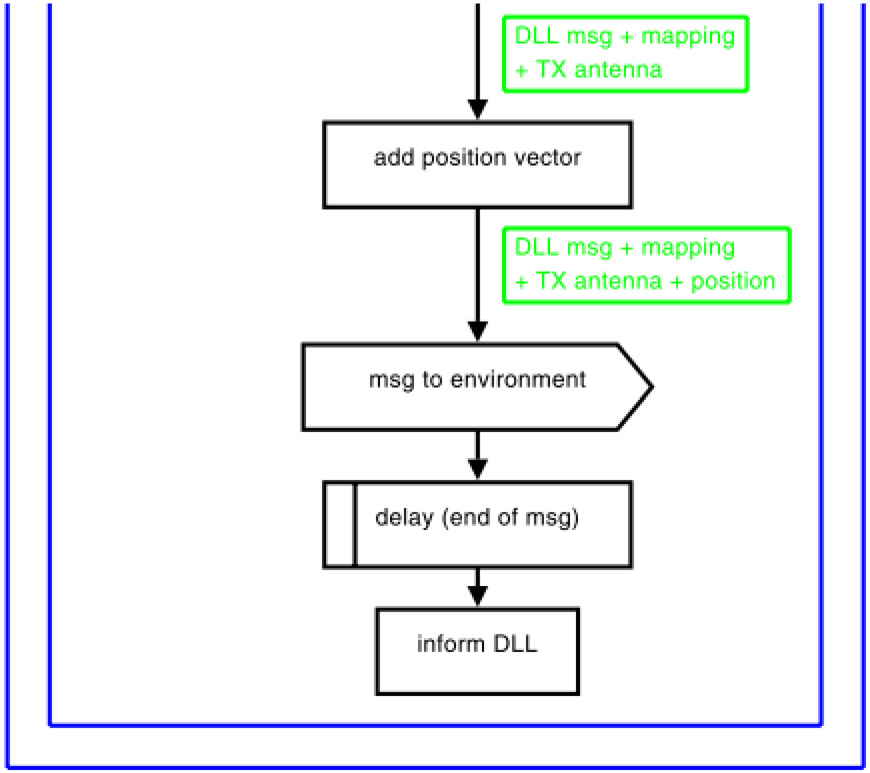
Example Packet Domain Physical Layer



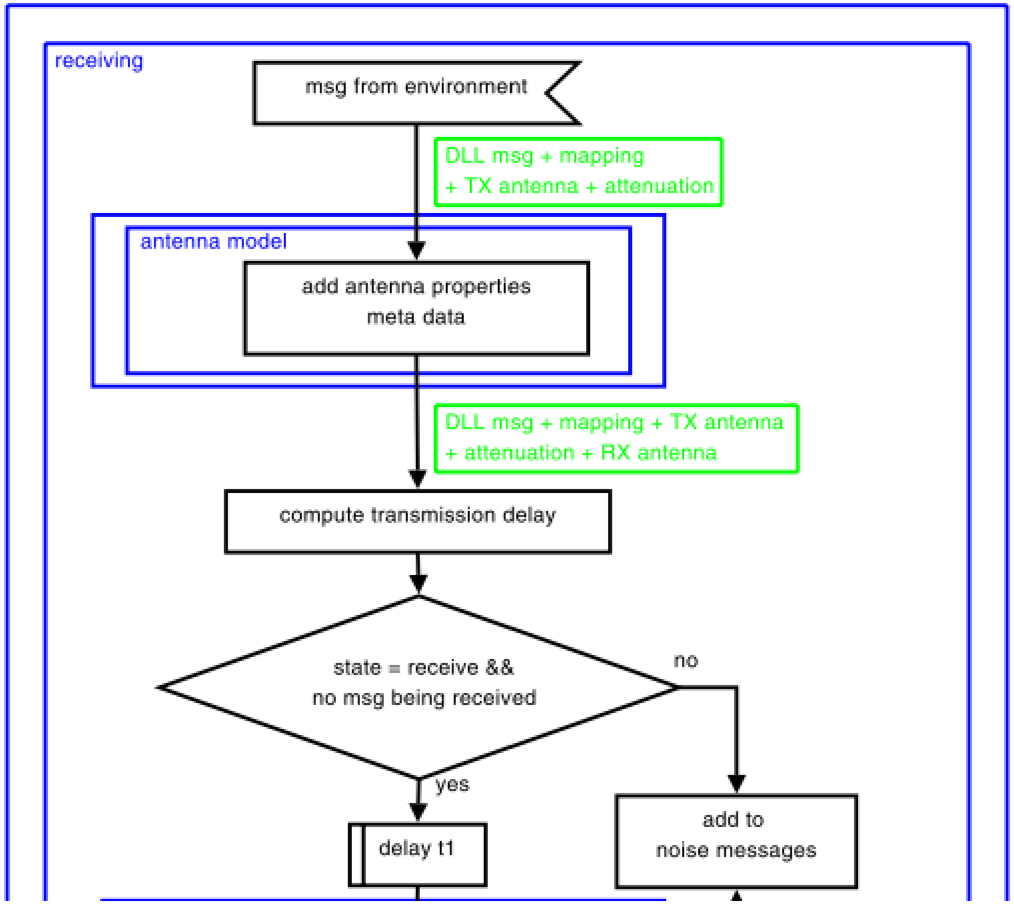
Sending model

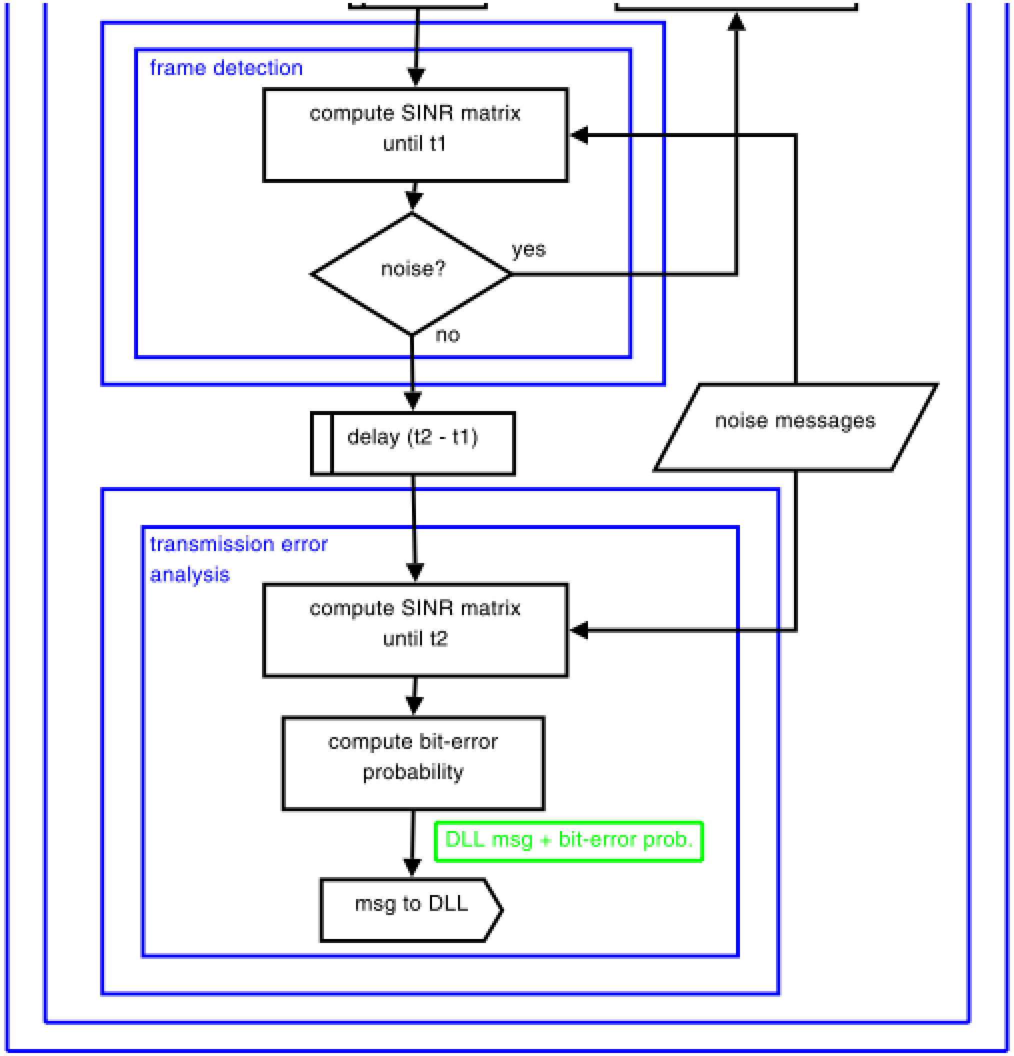



DLL msg
data resource mapping
add resource mapping
meta data
DLL msg + mapping
antenna model
add antenna properties
meta data
DLL msg + mapping
+ TX antenna


DLL msg + mapping
+ TX antenna
add position vector
DLL msg + mapping
+ TX antenna + position
msg to environment
delay (end of msg)
inform DLL

Receiving model




frame detection
compute SINR matrix until t1
noise?
yes
no
delay (t2 - t1)
noise messages
transmission error analysis
compute SINR matrix until t2
compute bit-error probability
DLL msg + bit-error prob.
msg to DLL