TELECOM PARIS
école nationale supérieure des télécommunications

INRIA
SOPHIA-ANTIPOLIS

Study and Implementation of IEEE 802.11 Physical Layer Model in YANS (Future NS-3) Network Simulator

Thesis of Master of Science
"Networked Computer Systems"

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B E G I N N I N G

Outline

- Motivations of the Thesis Work
- Importance of Knowing about Physical Layer
- IEEE 802.11 Module in YANS Network Simulator
- Introducing the Implemented Physical Layer in a step-by-step approach:
  Concepts and Implementation Choices
- A Typical Simulation Output
- Future Work

Motivations of the Thesis Work

- Thesis carried out in:
  INRIA, Planète Group
- YANS (**Y**et **A**nother **N**etwork **S**imulator) Network Simulator Objectives
- NS-3 Initiative and Planète Group's Partnership
- IEEE 802.11 Module in YANS (Future NS-3)

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Importance of knowing about the PHY

Digital Communications Researchers
But also, Networking Researchers:

A study by researchers at UCLA entitled:
“Effects of Wireless Physical Layer Modeling in Mobile Ad Hoc Networks”

- Factors relevant to the performance evaluation of higher layer protocols:
  - Signal reception method
  - Path loss, fading
  - Interference and noise computation
  - PHY preamble length

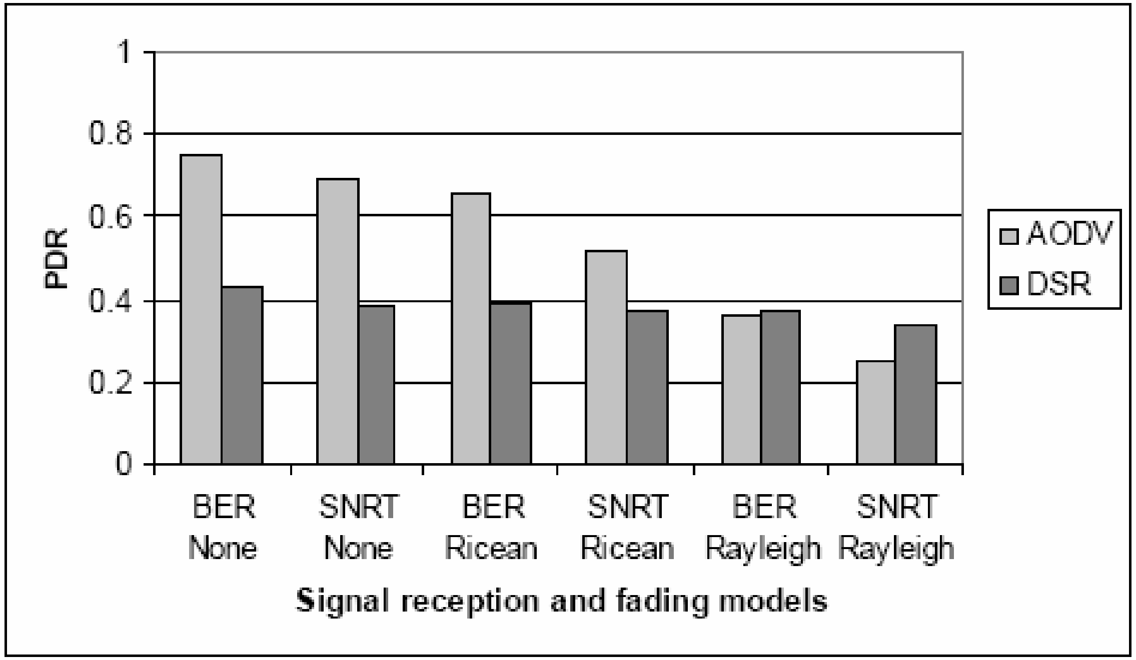
- These factors affect:
  - Absolute performance of a protocol
  - Relative ranking among protocols for the same scenario

Effect of Propagation Models on the Performance of Routing Protocols

- Scenario: 100 Nodes – Random Waypoint Mobility
  Flat Terrain [1200m^2] – 40 CBR sessions

Performance under increasingly harsh conditions:

- AODV : Deteriorates significantly
- DSR : Behaves more consistently
- Cause: Difference in their route discovery processes due to link breaks



- AODV: Ad-hoc On-demand Distance Vector
- DSR: Dynamic Source Routing
- PDR: Packet Delivery Ratio
- Reception Method: BER-based

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IEEE 802.11 Module in YANS Network Simulator

MAC Layer:

- Infrastructure: HCCA
  HCF(Hybrid Coordination Function) Controlled Channel Access
- Ad-hoc: DCF & EDCA
  Enhanced DCF (Distributed Channel Access) Channel Access
- The MAC used in this work: Ad-hoc Mode

PHY Layer:

- 2 Events per packet: one for first bit and one for last bit
- Any other packet reception between these 2 events: recorded in Noise Interference Vector
- Chunk Success Rate → PER → Decision on Reception

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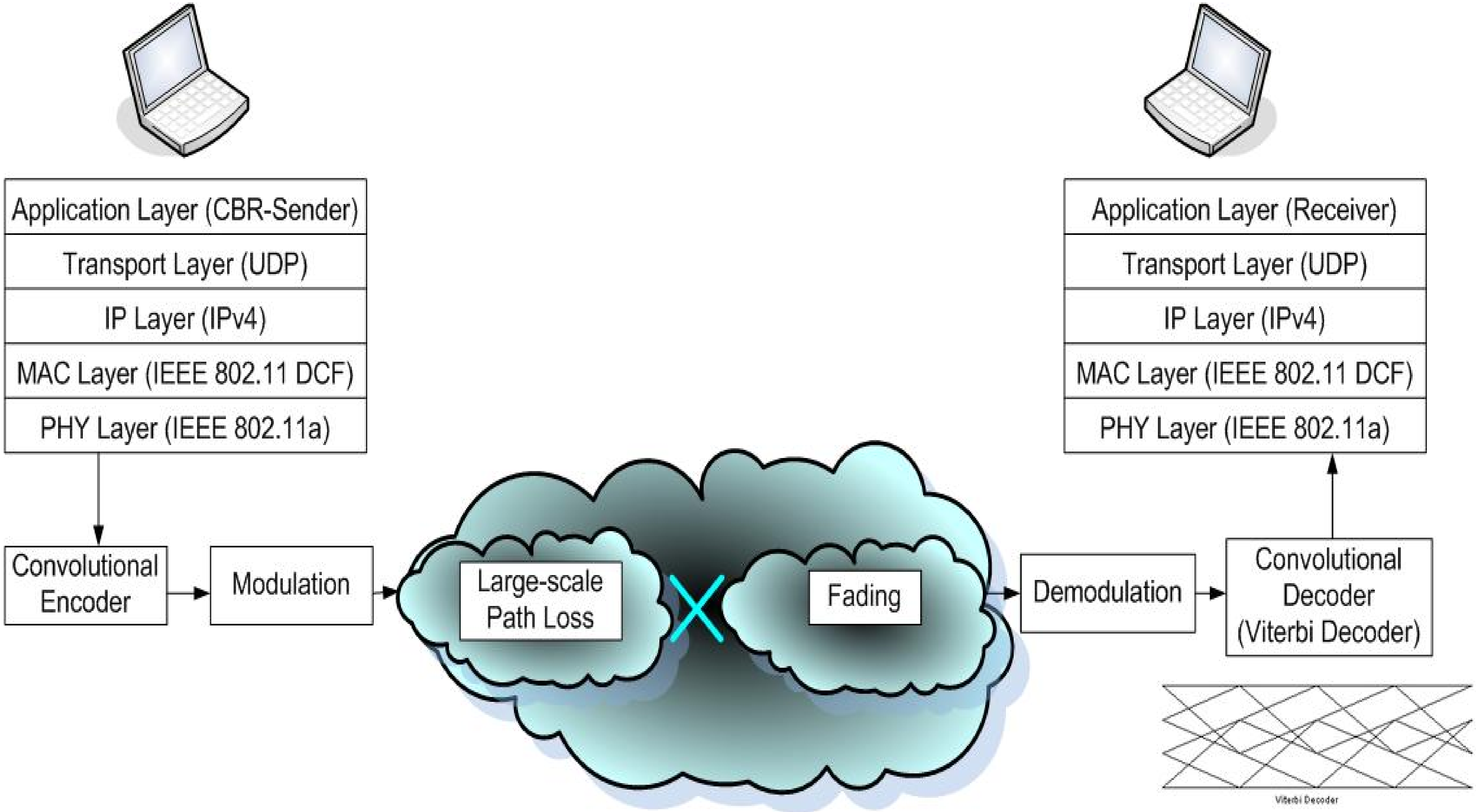
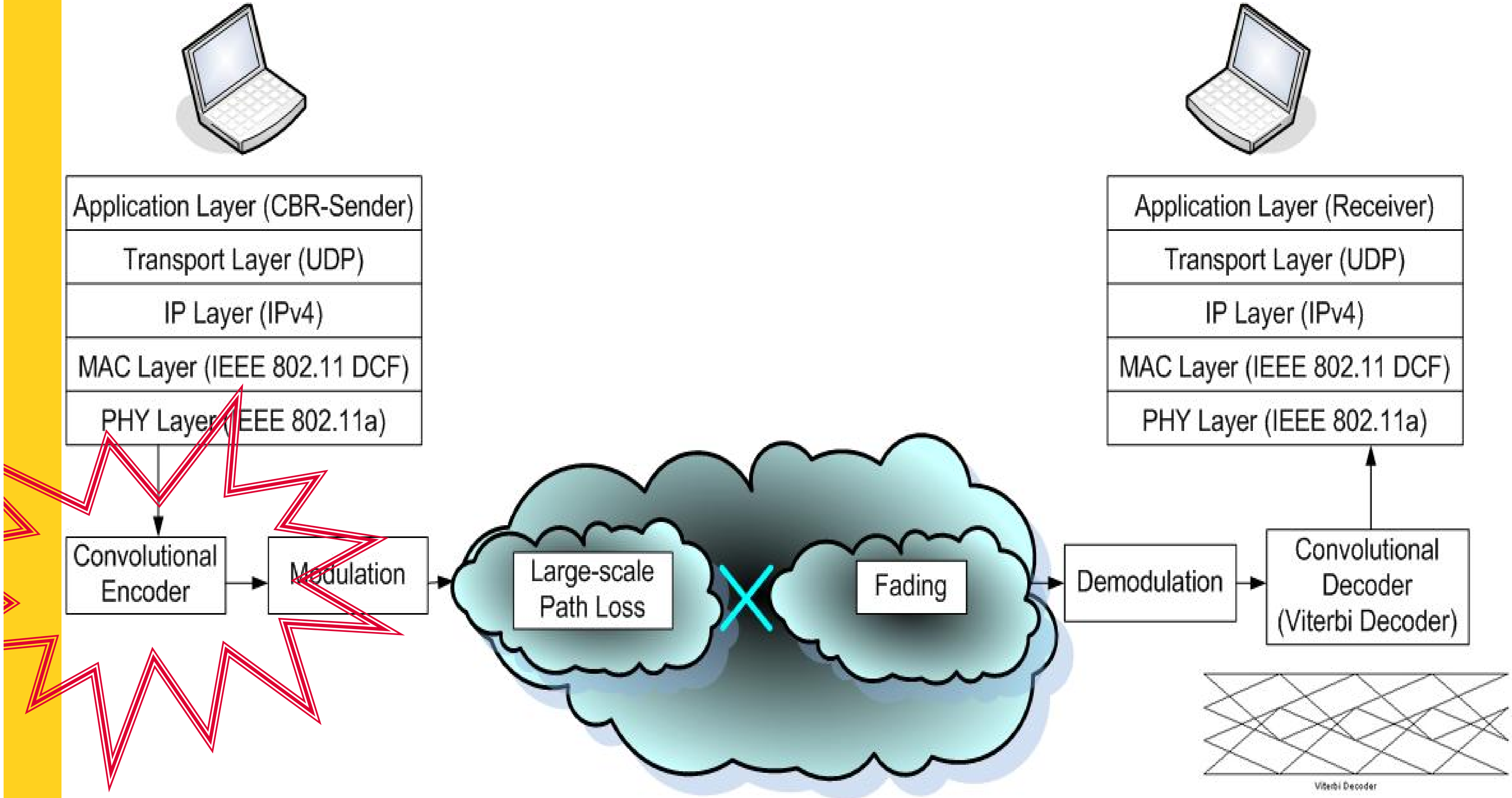
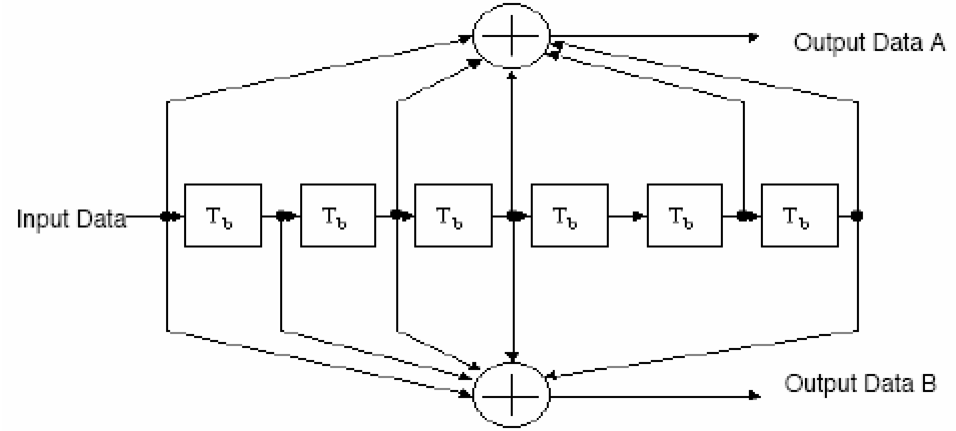
Overall View



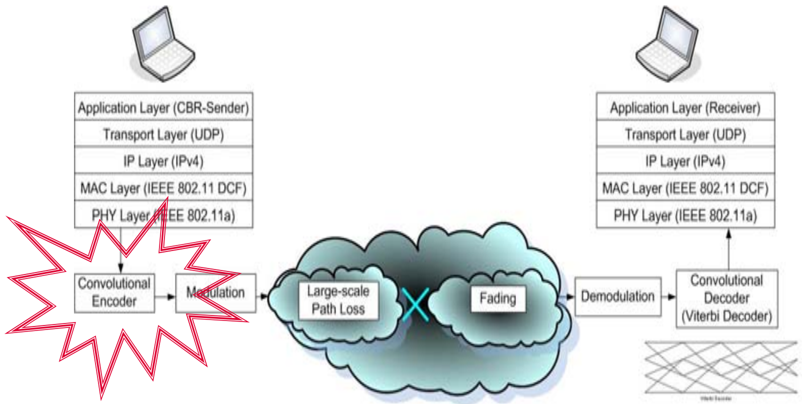
Convolutional Encoder



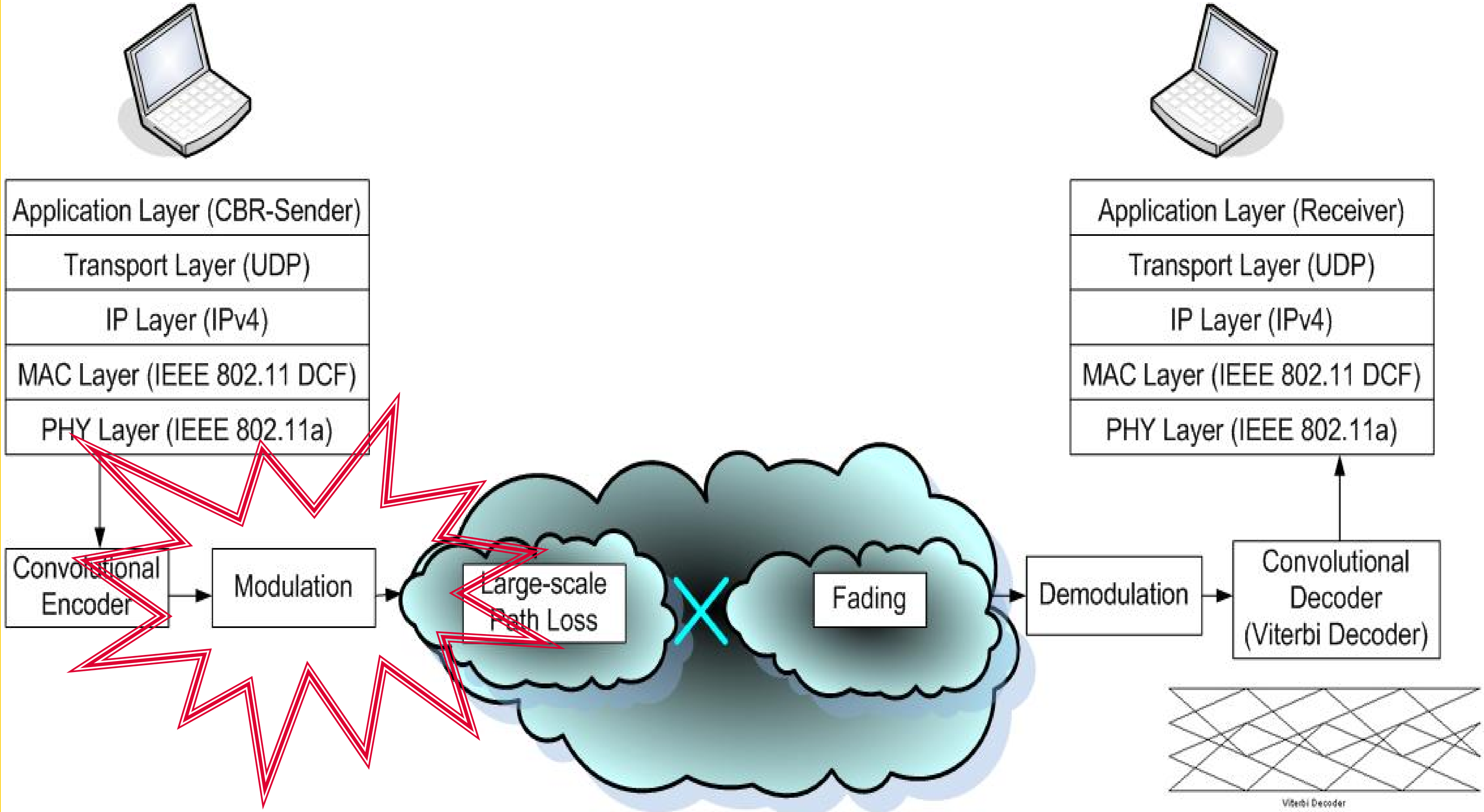
Convolutional Encoder



- Memory Constraint Length: 6
- Coding Rate: 1/2
- With Puncturing: 2/3 , 3/4

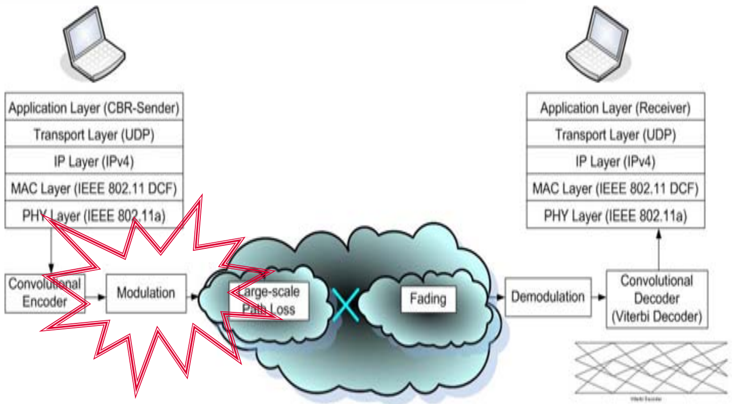


Modulation Schemes

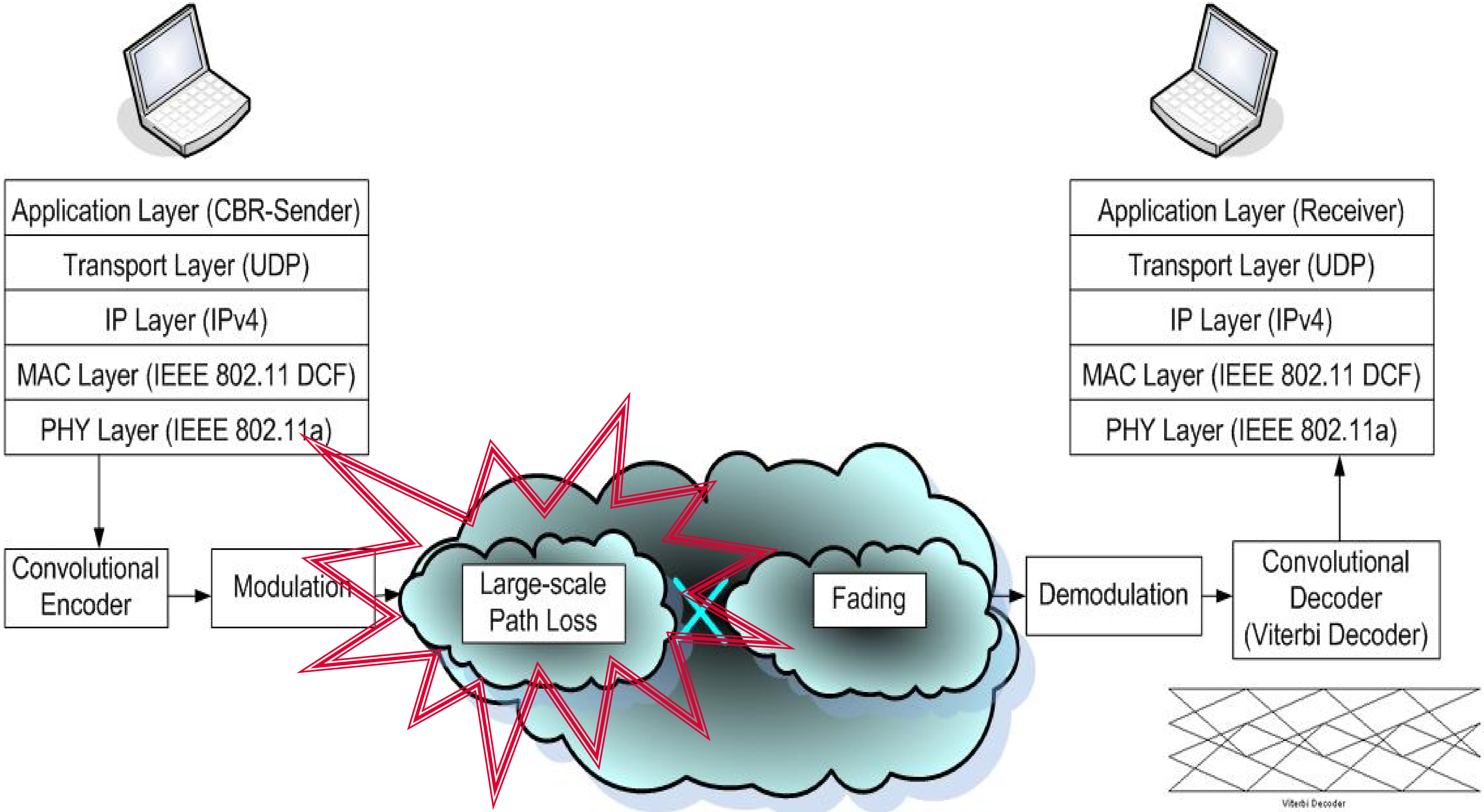


Modulation Schemes

Data rate (Mbits/s)	Modulation	Coding rate (R)	Coded bits per subcarrier (N_{BPSC})	Coded bits per OFDM symbol (N_{CBPS})	Data bits per OFDM symbol (N_{DBPS})
6	BPSK	1/2	1	48	24
9	BPSK	3/4	1	48	36
12	QPSK	1/2	2	96	48
18	QPSK	3/4	2	96	72
24	16-QAM	1/2	4	192	96
36	16-QAM	3/4	4	192	144
48	64-QAM	2/3	6	288	192
54	64-QAM	3/4	6	288	216



Large-scale Path Loss Models



Large-scale Path Loss Models

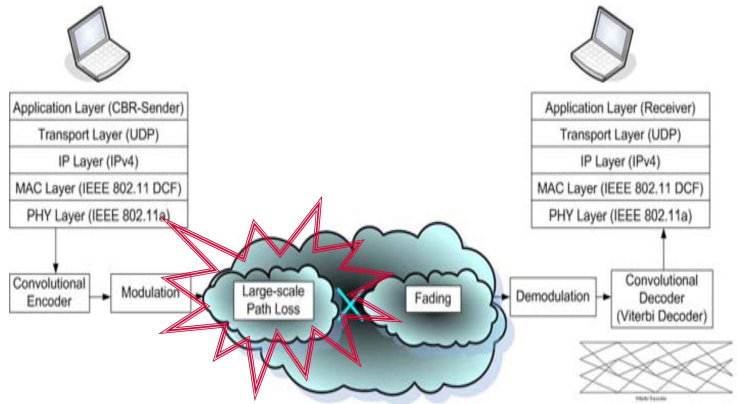
- Free-Space: Unobstructed LOS ; No other object

  $P_r \sim f\,(1/d^2)$

- Two-Ray: Unobstructed LOS + Ground-reflected Ray ; No other object

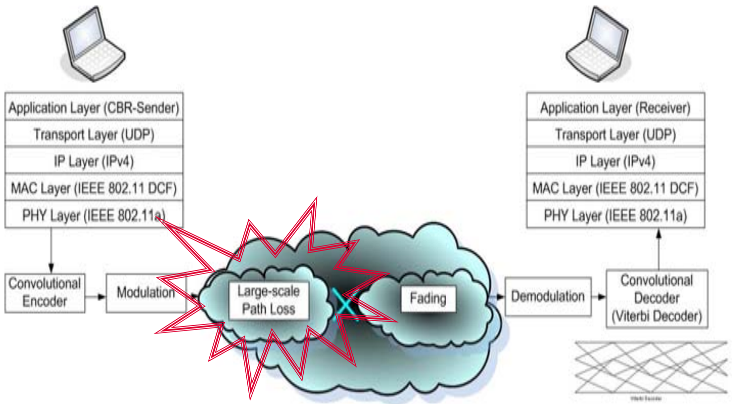
  $P_r \sim f\,(h_r h_t / d^4)$

- Shadowing …

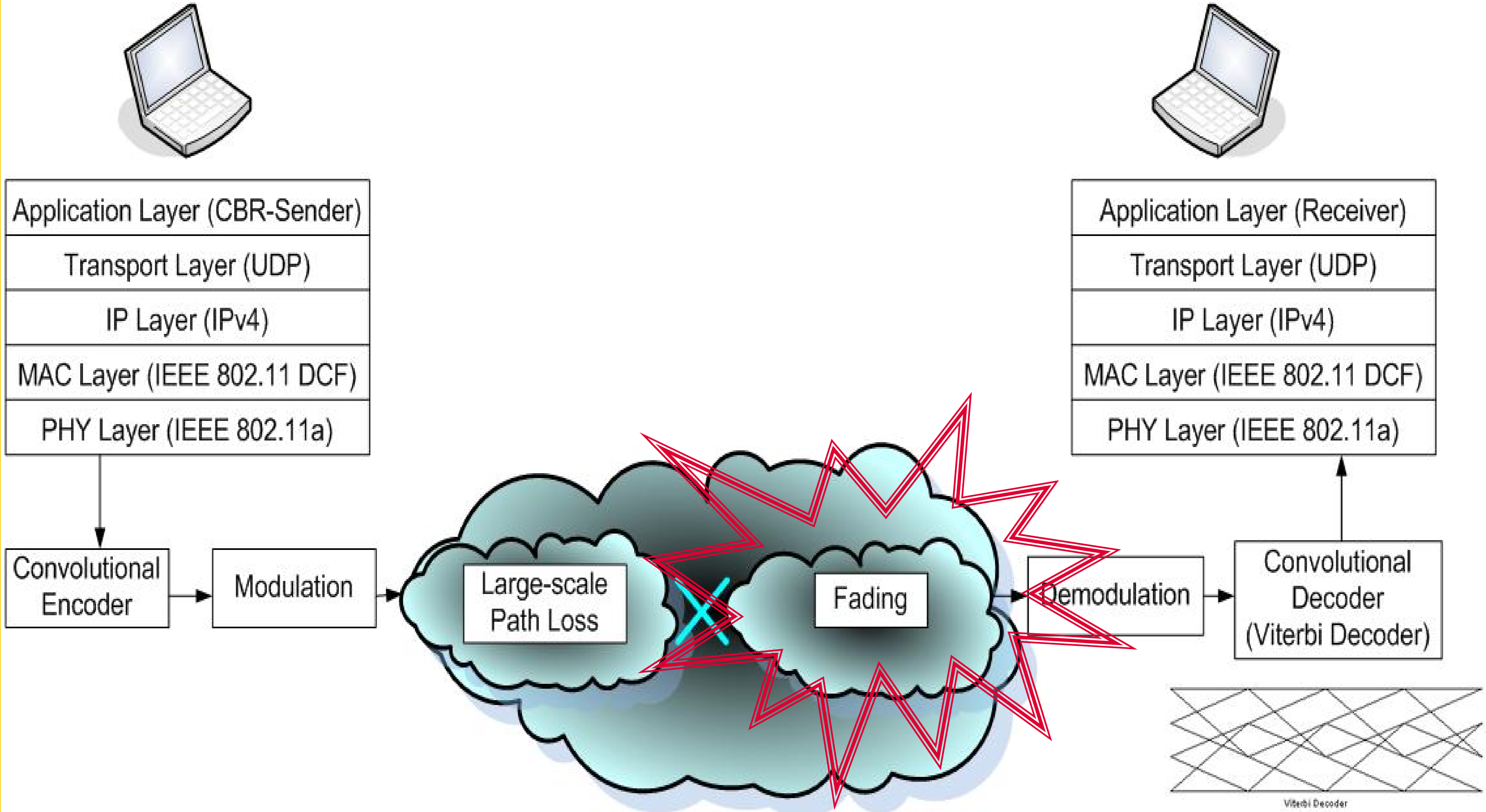


Large-scale Path Loss Models: Shadowing

- LOS may exist
- Accounts for all the scattering due to other objects
- Suitable for Indoor IEEE 802.11
- $P_r \sim f\,($ *- Reference Power from Free-Space model,*
  - Path-loss Exponent (i.e., 1 / d ˣ),
  - Shadowing (Accounts for:
  Same Distance, but different signal values) $)$
- *Shadowing random values are generated using IT++*



Fading Effect

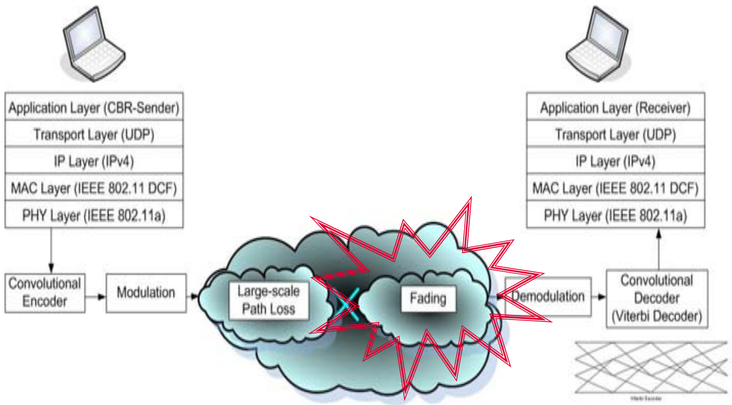


Fading Effect: Involved Concepts

- Fading describes:
  - rapid fluctuations of the amplitudes/phases
  - multipath delays over a short period of time/distance

- Coherence Bandwidth and Delay Spread
  - Inversely proportional
  - Indicate the time dispersive nature of the channel

- Coherence Time and Doppler Spread
  - Indicate time varying nature of the channel due to motion
  - Former is the time dual of the latter



Fading Types

- Slow/Fast Fading:

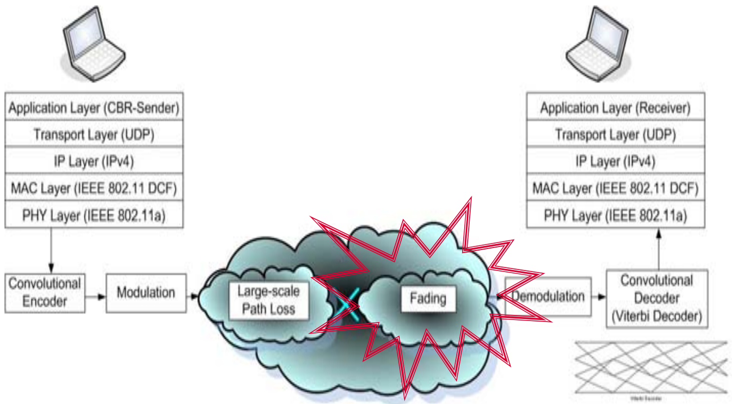
  Increase in movements = Increase in Doppler Spread
  = Going from Slow to Fast Fading

- Frequency selective/non-selective:

  Channel Coherence BW:
  Frequencies that experience equal gain/linear phase → no distortion
  (Signal BW < Ch. Coherence BW) → Frequency non-selective fading

- Fading type in Indoor IEEE 802.11 Networks:

  Slow Frequency non-selective
  i.e., Rayleigh / Rician

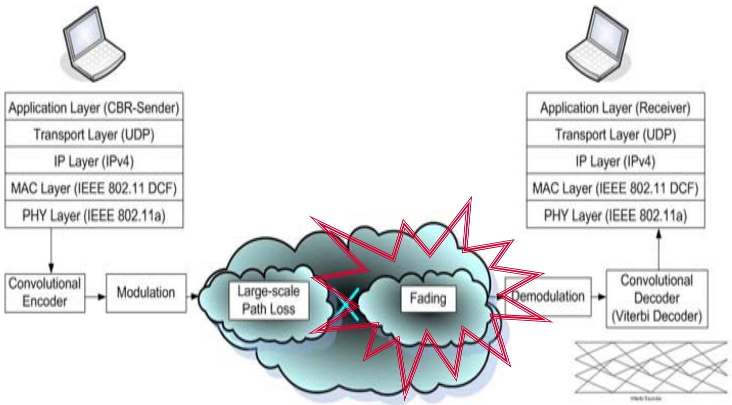


Fading Effect: Implementation Issues

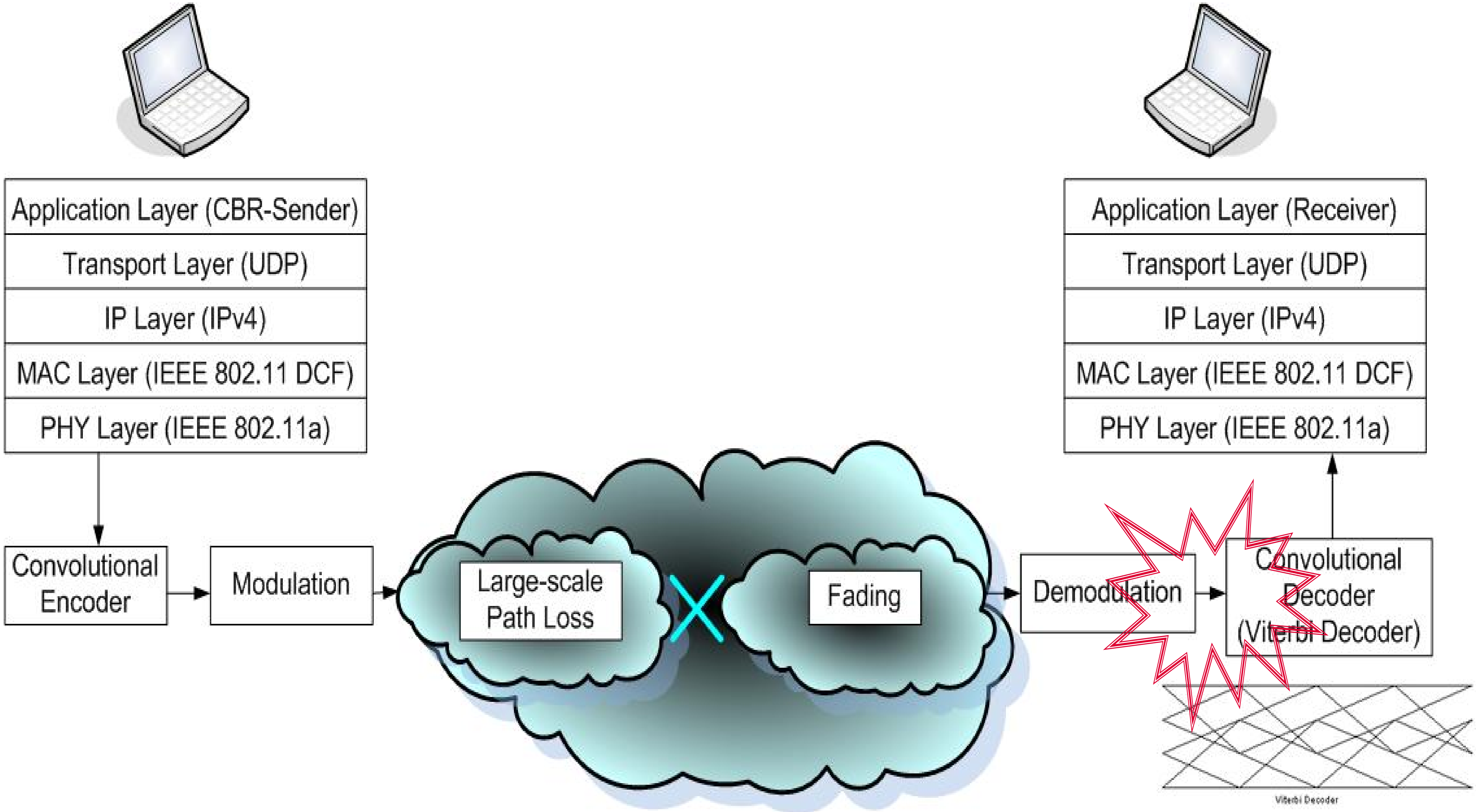
- Current Model: A multiplicative fading factor with average power of 1
- Fading process is generated using IT++

  Parameters:

  - Doppler Frequency
  - Rician Factor



BER (After Demodulator-Before Decoder)



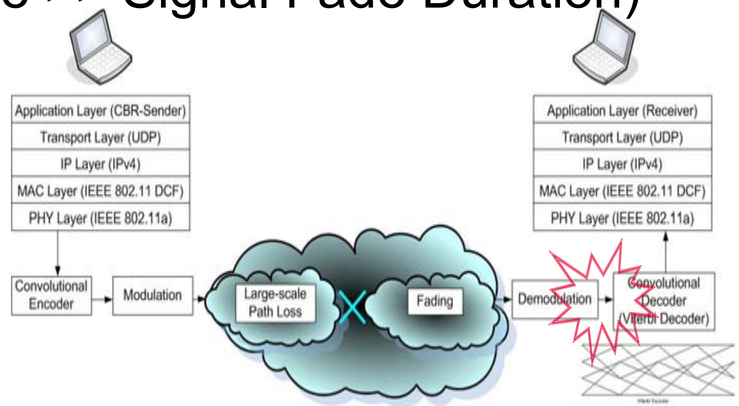
BER (After Demodulator-Before Decoder)

$Pr \rightarrow SNIR \rightarrow E_{bit}/N_0 \rightarrow BER$

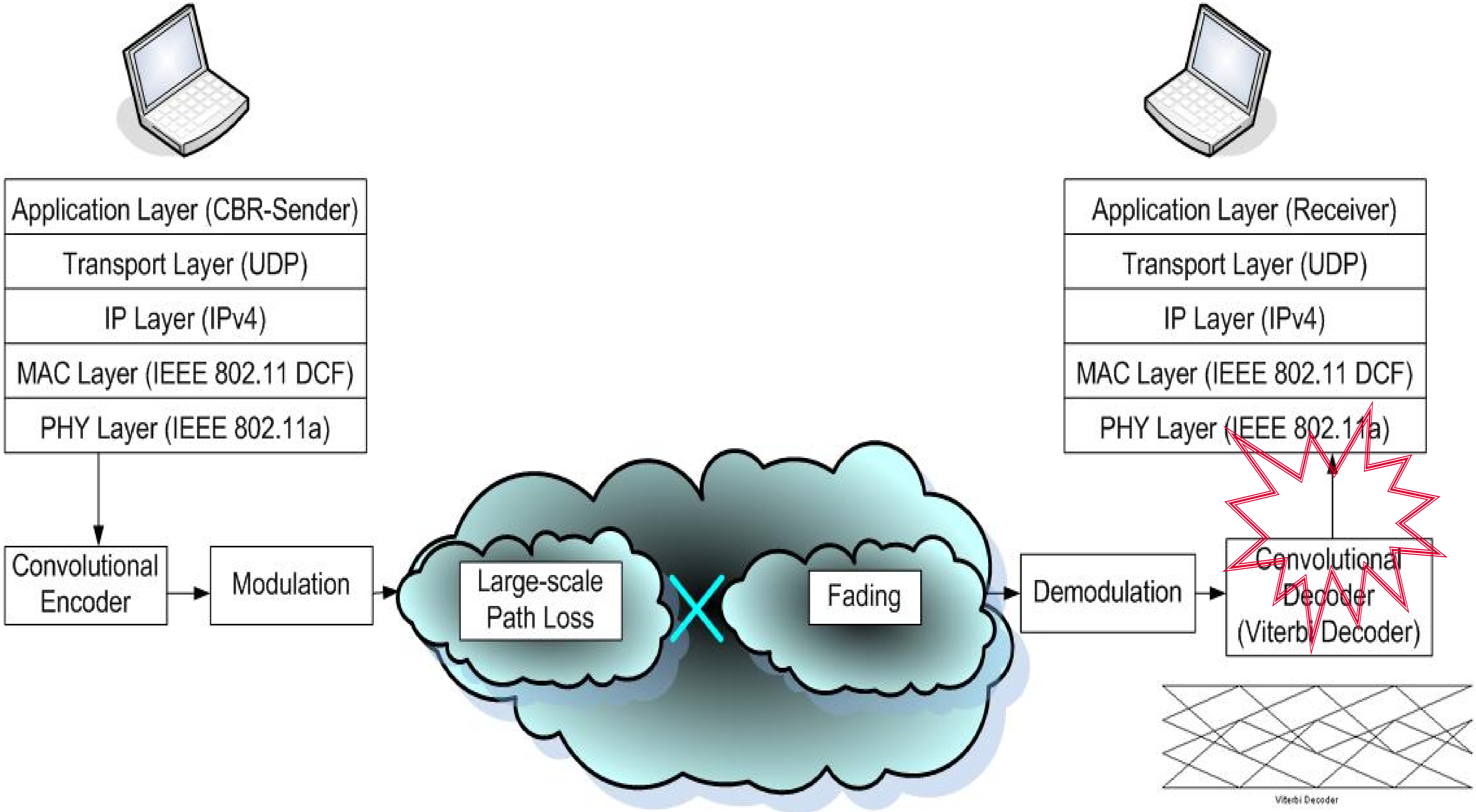
Different BER formulas depending on:

- Modulation Type: BPSK, QPSK, M-QAM

- Channel Type:
  - AWGN
  - Slow-Fading (Symbol Trans. Time << Signal Fade Duration)
  - Normal Fading (Symbol Trans. Time ~ Signal Fade Duration)
  - Fast-Fading (Symbol Trans. Time >> Signal Fade Duration)



BER (After Decoder)



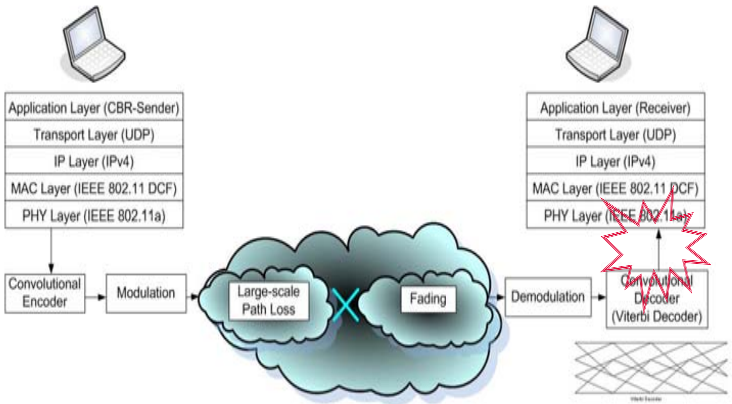
BER (After Decoder)

- Error correcting mechanism (Convolutional Codes) is capable of reducing the BER
- *BER(before decoder) → P_k → BER*

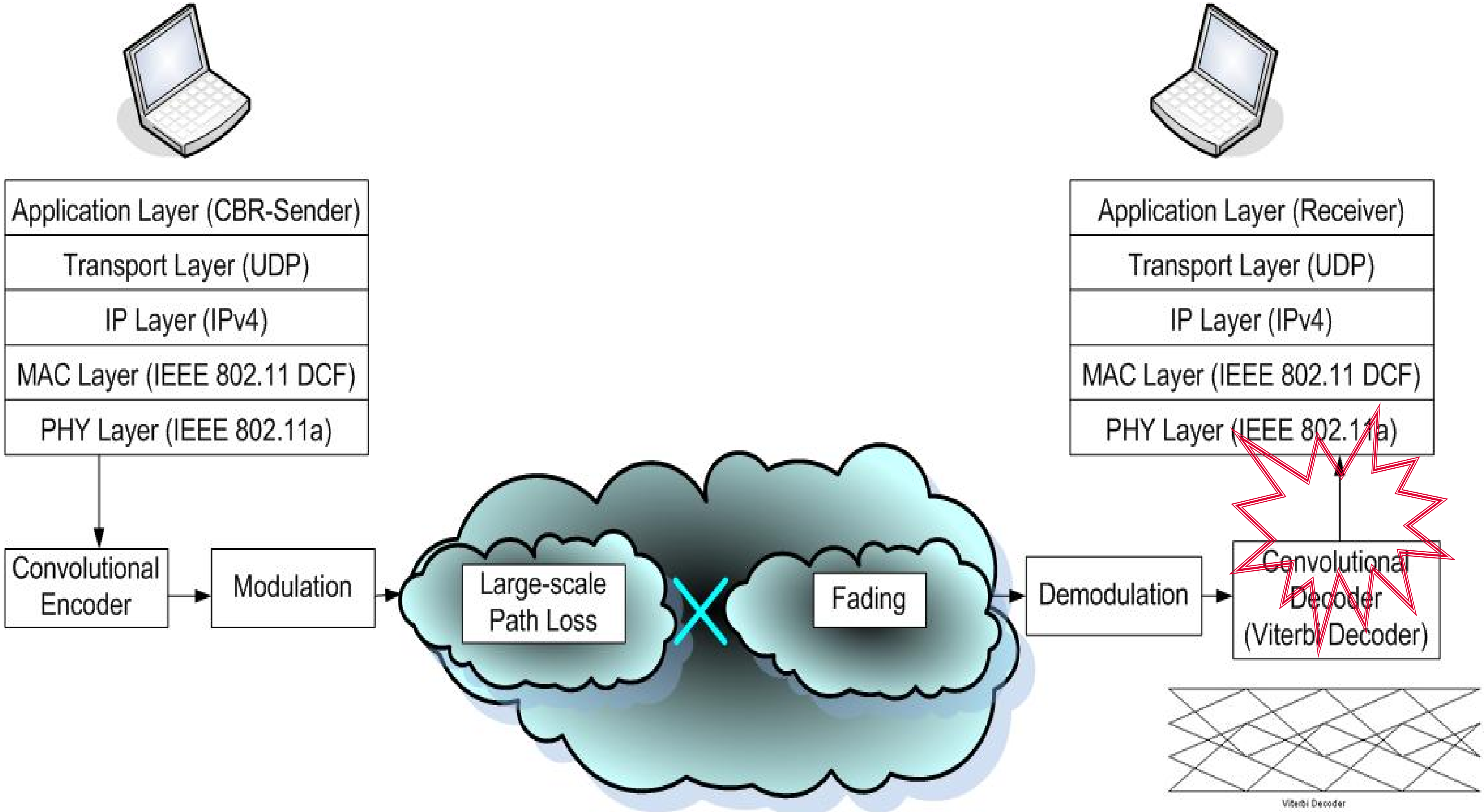
  - P_k : *The probability of selecting an incorrect path by the Viterbi decoder which is in distance k from the all-zero path*

  - C_k : *Bit error number associated with each error event of distance k*

  - BER = $\Sigma\, C_k \times P_k$



Packet Error Rate



Packet Error Rate

Error Distribution within the packet:

- Uniform:

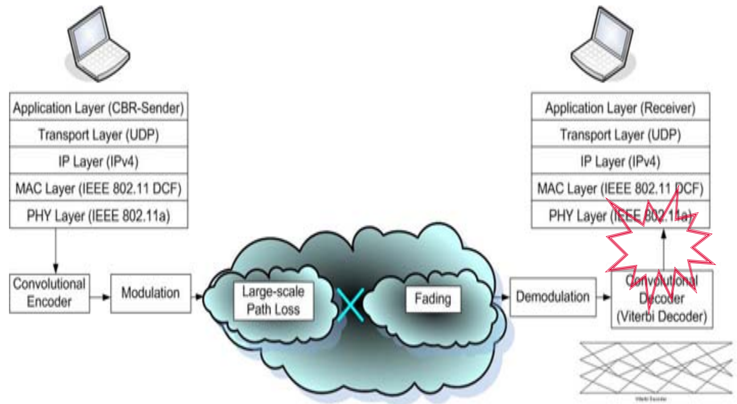
$$PER = 1 - (1 - BER)^{nbits}$$

- Non-Uniform:

  - *Argues that above method leads to over-estimation of PER*
  - *Error Event Rate = f (SNIR, encoder details)*
  - $\lambda = 1 / W = f$ *(EER, SNIR, encoder details)*

  Where, *W* is "Mean length of errorless period"

  - $PER = 1 - (1 - \lambda)^{nbits}$
  - *Theory still under refinement*



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A Typical Simulation Output

```
bash-2.05b$ ./main-80211-adhoc
[Large-scale path loss model: Free Space]
[Fading channel is used and forms the 2nd part of the channel model]
[BER: Slow-Fading Channel]
[PER Calculation Method (Error Distribution at the Viterbi Decoder's
  Output: Non-Uniform)]
[Error masks are being generated]
...
Time:2
Sent Rate (Application Layer):25.1969 Mb/s
Sent Rate(MAC): 26.0031 Mb/s
Receiver Throughput(MAC): 11.3364 Mb/s
Receiver Throughput(Application Layer): 10.9849 Mb/s
x = 10
SNIR(Instant Value): 2132.22
Bit Error Probability(Instant Value): 0.000132027
Bit Error Probability-After Decoder(Instant Value): 1.48246e-15
Packet Error Probability(Instant Value): 9.89928e-11
Current PHY Mode: 24 Mb/s
...
```

Future Work : Measurement-based Validation

- There is NO one BEST simulator configuration

As our future work, we intend to:

- Study ORBIT and Emulab IEEE 802.11 testbeds
- Adapt the simulator PHY parameters to the environment in which these testbeds are installed

Expected results:

- ORBIT: Free-Space or Two-Ray

  [Fading due to multipath delay shouldn't be significant to the point that we need to consider the channel as Frequency-Selective]
- Emulab: Depending on which set of machines are chosen in the campus, different results could be achieved

Thank you for your attention …

Q&A