Accuracy Enhancements of the 802.11 Model and EDCA QoS Extensions in ns-3

Completion Talk

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DSN

Roadmap

Objectives

- Compare 802.11 implementations of new ns-3 network simulator with ns-2.
- Transfer extended ns-2 features added by the DSN to new ns-3 design.
- Implement EDCA extensions in ns-3.
- Evaluate performance gain of switching to ns-3.

Constraints

- All features must be thoroughly tested, evaluated and documented.
- Integrate cleanly into ns-3 design, which uses state-of-the-art software engineering methods.
- Researchers must be able to use them without detailed lower-layer knowledge.

Feature Comparison: ns-3.3 vs. ns-2.33

PHY Layer:

- – No probabilistic Nakagami propagation model.
- – Lacks modeling of frame capture effect.
- \+ BER/PER reception criterion for 802.11a. Results unequal to ns-2's SINR criterion.

MAC Layer:

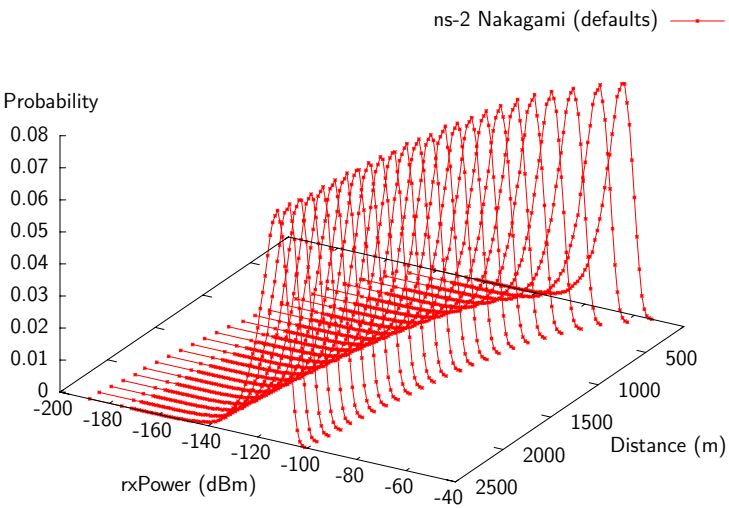
- – Support for EDCA extensions missing.
- \+ Overall good software design.

Nakagami Propagation Loss Model in ns-3

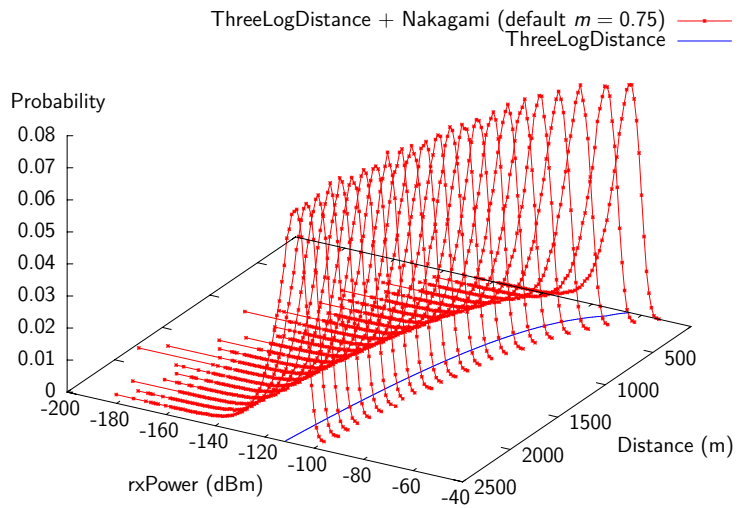
Ported Nakagami propagation loss model to ns-3.

Extensively verified against ns-2 and the analytic probability density function.

ns-2

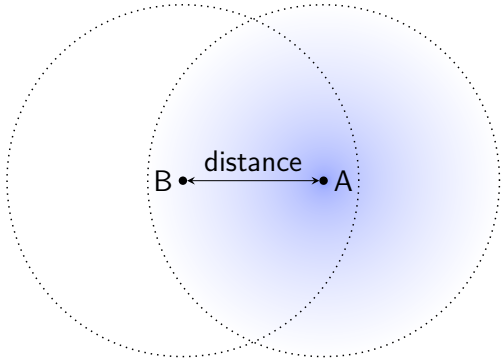


ns-3

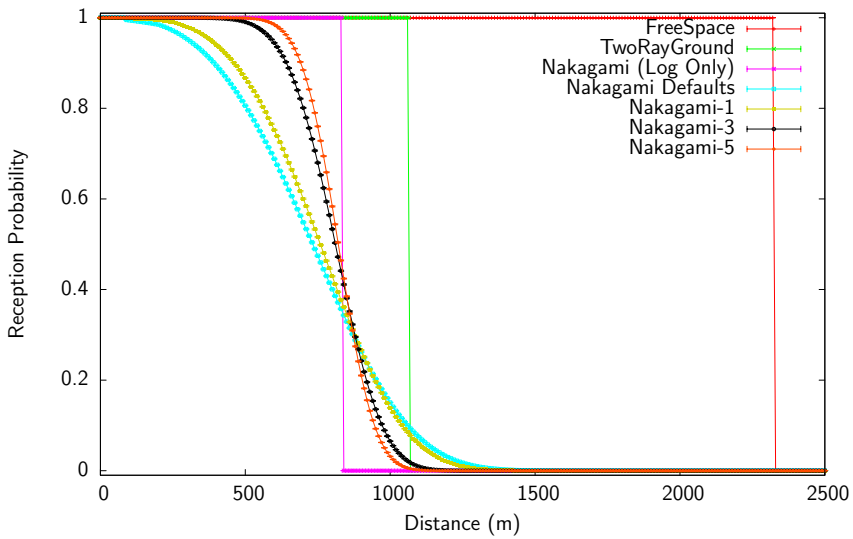


Reception Criteria: SINR

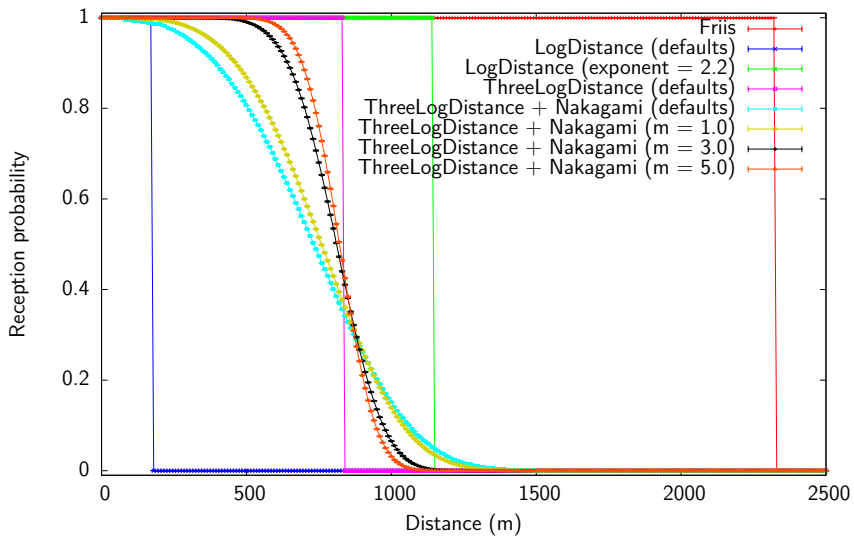
Implemented ns-2's SINR reception criterion in ns-3 as `Ns2ExtWifiPhy`.



ns-2



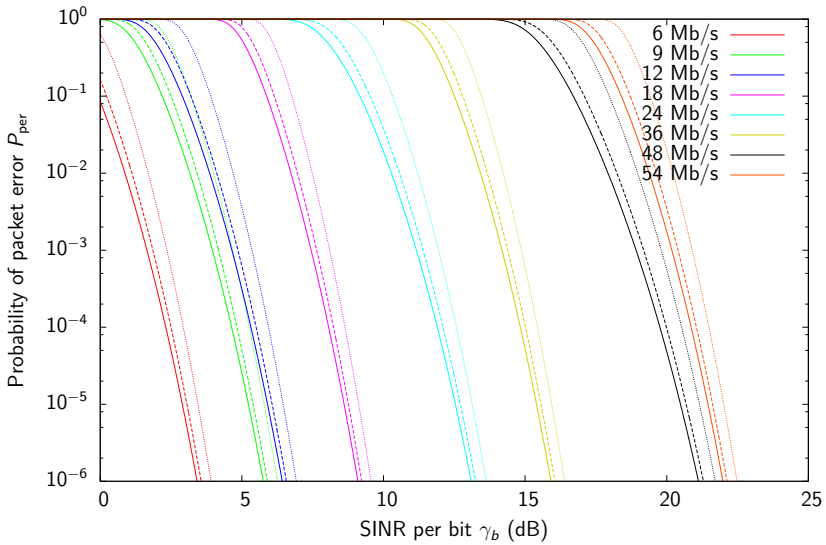
ns-3



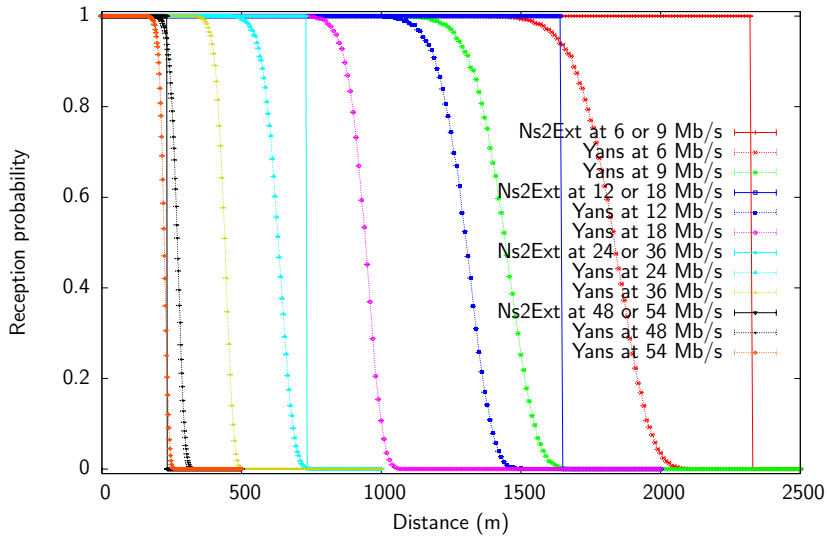
Discussion of SINR and BER/PER

Detailed explanation of existing BER/PER reception in ns-3. Discussion and comparison against SINR.

Packet Error Rate (PER)

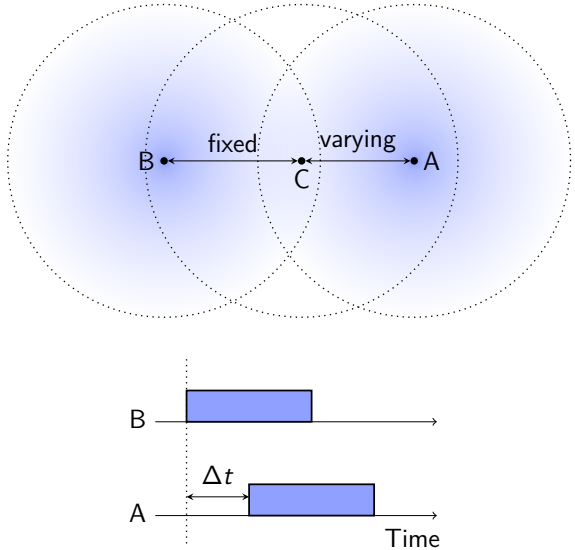


Free-space Reception Range

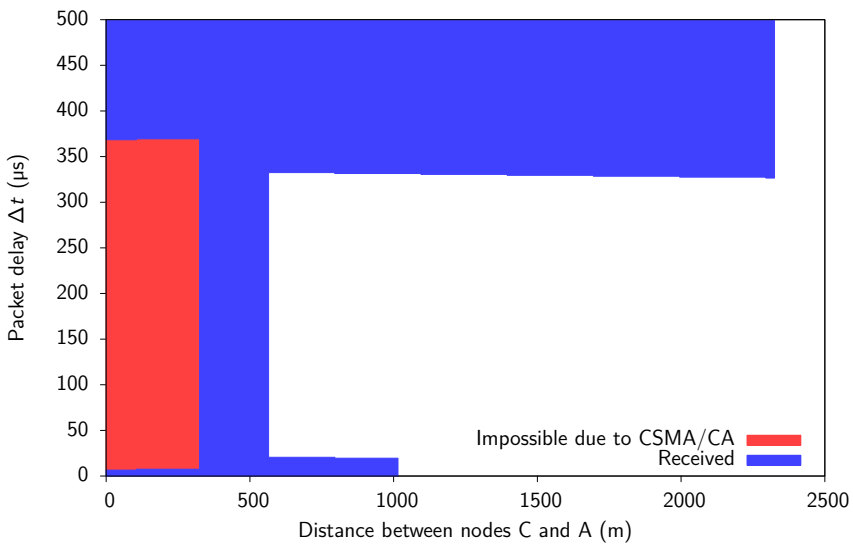


Frame Capture Effect

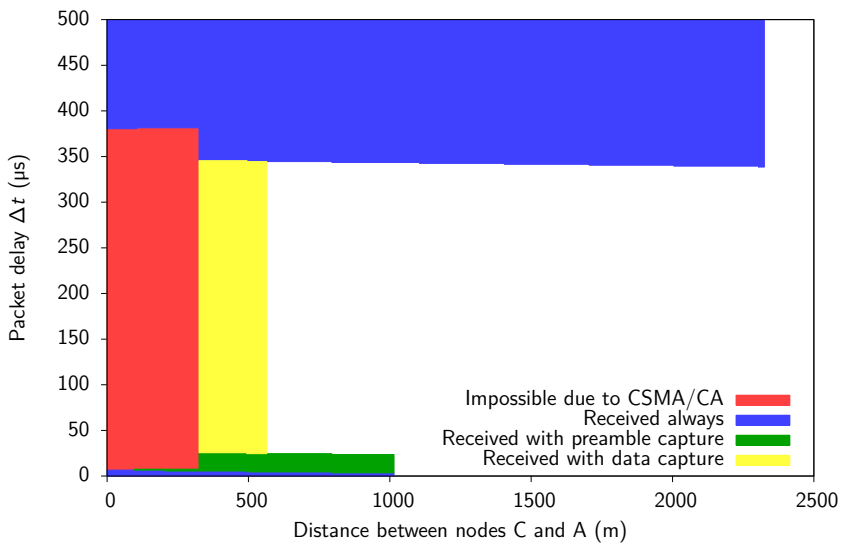
Added frame capture effect to `Ns2ExtWifiPhy`. Evaluated against ns-2.



ns-2

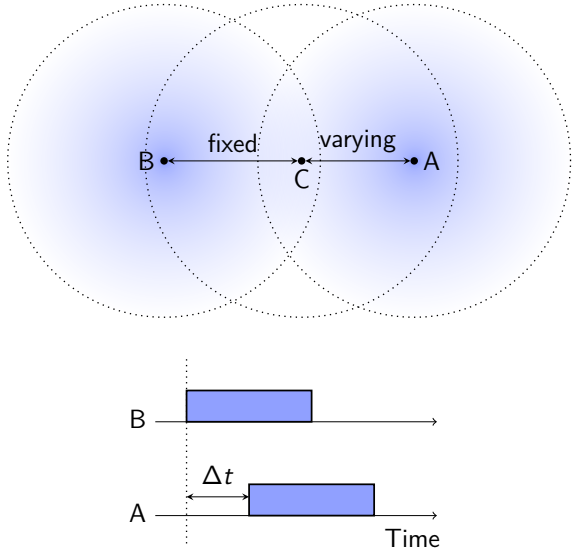


ns-3

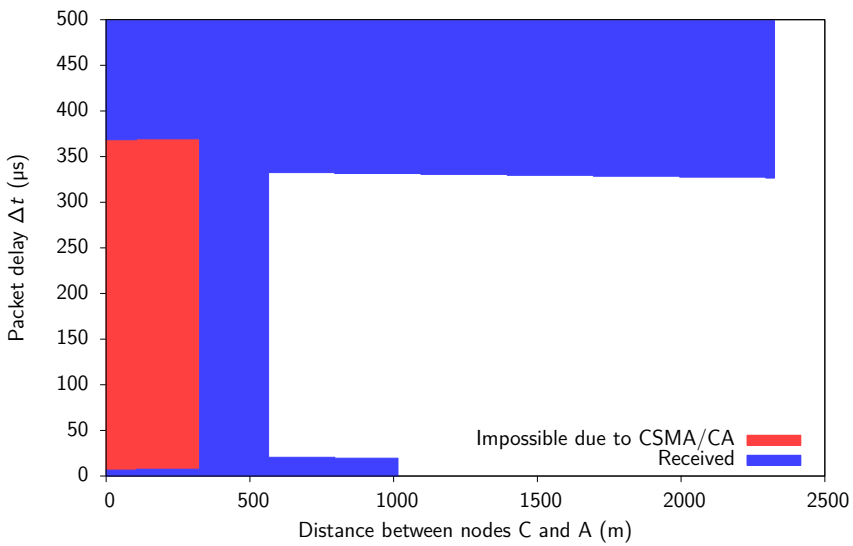


Frame Capture Effect

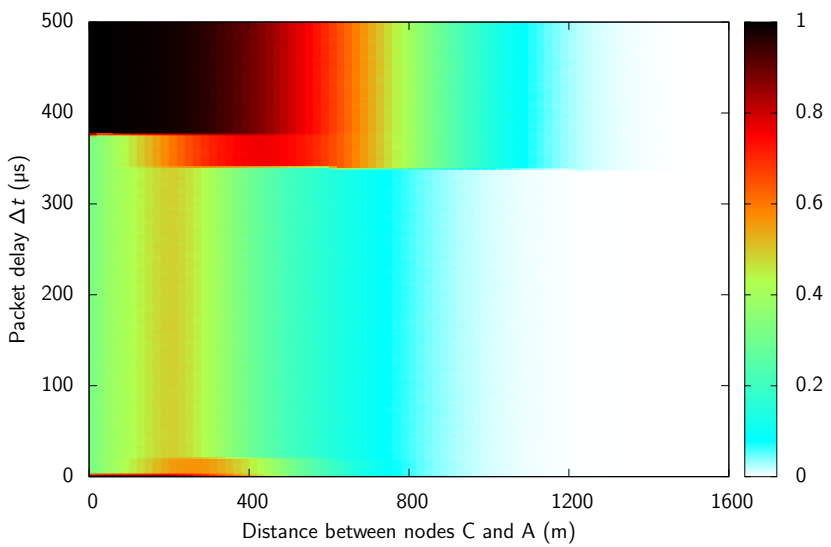
Added frame capture effect to `Ns2ExtWifiPhy`. Evaluated against ns-2.



ns-2

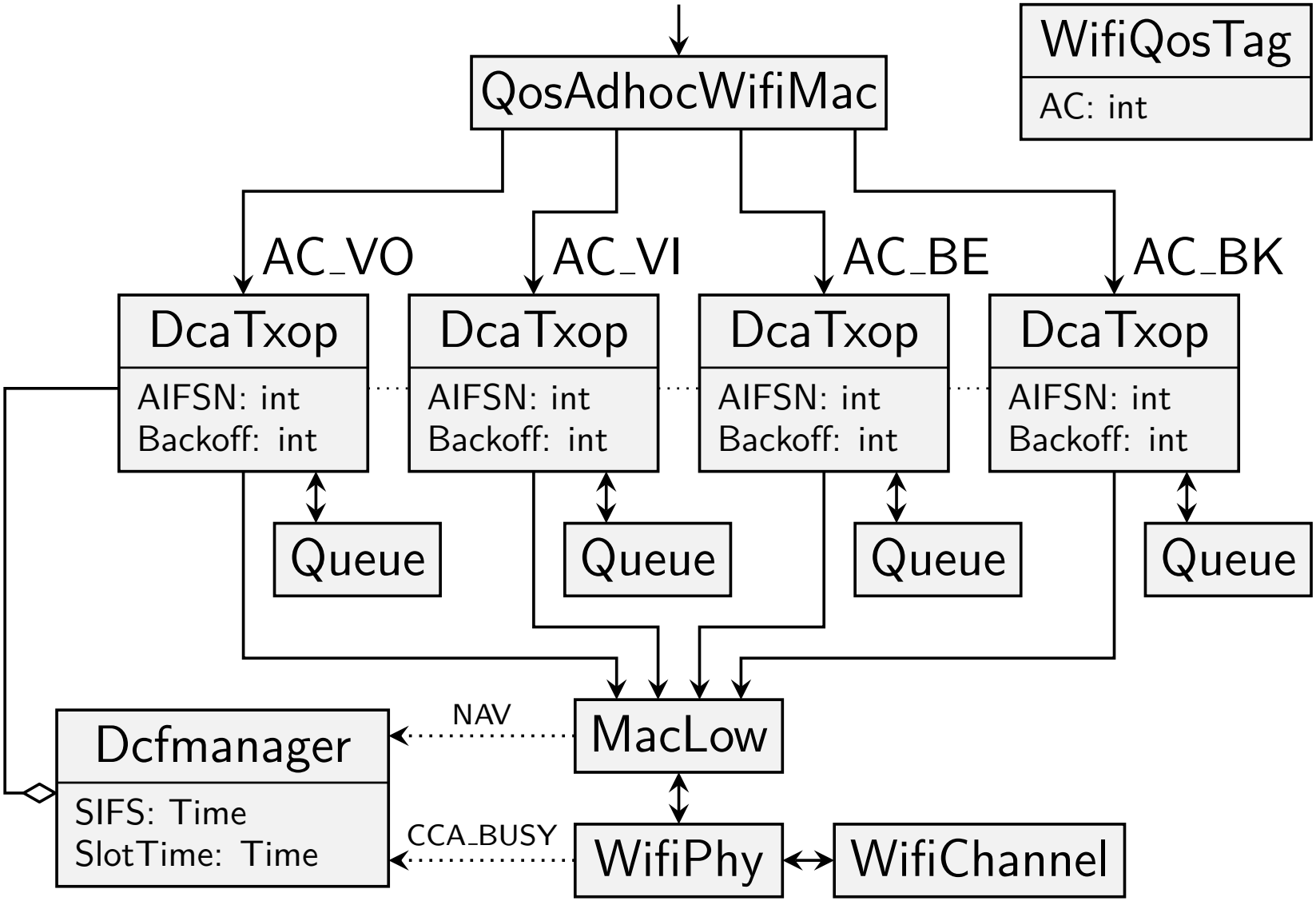


ns-3

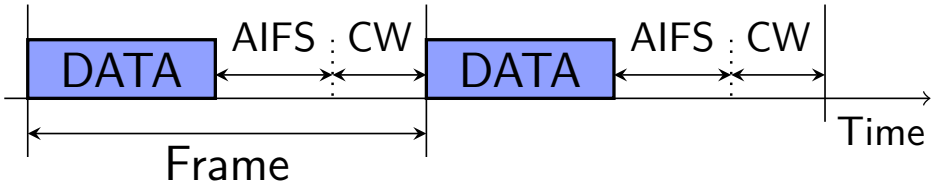


EDCA Implementation

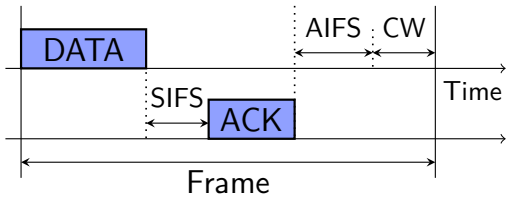
- Extended ns-3 with EDCA capabilities.
- Builds up on the well designed DCF classes.
- Added TXOP limits and burst sequences.
- Tested individual maximum throughput against analytical reference values.
- Experiment with differently prioritized traffic streams shows relative QoS.


QosAdhocWifiMac
WifiQosTag
AC: int
AC_VO
AC_VI
AC_BE
AC_BK
DcaTxop
AIFSN: int
Backoff: int
Queue
NAV
MacLow
Dcfmanager
SIFS: Time
SlotTime: Time
CCA_BUSY
WifiPhy
WifiChannel

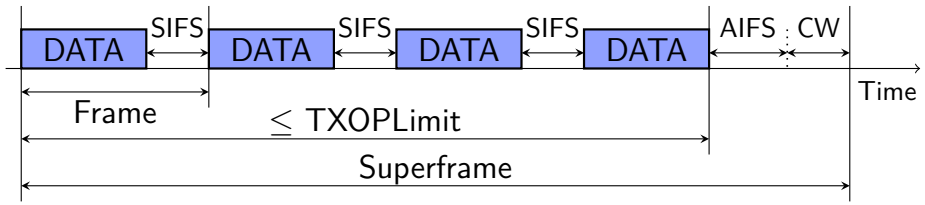
Maximum Throughput Experiment



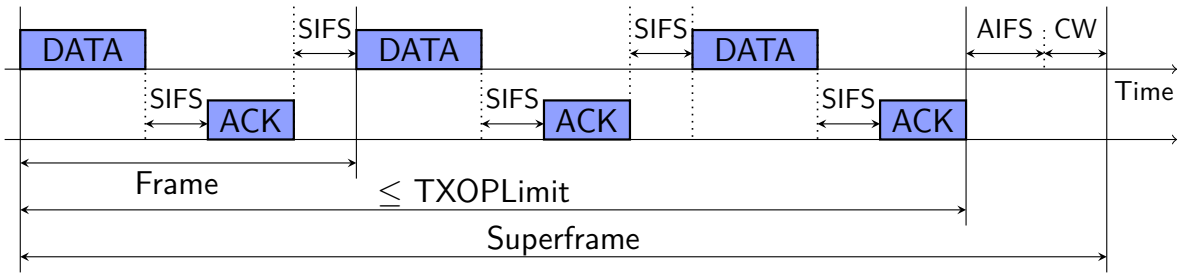
Without ACK



With ACK



TXOP burst without ACKs



TXOP burst with ACKs

Maximum Throughput Experiment

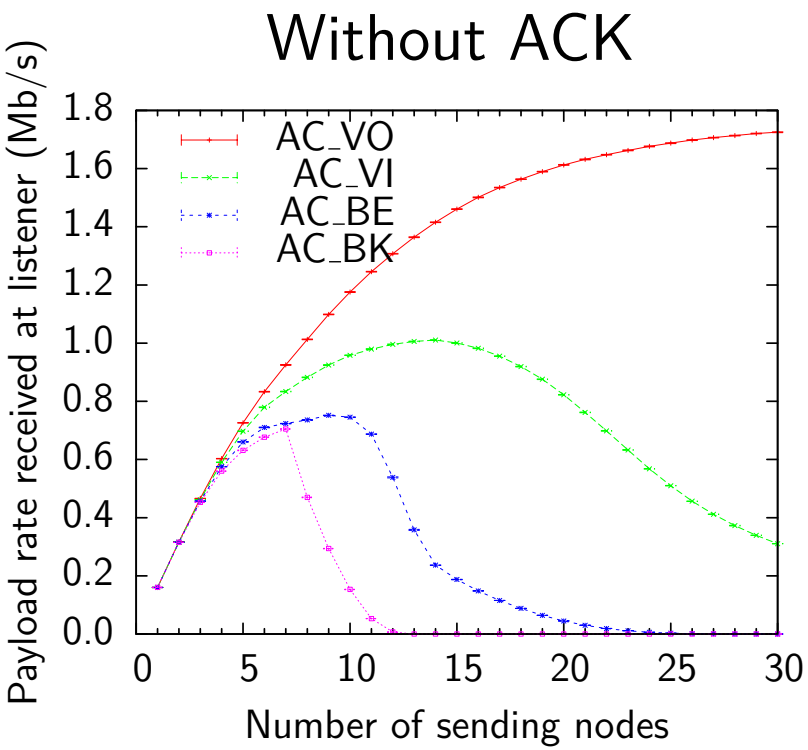
Reference value in B/s and relative difference of experimental result with 99 % error margin for 54 Mb/s data rate.

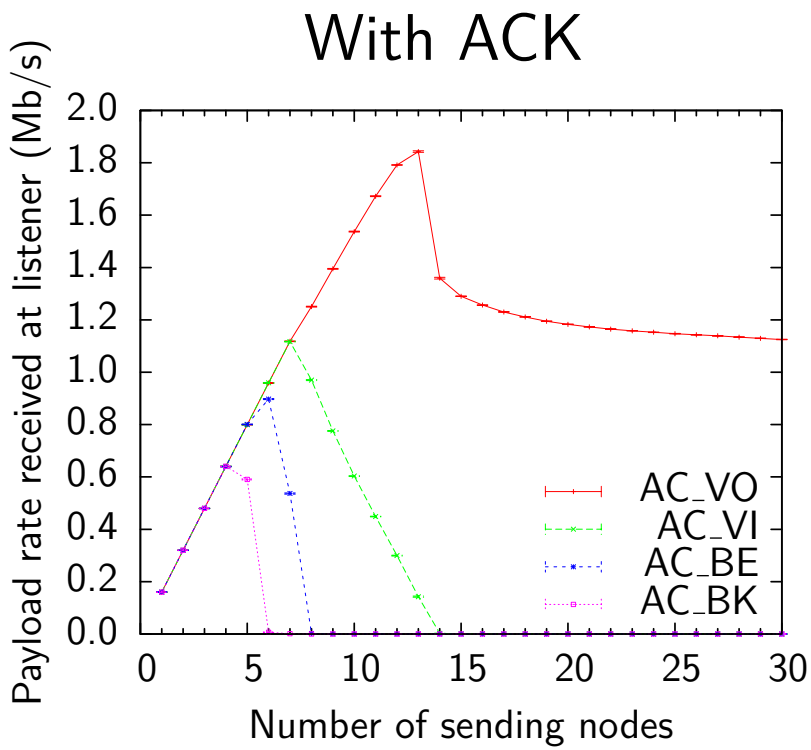
	80 B - noACK	80 B - ACK	2304 B - ACK
DCF	4 522 908 0.01 ± 0.11 ‰	3 176 179 0.01 ± 0.10 ‰	34 810 198 0.01 ± 0.04 ‰
AC_VO 802.11p/D4.02	7 314 286 0.03 ± 0.05 ‰	4 338 983 0.01 ± 0.02 ‰	38 763 407 0.01 ± 0.01 ‰
AC_BK 802.11p/D4.02	3 129 584 -0.06 ± 0.1 ‰	2 419 660 0.02 ± 0.09 ‰	31 108 861 0.01 ± 0.04 ‰

Tested 216 configurations.

Maximum relative difference was 0.85 ± 0.11 ‰.

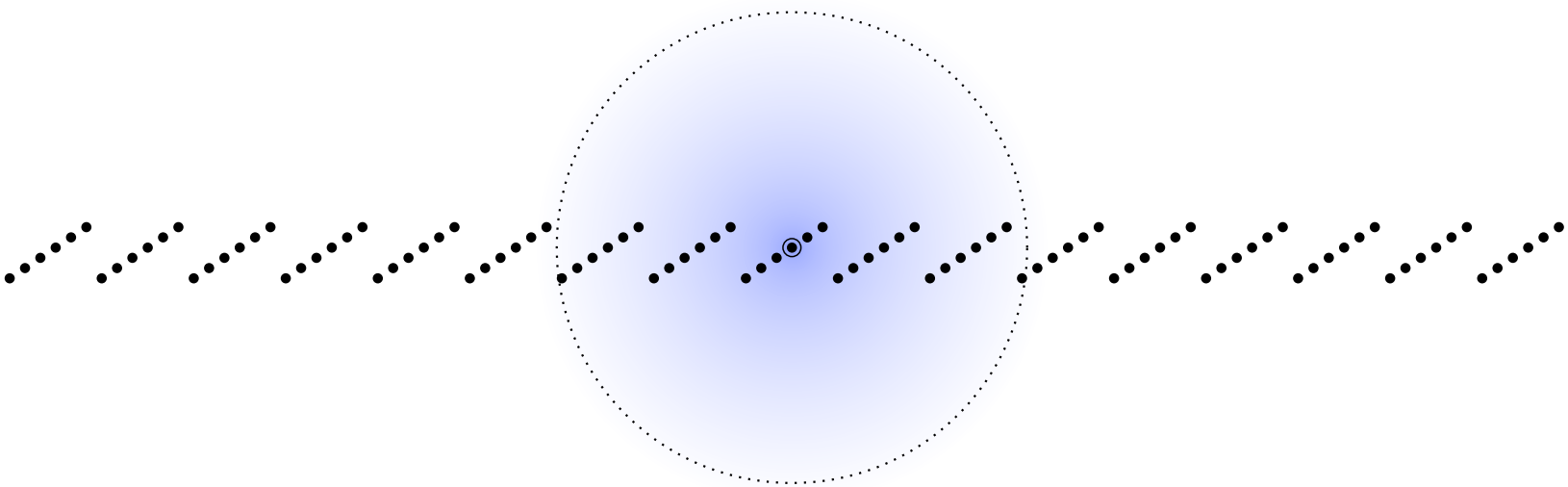
EDCA Traffic Streams Experiment





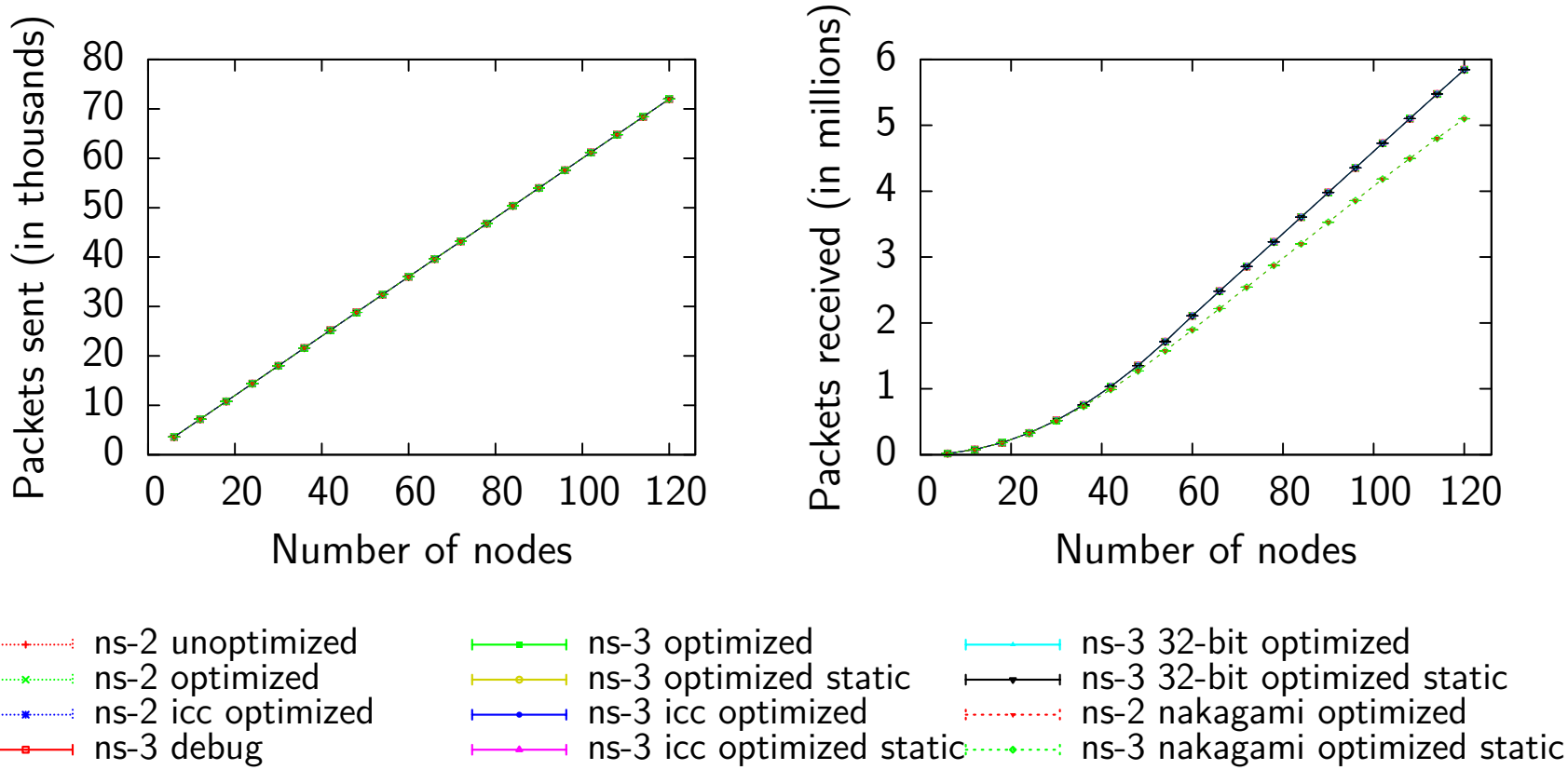
Each node sends four 160 Kb/s streams with different ACs.
As the number of nodes increases the medium is saturated.

Speed Comparison – Highway Scenario

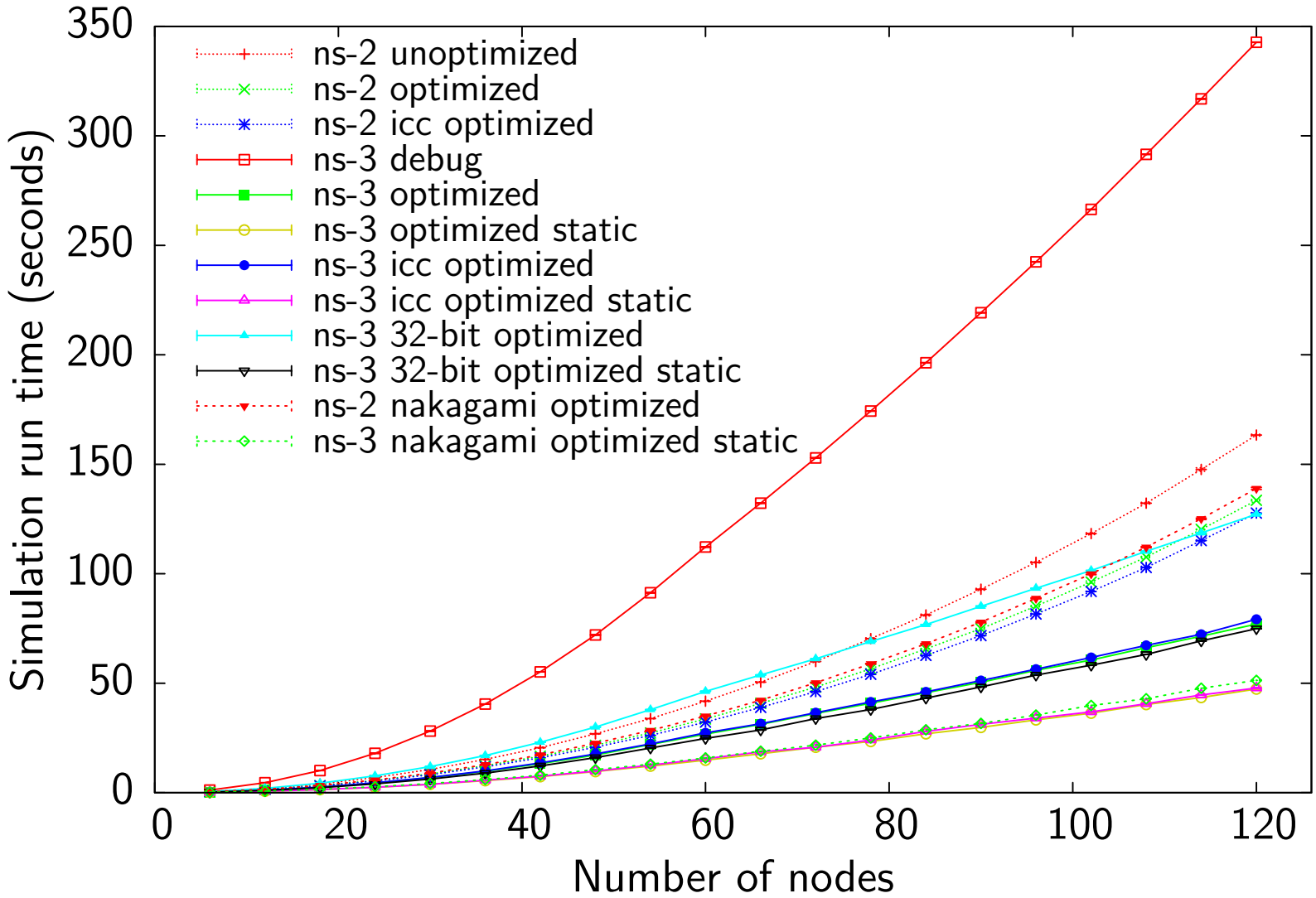


- Modeled identically in both ns-2 and ns-3.
- Made possible with newly added components.

Speed Comparison – Results



Speed Comparison – Results



Speed Comparison – Results

- Slowest configuration: ns-3 in debug mode.
- ns-3 optimized mode gives 76.3±0.5% reduction.
- ns-3 optimized with static linking yields further reduction of 42.6±1.2%.
- Compilation without `-fPIC` yielded a reduction of only 1.1±0.3%.
- icc vs. gcc: no improvement, even slight speed decrease (1.9±0.4%).
- Speed increase of ns-3 over identical ns-2 simulation: 58.6±1.8%.
- Enabling Nakagami propagation increases run time by 8.1±1.0% in ns-3 and 3.8±0.4% in ns-2.

Conclusion

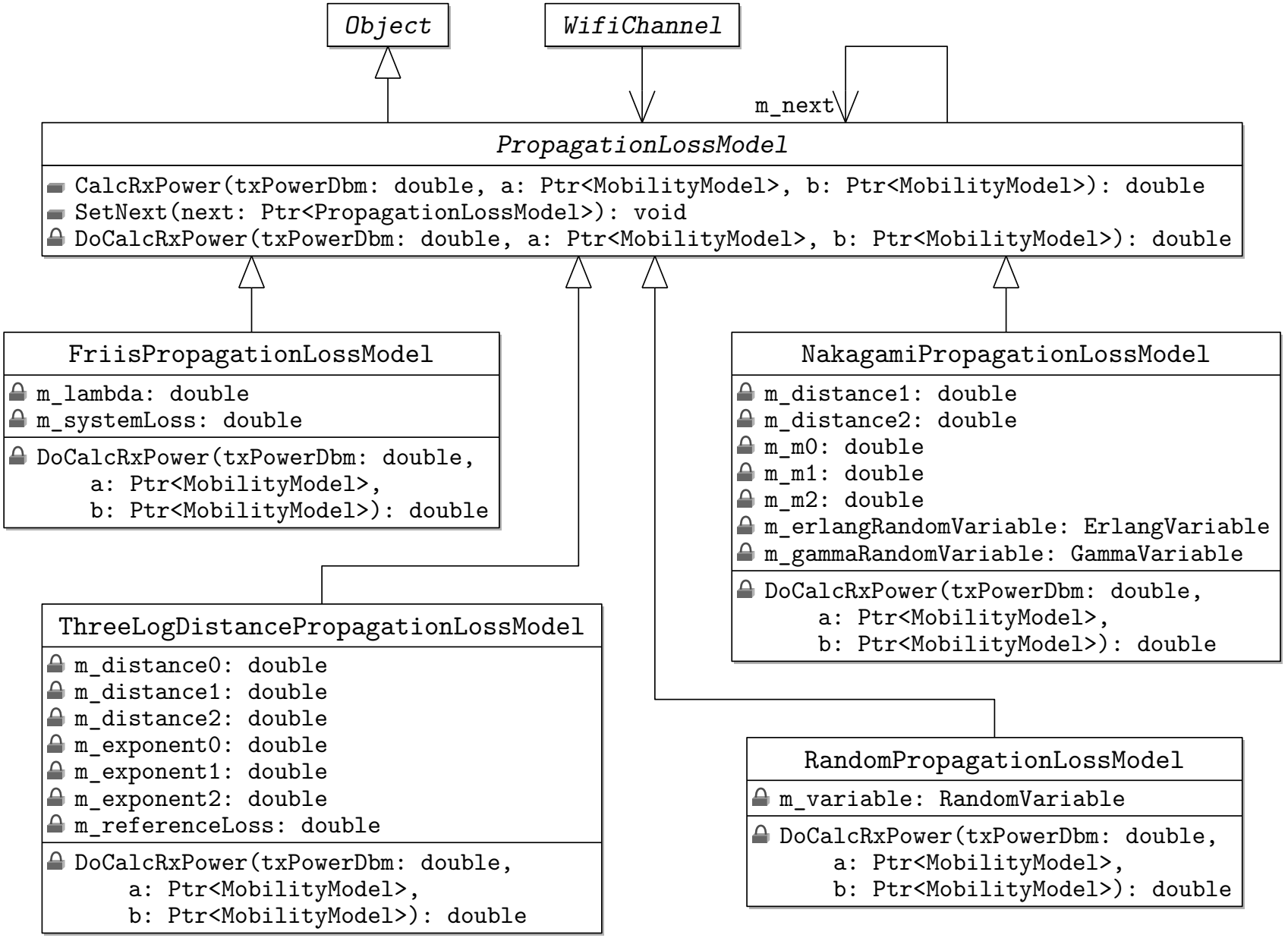
- Extended ns-3 802.11 PHY layer to show equivalent behavior as ns-2.
- Improved MAC layer with EDCA extensions.
- All enhancements thoroughly verified.
- Speed test of ns-3 shows up to 59 % execution time reduction over ns-2.

Thank you for your attention.

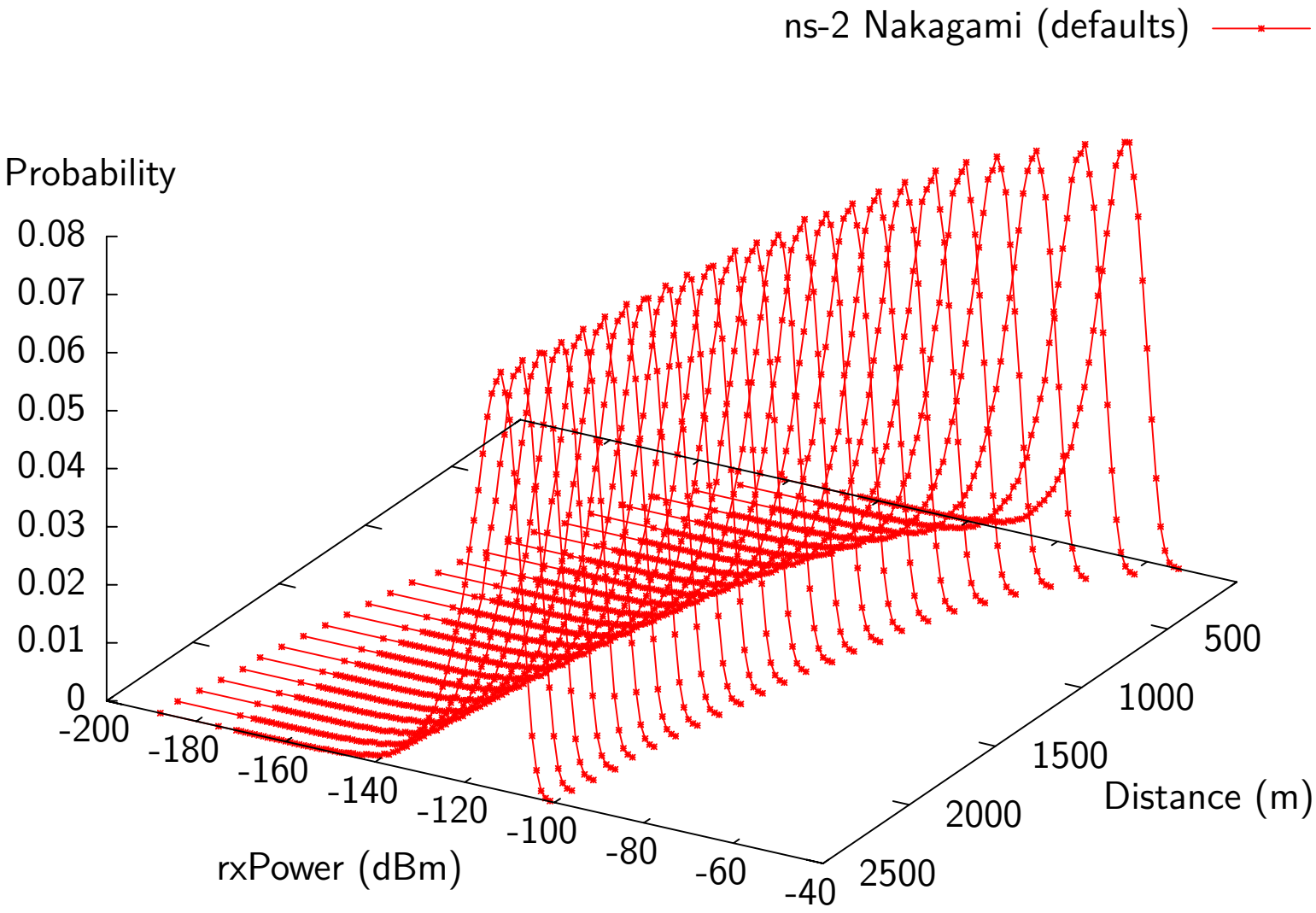
Appendix

5 Enlarged Plots and Figures

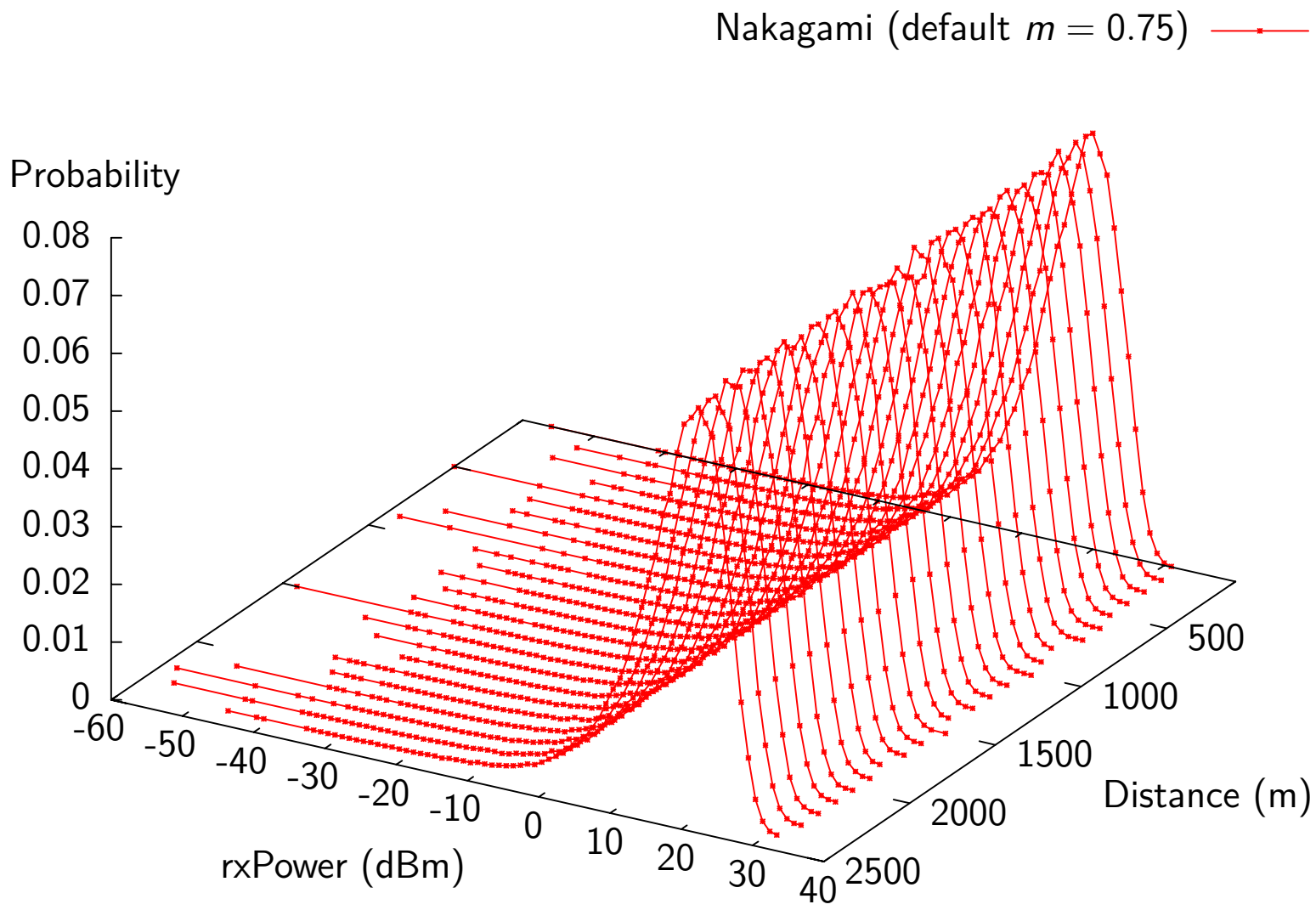
- Propagation Loss Models
- Reception Criteria
- Frame Capture Effect
- EDCA Implementation


Object
WifiChannel
m_next
PropagationLossModel
CalcRxPower(txPowerDbm: double, a: Ptr<MobilityModel>, b: Ptr<MobilityModel>): double
SetNext(next: Ptr<PropagationLossModel>): void
DoCalcRxPower(txPowerDbm: double, a: Ptr<MobilityModel>, b: Ptr<MobilityModel>): double
FriisPropagationLossModel
m_lambda: double
m_systemLoss: double
DoCalcRxPower(txPowerDbm: double, a: Ptr<MobilityModel>, b: Ptr<MobilityModel>): double
NakagamiPropagationLossModel
m_distance1: double
m_distance2: double
m_m0: double
m_m1: double
m_m2: double
m_erlangRandomVariable: ErlangVariable
m_gammaRandomVariable: GammaVariable
DoCalcRxPower(txPowerDbm: double, a: Ptr<MobilityModel>, b: Ptr<MobilityModel>): double
ThreeLogDistancePropagationLossModel
m_distance0: double
m_distance1: double
m_distance2: double
m_exponent0: double
m_exponent1: double
m_exponent2: double
m_referenceLoss: double
DoCalcRxPower(txPowerDbm: double, a: Ptr<MobilityModel>, b: Ptr<MobilityModel>): double
RandomPropagationLossModel
m_variable: RandomVariable
DoCalcRxPower(txPowerDbm: double, a: Ptr<MobilityModel>, b: Ptr<MobilityModel>): double

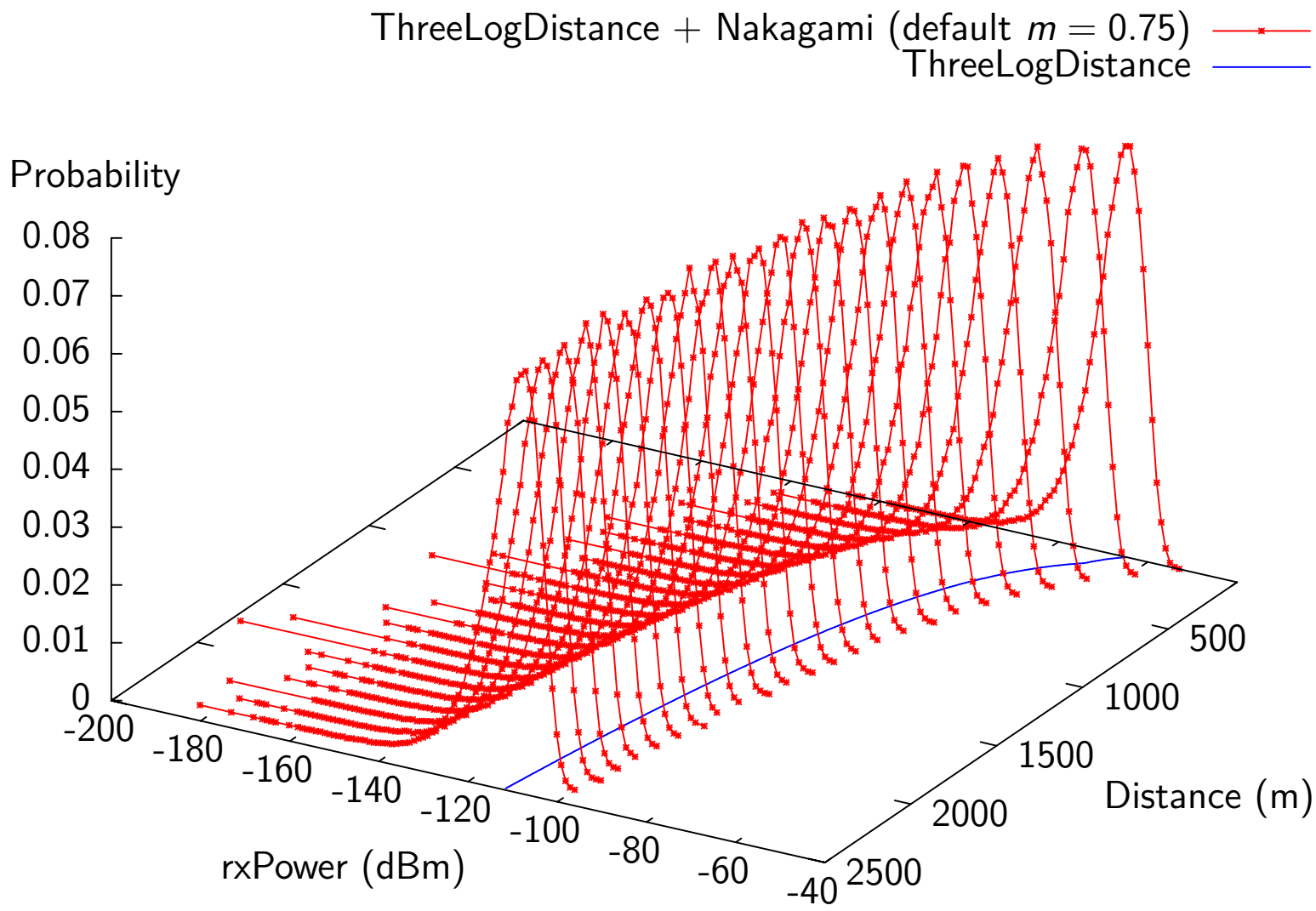
ns-2 Nakagami Reception Power



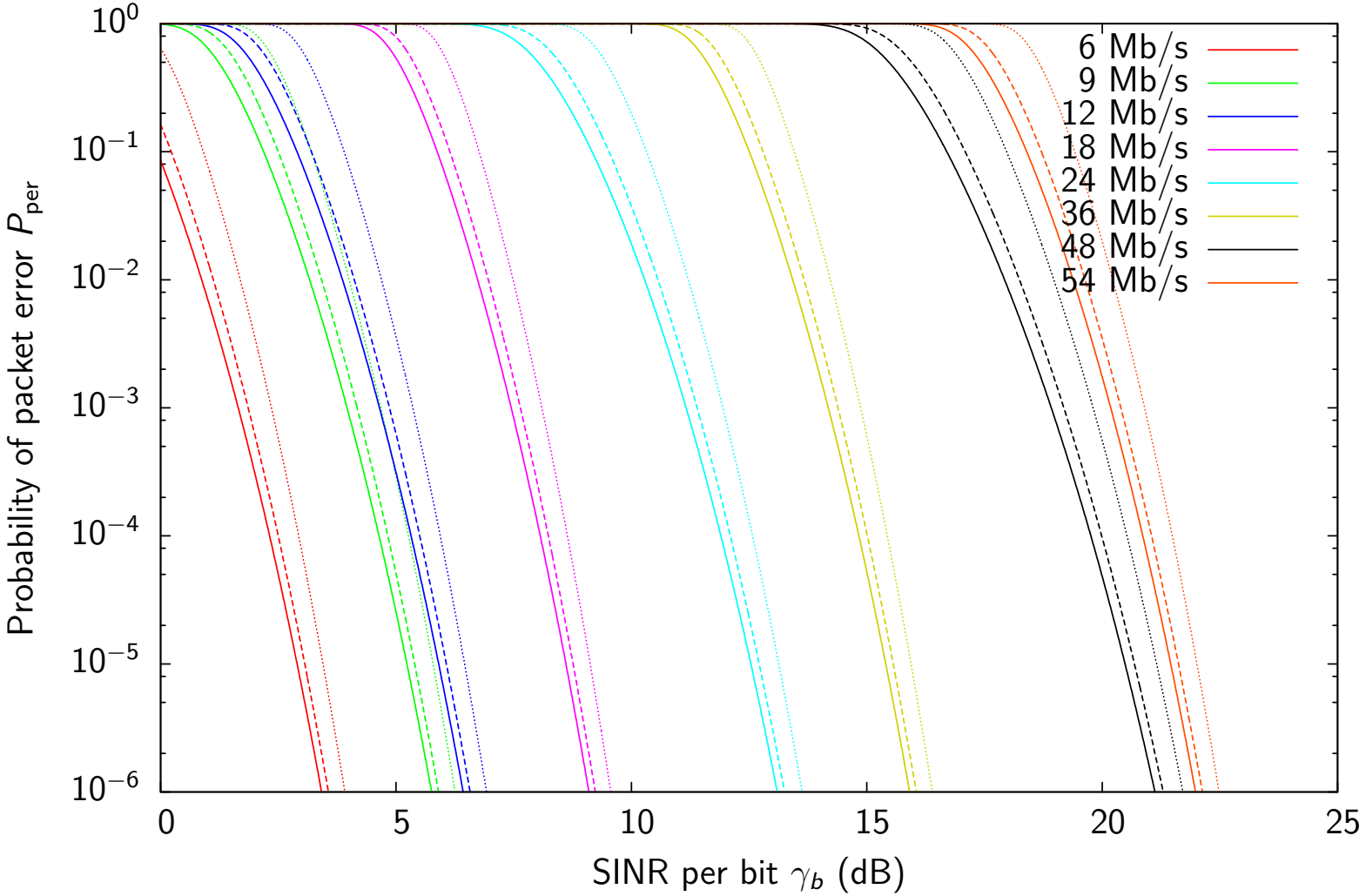
ns-3 NakagamiPropagationLossModel



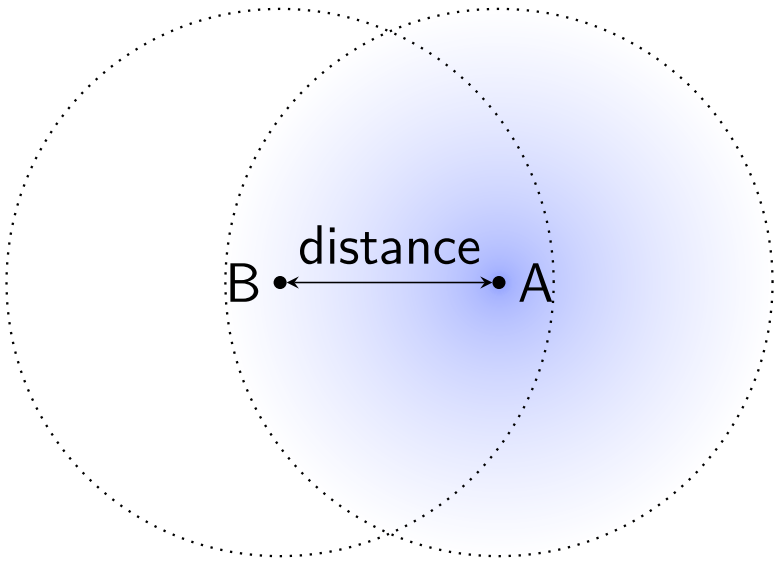
ns-3 ThreeLogDistance and Nakagami



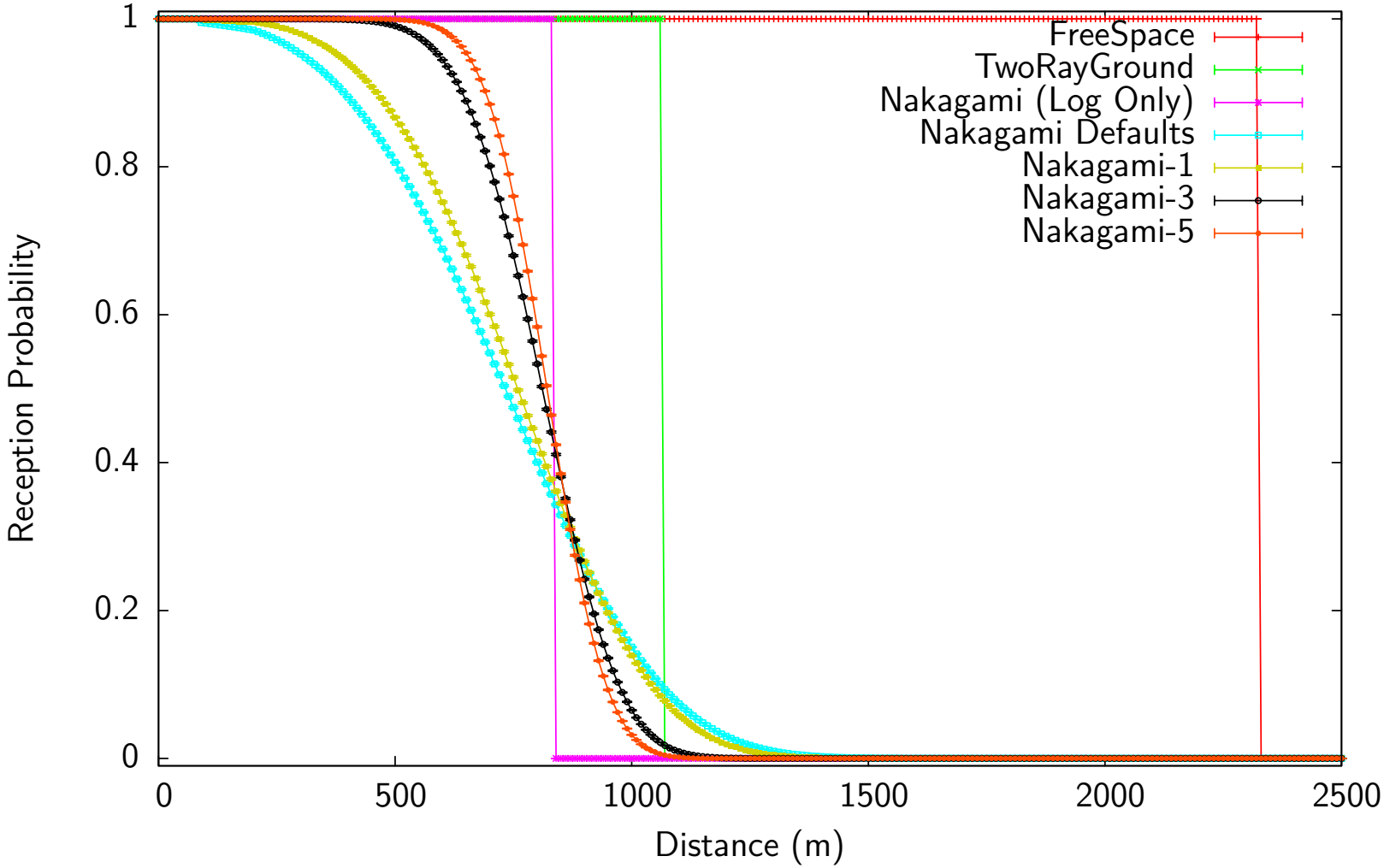
PER for Different Modes



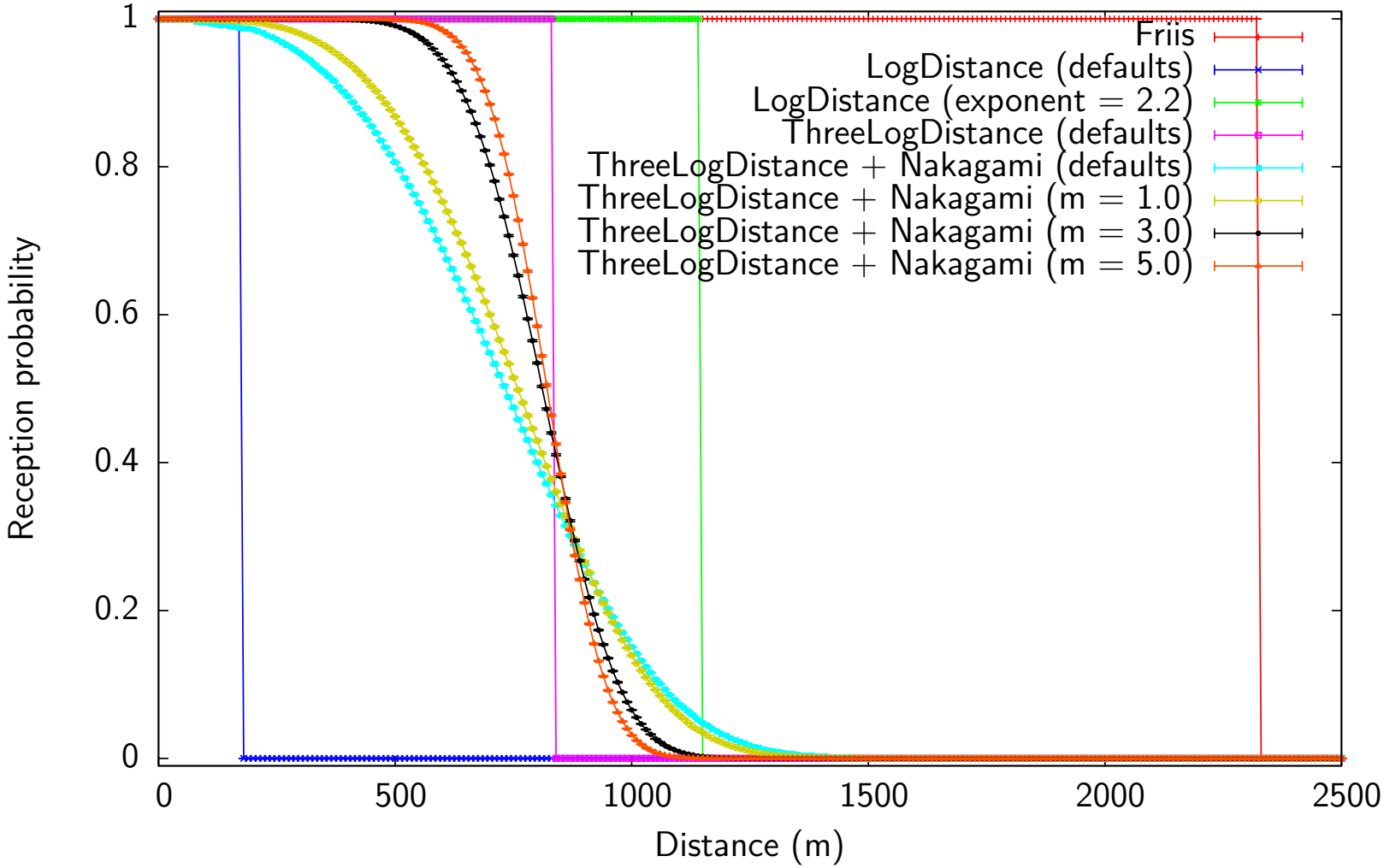
Two Nodes Experiment Scenario



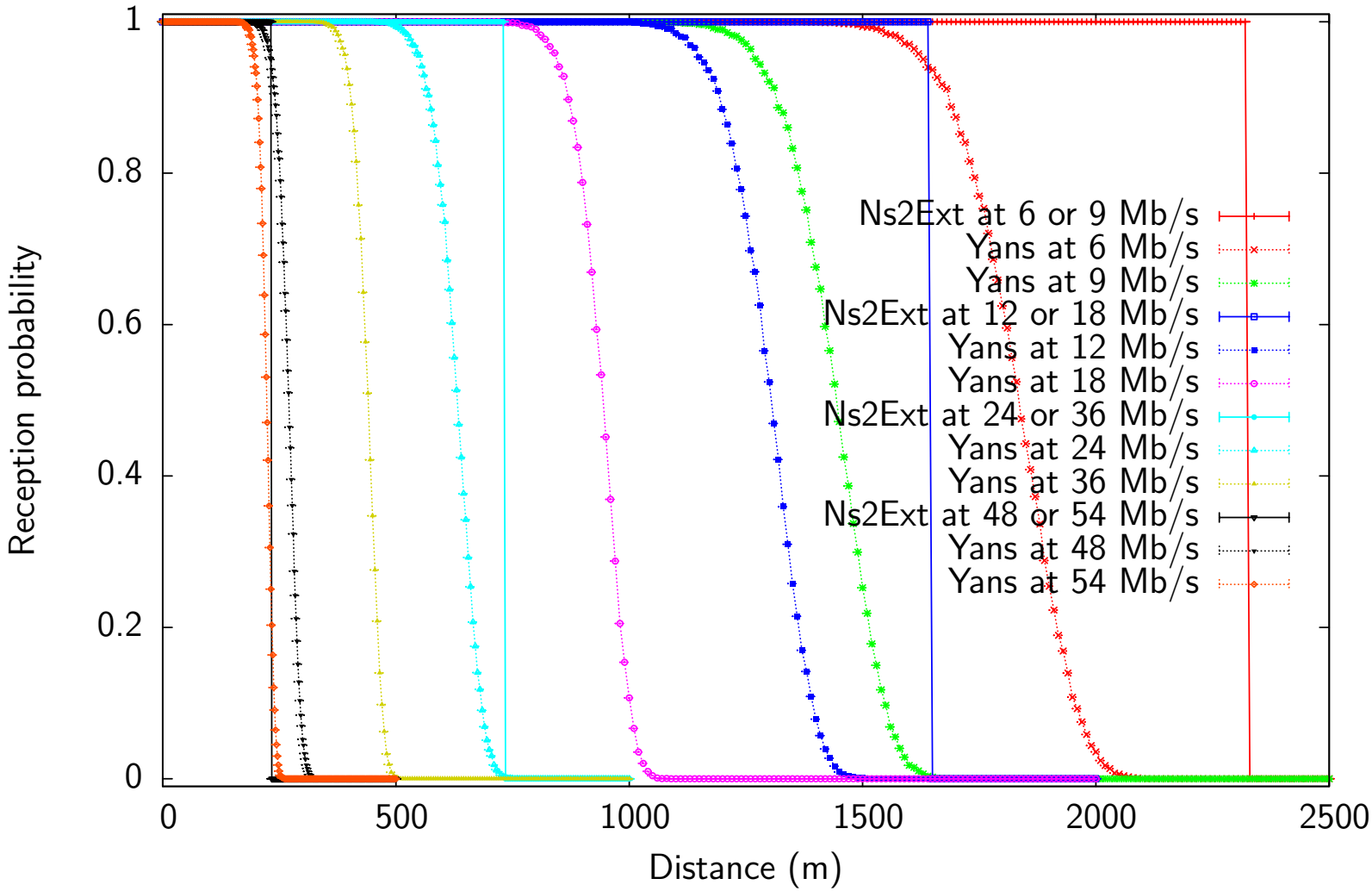
ns-2 Two Nodes Reception Range



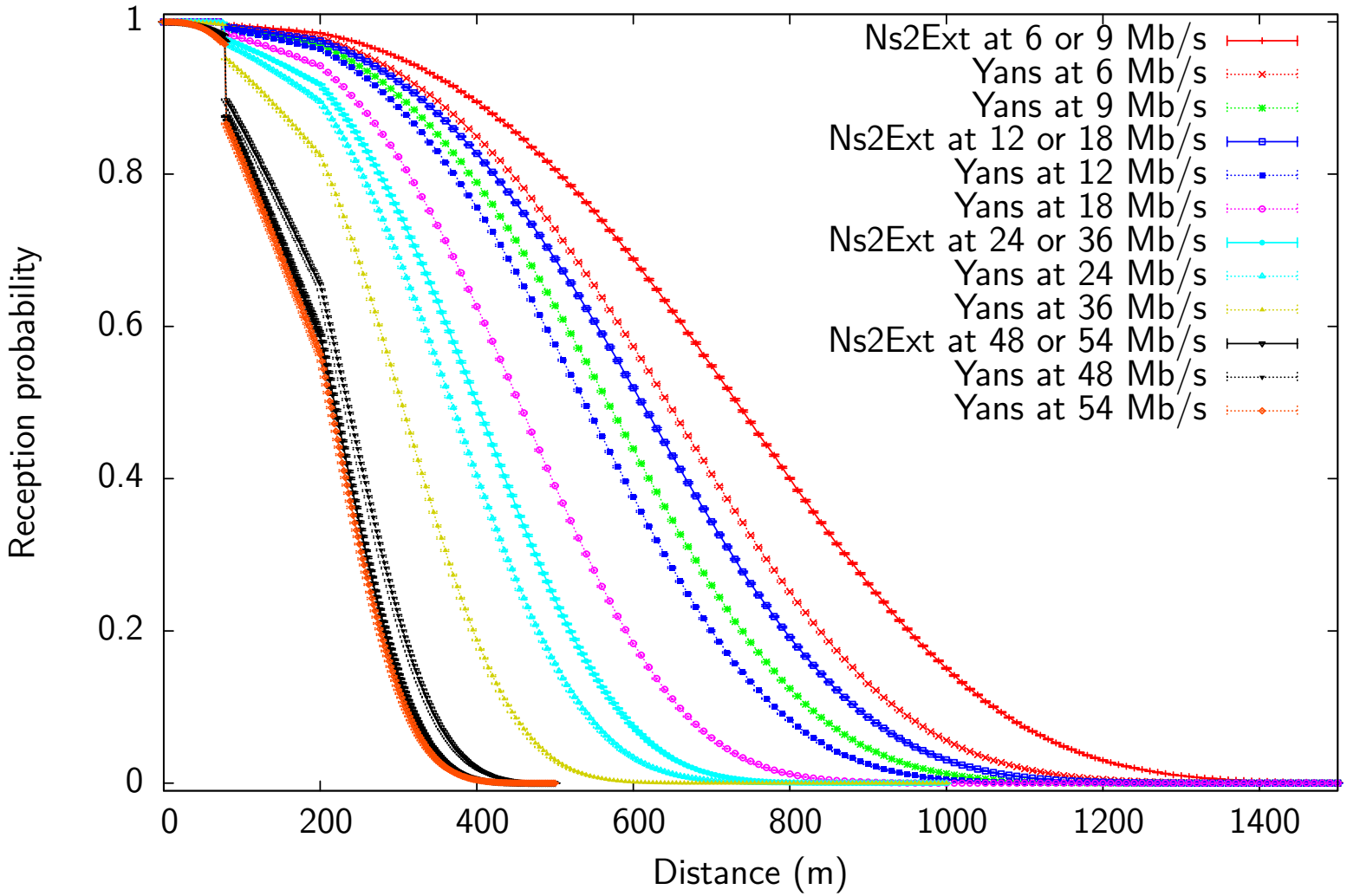
ns-3 Two Nodes Reception Range



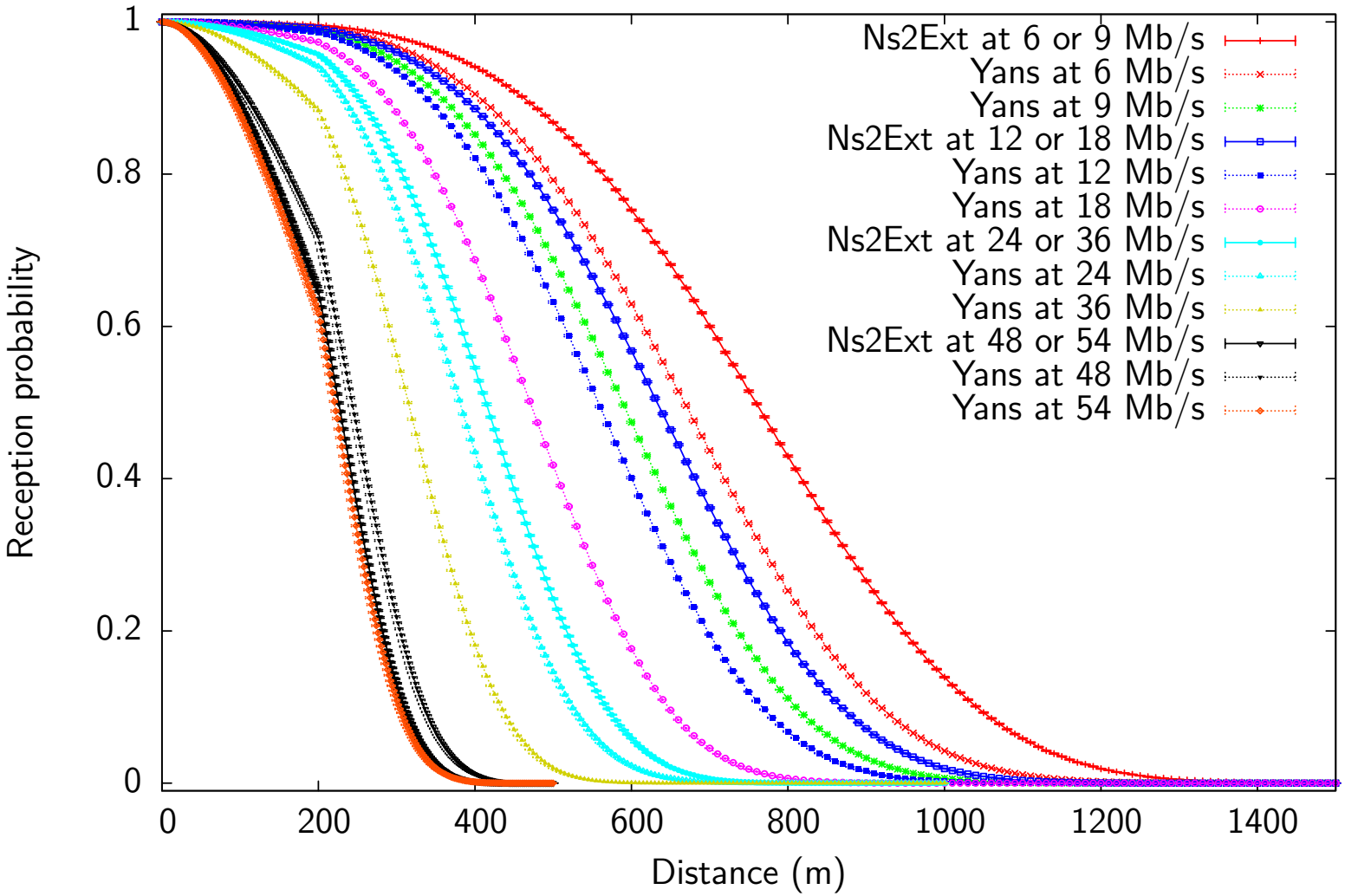
ns-3 Mixed PHY Models Free-Space



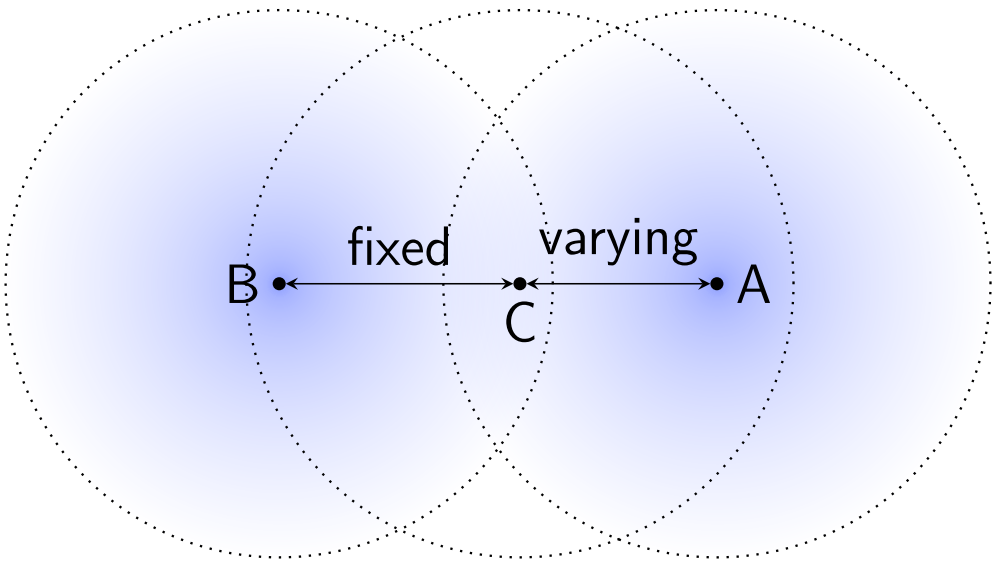
ns-3 Mixed PHY Models Nakagami

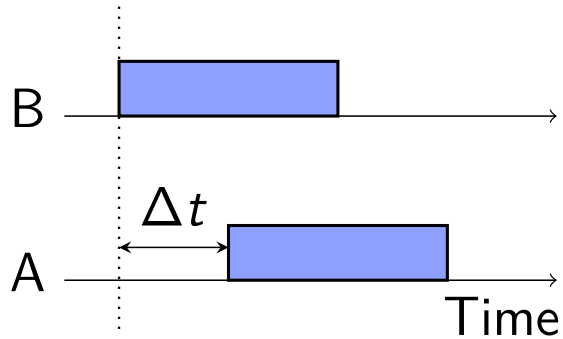


ns-3 Mixed PHY Models Nakagami $m=1$

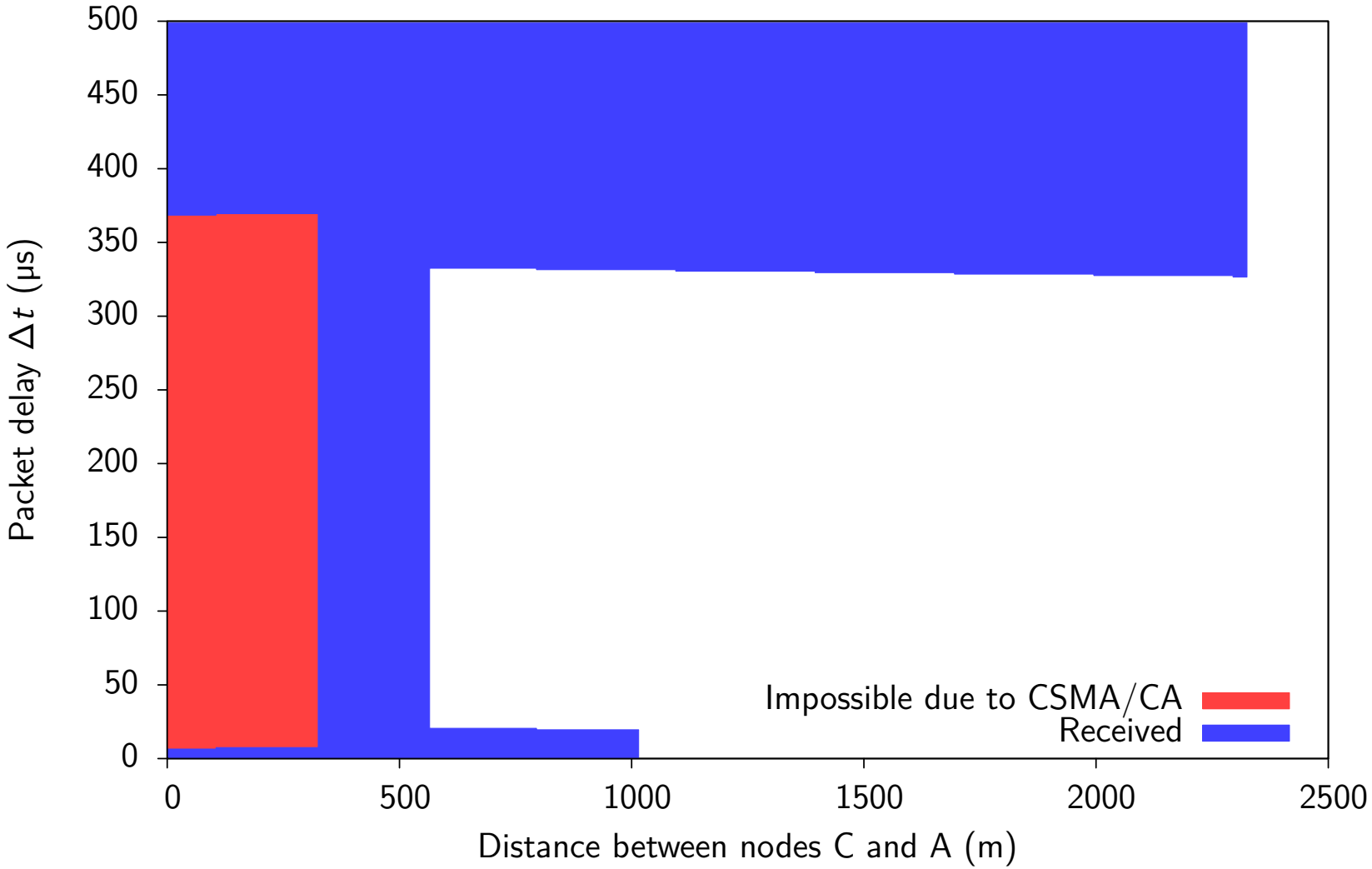


Three Nodes Capture Experiment

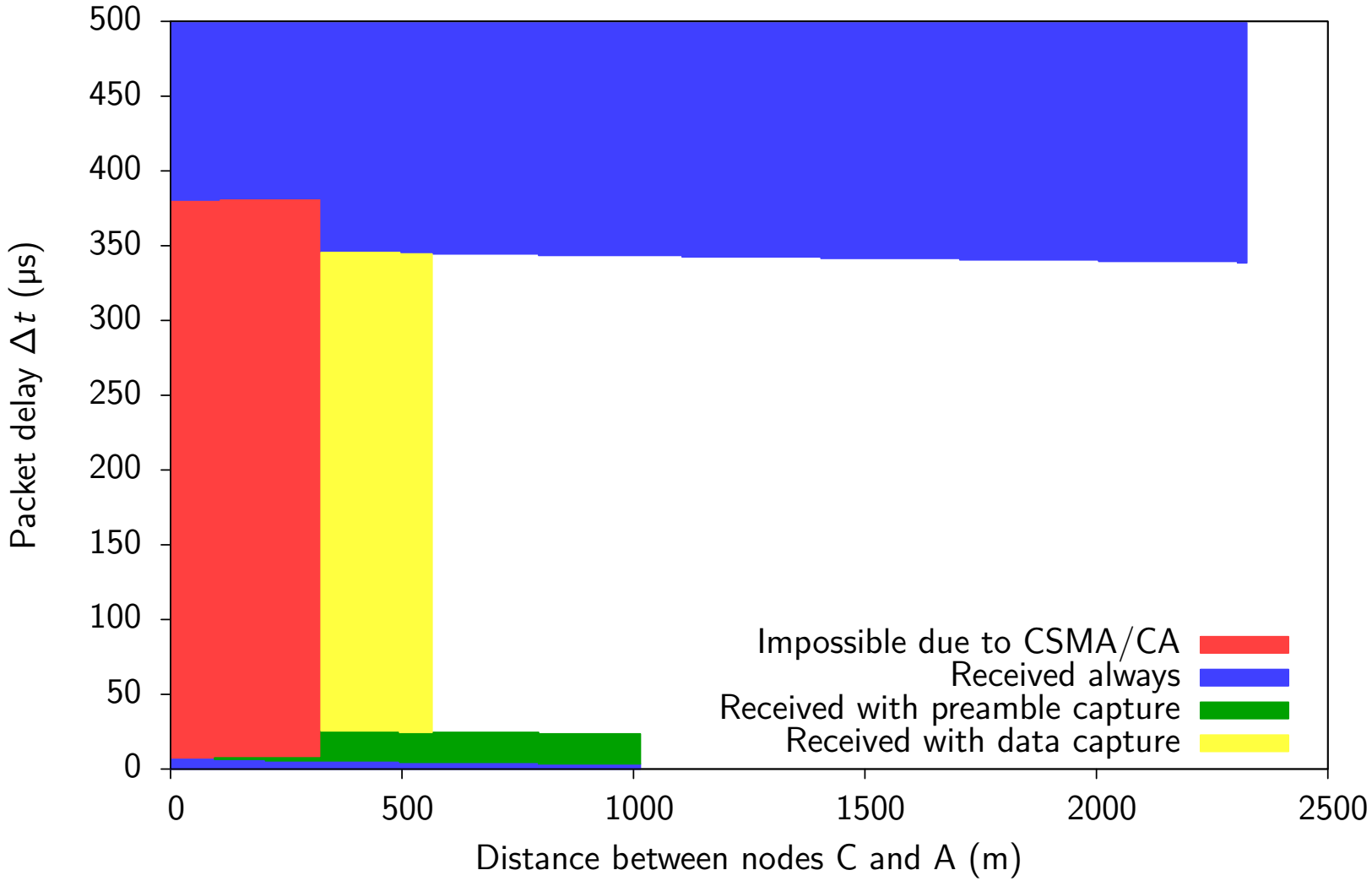




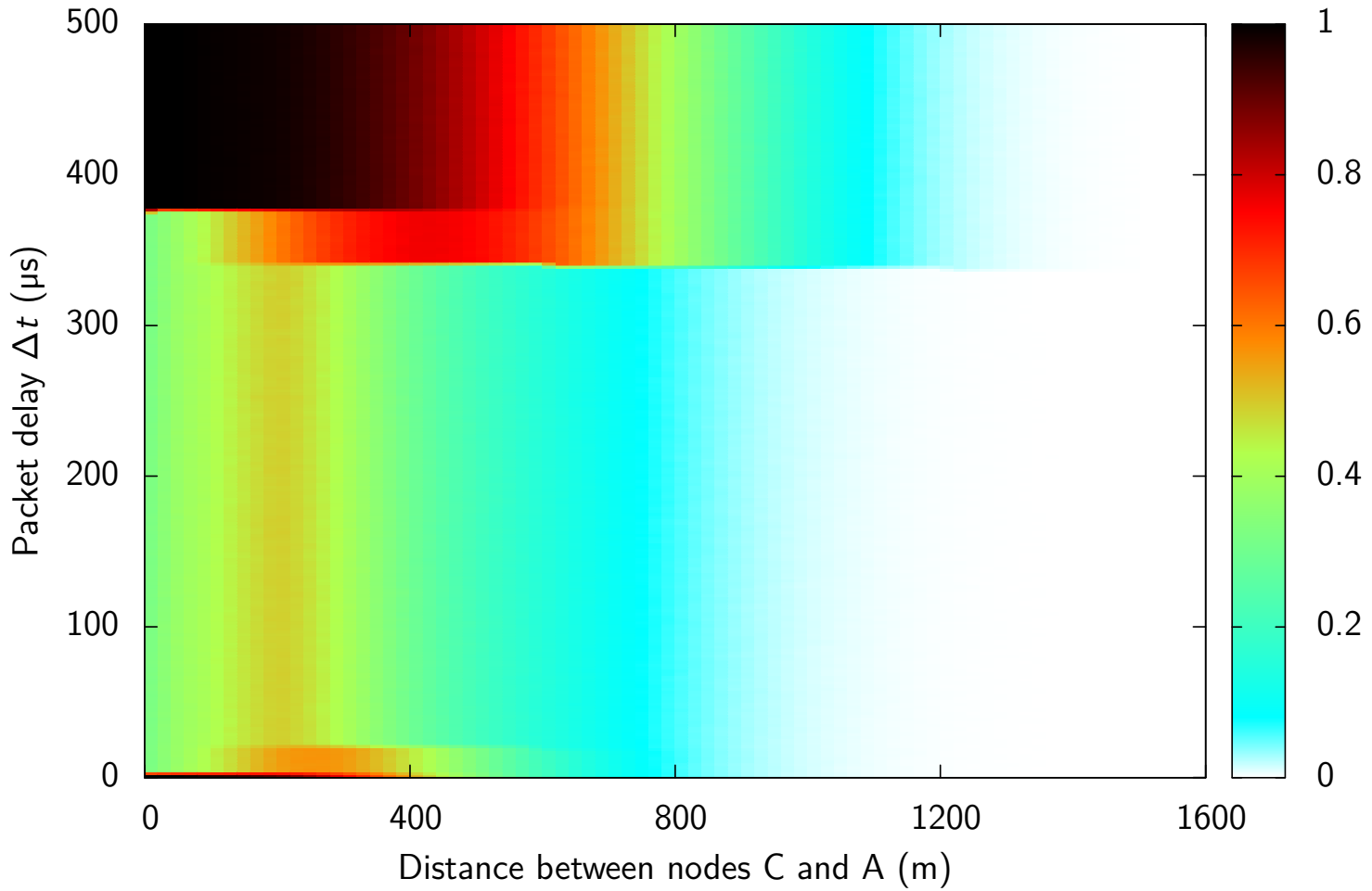
ns-2 Three Nodes Capture



ns-3 Three Nodes Capture



ns-3 Three Nodes Capture Nakagami



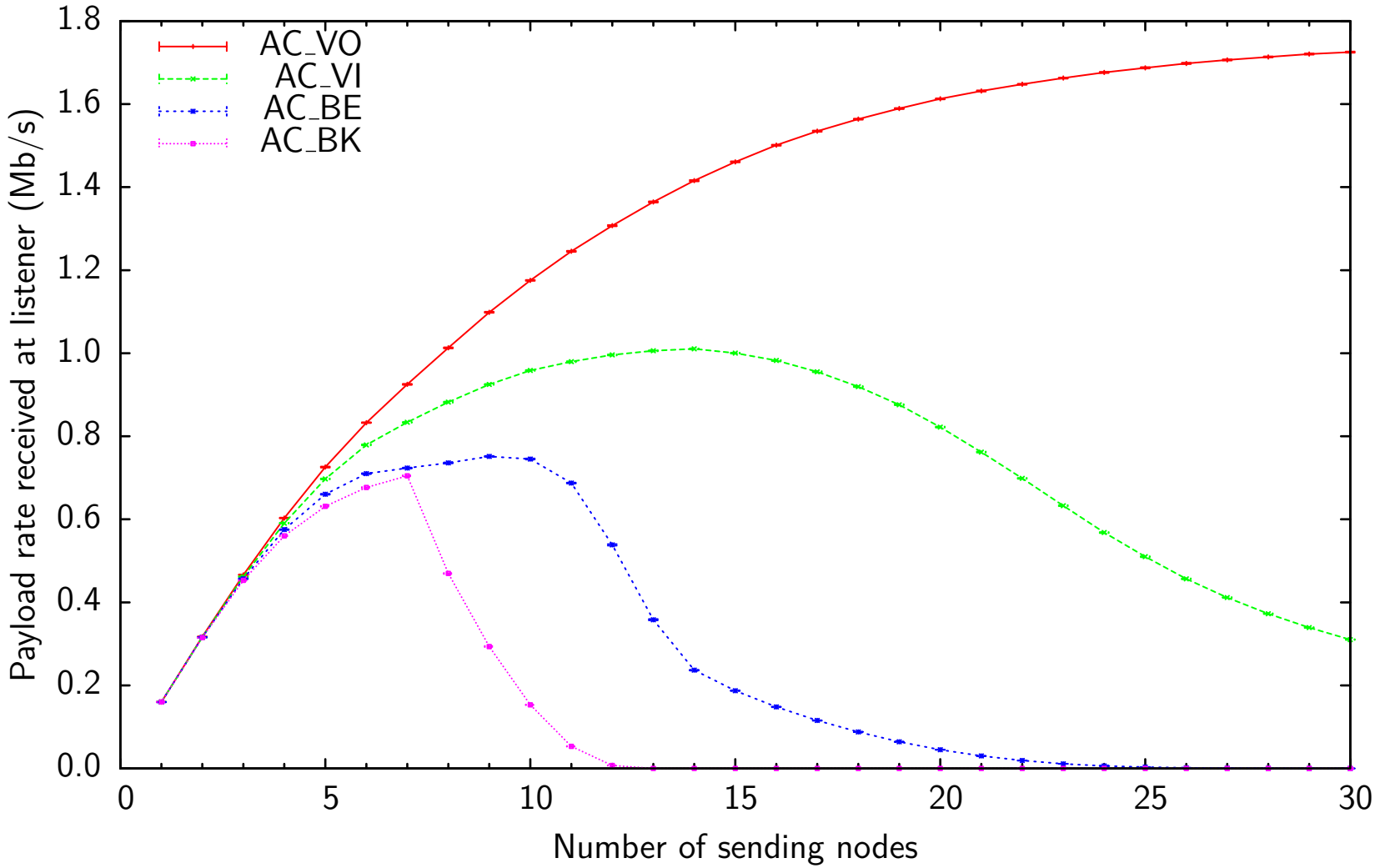
Maximum Throughput Experiment

Reference value and difference of experimental result in B/s with 99 % error margin for 54 Mb/s data rate.

	80 B - noACK	80 B - ACK	2304 B - ACK
DCF	4 522 908 46 ± 514	3 176 179 23 ± 317	34 810 198 474 ± 1 377
AC_VO 802.11p/D4.02	7 314 286 212 ± 392	4 338 983 39 ± 101	38 763 407 249 ± 390
AC_BK 802.11p/D4.02	3 129 584 −182 ± 302	2 419 660 48 ± 223	31 108 861 191 ± 1 196

Tested 216 configurations.
Maximum difference was 701 B/s ± 1 661.

EDCA Traffic Streams – no ACK



EDCA Traffic Streams – with ACK