

Introducing Probabilistic Radio Propagation Models in OMNeT++ Mobility Framework and Cross Validation Check with NS-2



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Why probabilistic models?

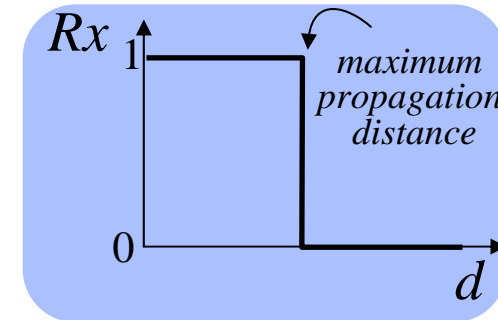
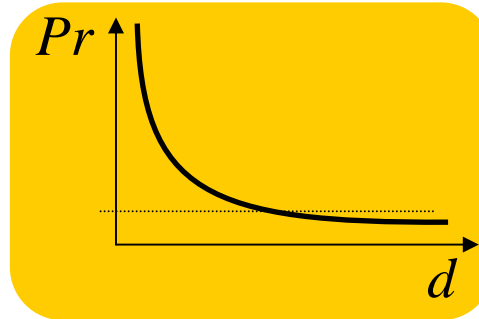
- Radio propagation models
 - Determine signal strength at receiving node
 - Simple deterministic models
 - ▶ Signal strength is a simple function of distance
- Consequences of deterministic models [Kotz2004]
 - A radio's transmission area is circular
 - All radios have equal range
 - If I can hear you, you can hear me
 - If I can hear you at all, I can hear you perfectly
- Deterministic models are unrealistic
 - But standard model for many simulators

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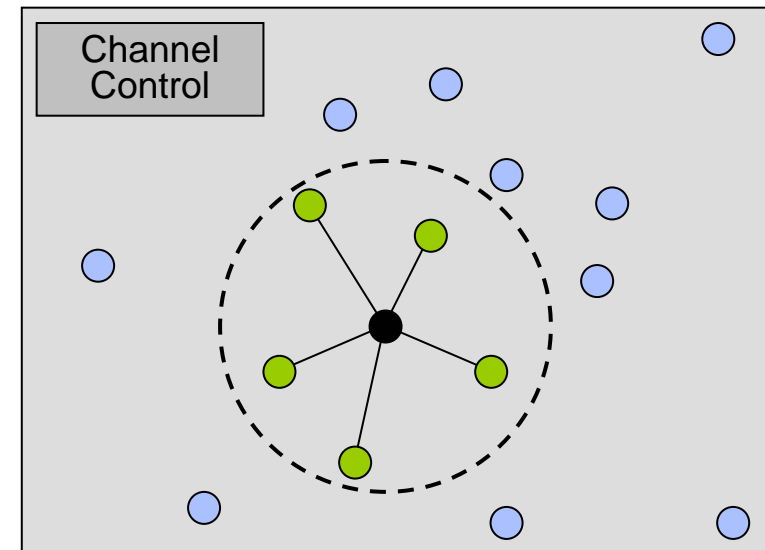


- Deterministic Free Space propagation model

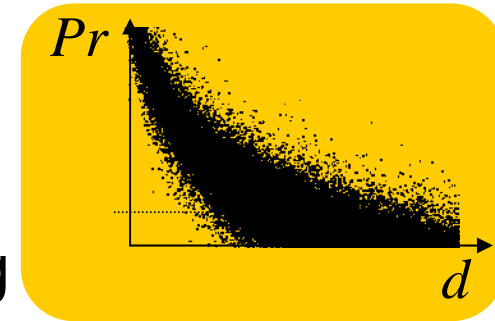
$$Pr_{\text{det}}(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L}$$



- All relevant rx events in unit disk graph
- Basis for MF Channel Control implementation
 - Connects nodes in max. propagation distance



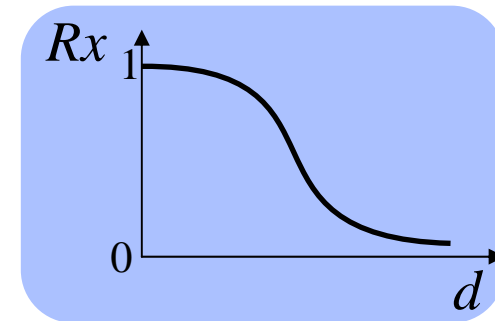
- General structure
 - Use deterministic path loss
 - ▶ Average reception power
 - Add probabilistic small scale fading
 - ▶ Characterized by some distribution



- $Pr_{Distr}(d; args) \sim Distr(Pr_{det}(d); args)$

- Newly included models

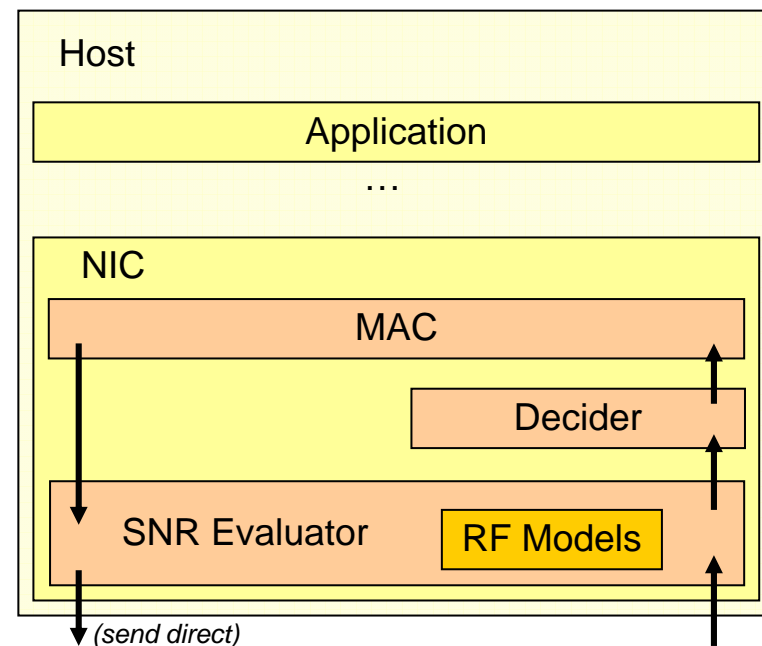
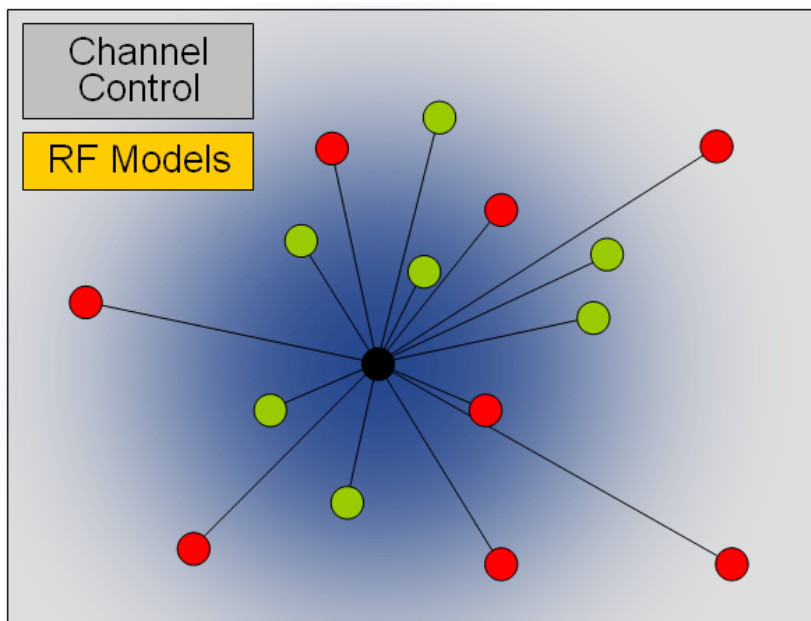
- Log Normal Shadowing
- Rayleigh
- Rice
- Nakagami



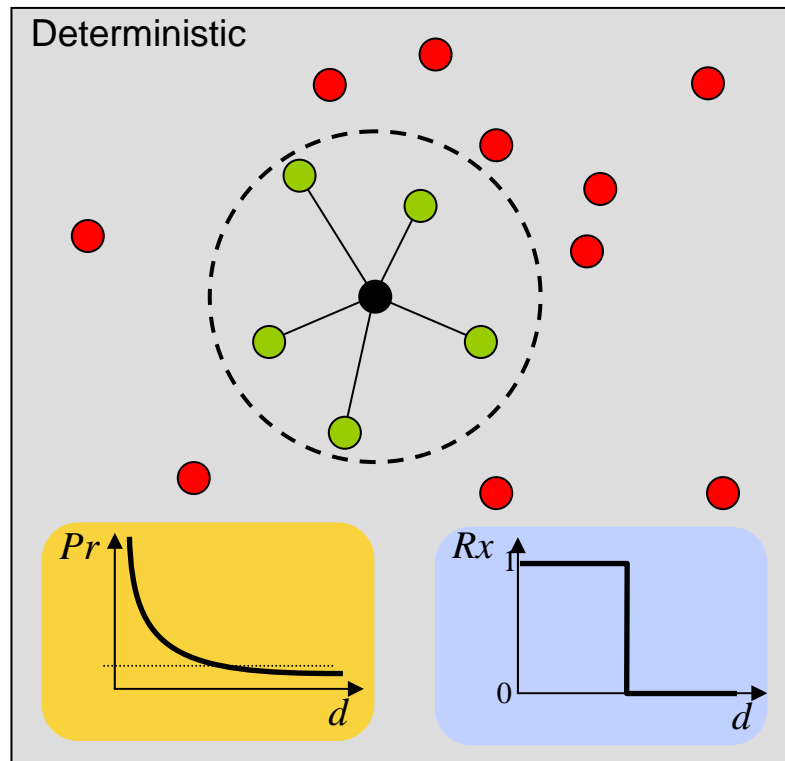
$$Pr_{Nak}(d; m) \sim Gamma\left(m, \frac{Pr_{det}(d)}{m}\right)$$

[Nakagami1960] [Rappaport1996]

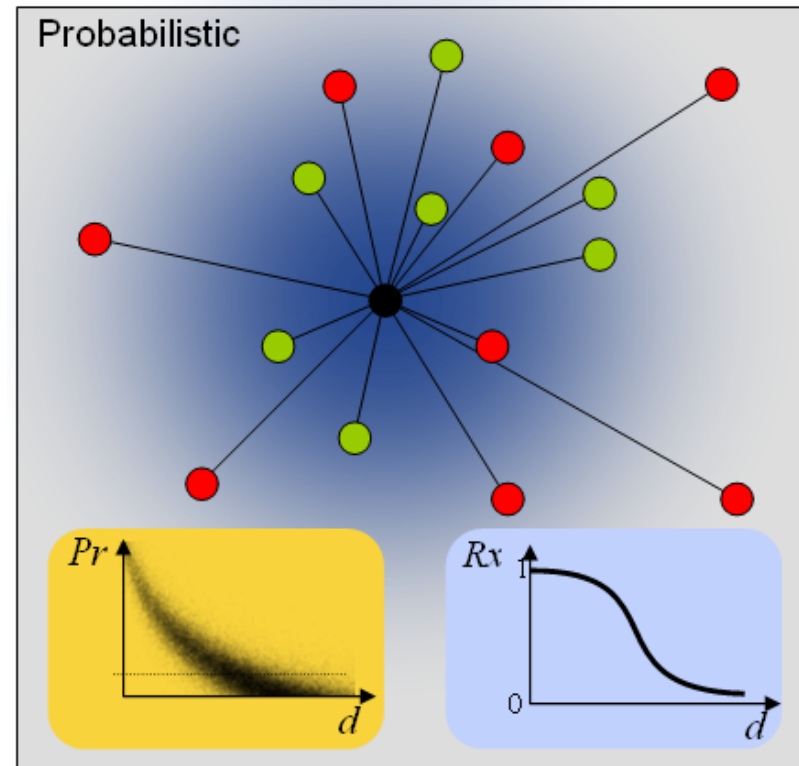
- Only ,connected' nodes receive events
 - Channel Control cares about connections
 - Needs access to the RF module
- Calculate $Pr(d)$ on each message arrival
 - RF Models needed in host module
 - SNREval keeps track of SNIR



- Rx Probability = {0, 1}
- Relevant events in max propagation distance
- $\text{cost}_{\text{tx}} \sim \#\text{nodes in 'circle'}$

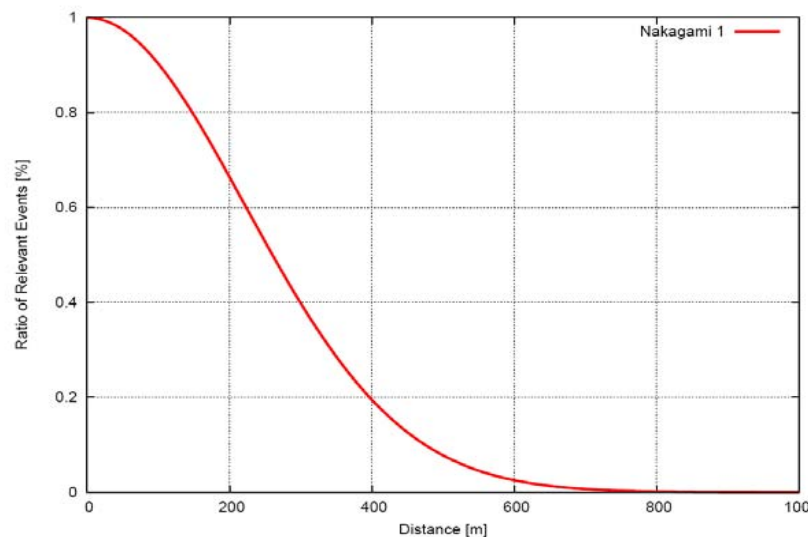


- Rx Probability $\neq 0$
- All events may be relevant
- All nodes have to be informed
- $\text{cost}_{\text{tx}} \sim \#\text{nodes in scenario}$



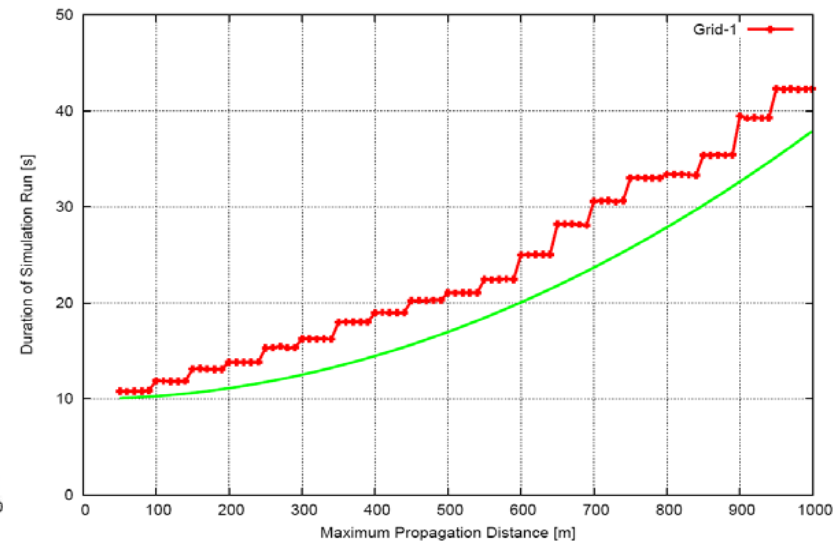
- Max propagation distance (MPD) is tradeoff parameter
 - Accuracy vs. speed of simulation
 - Large MPD → slow but accurate simulation
 - Small MPD → fast but inaccurate simulation

Relevance



Probability of relevant event wrt/ distance

Duration



Duration of simulation wrt/ MPD

How to determine MPD (sketch)

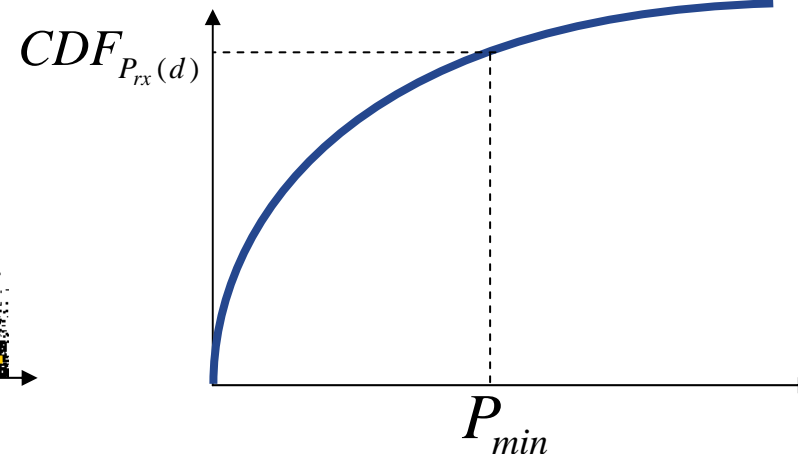
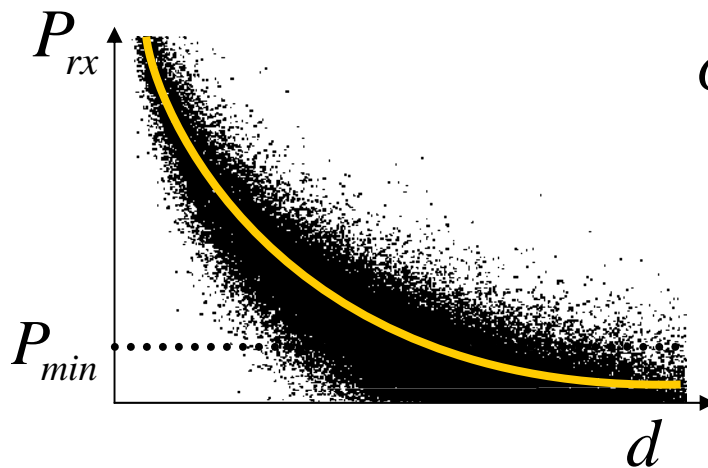
- Track one single event
- Node's goal
 - receive all relevant events
- Relevant event
 - $P_{rx}(d) > P_{min}$
- For which distance d holds:
 - $\text{Prob}(\text{relevant evt}) < \text{accuracy}$
 - $\text{Prob}(P_{rx}(d) > P_{min}) < \text{accuracy}$

- $P_{rx}(d) \sim$ probability distribution
- Cumulative density function

$$CDF_{P_{rx}(d)}(P_{min}) = \text{Prob}(P_{rx}(d) \leq P_{min})$$

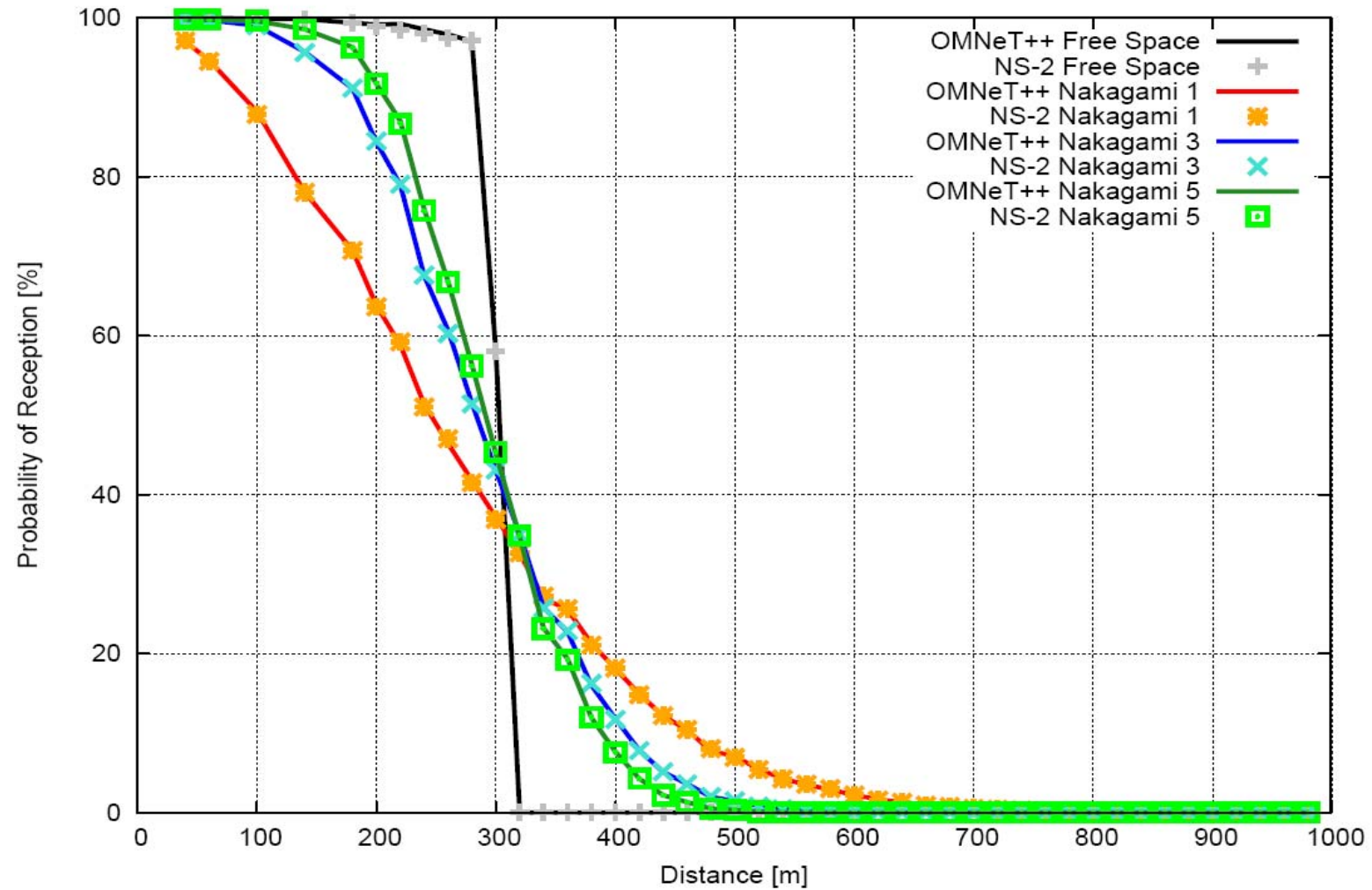
$$1 - CDF_{P_{rx}(d)}(P_{min}) = \text{Prob}(P_{rx}(d) > P_{min})$$

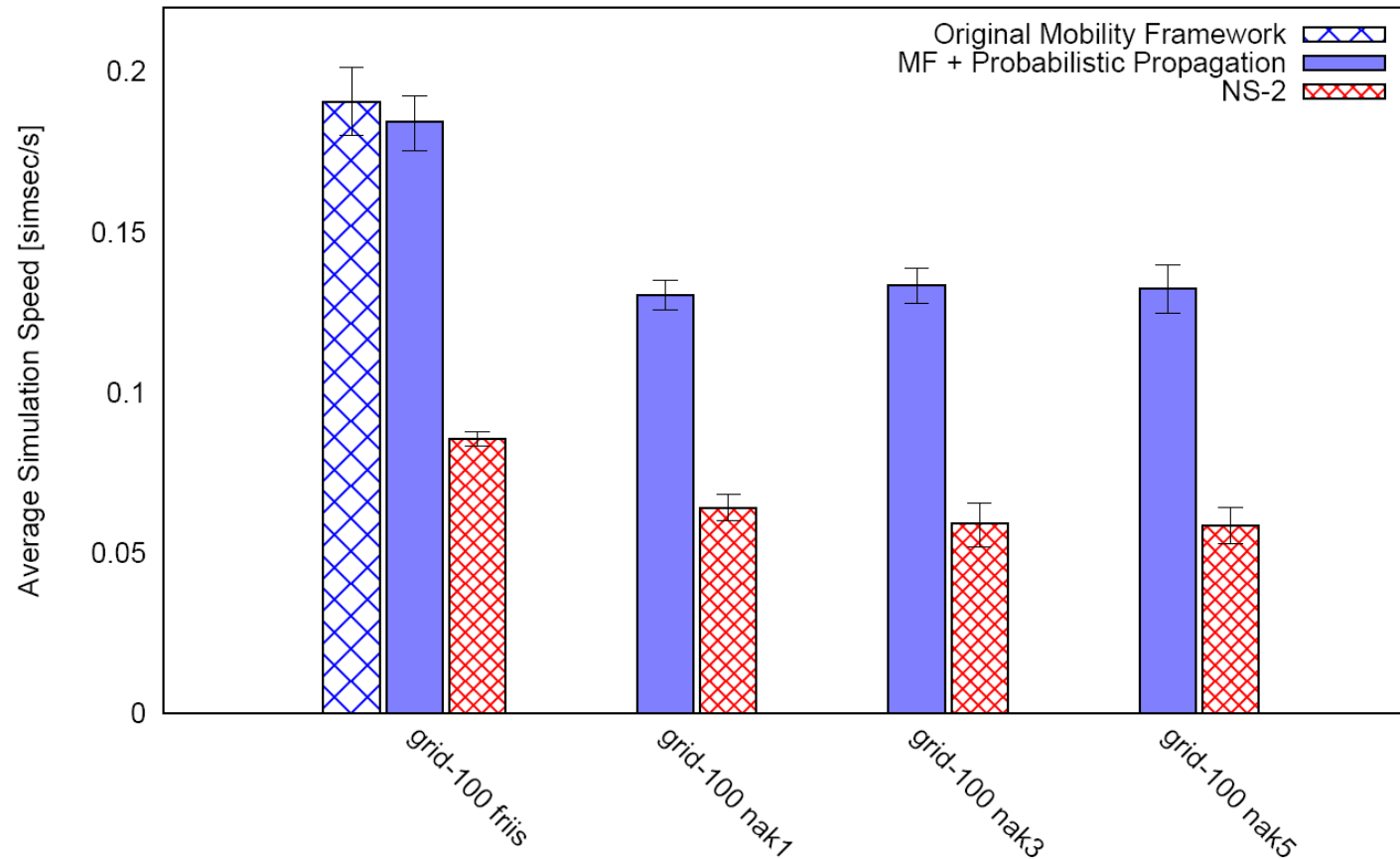
- $1 - CDF_{P_{rx}(d)}(P_{min}) < \text{accuracy}$
- Invert CDF to get the MPD
 - Restrict connectivity to distances $<$ MPD



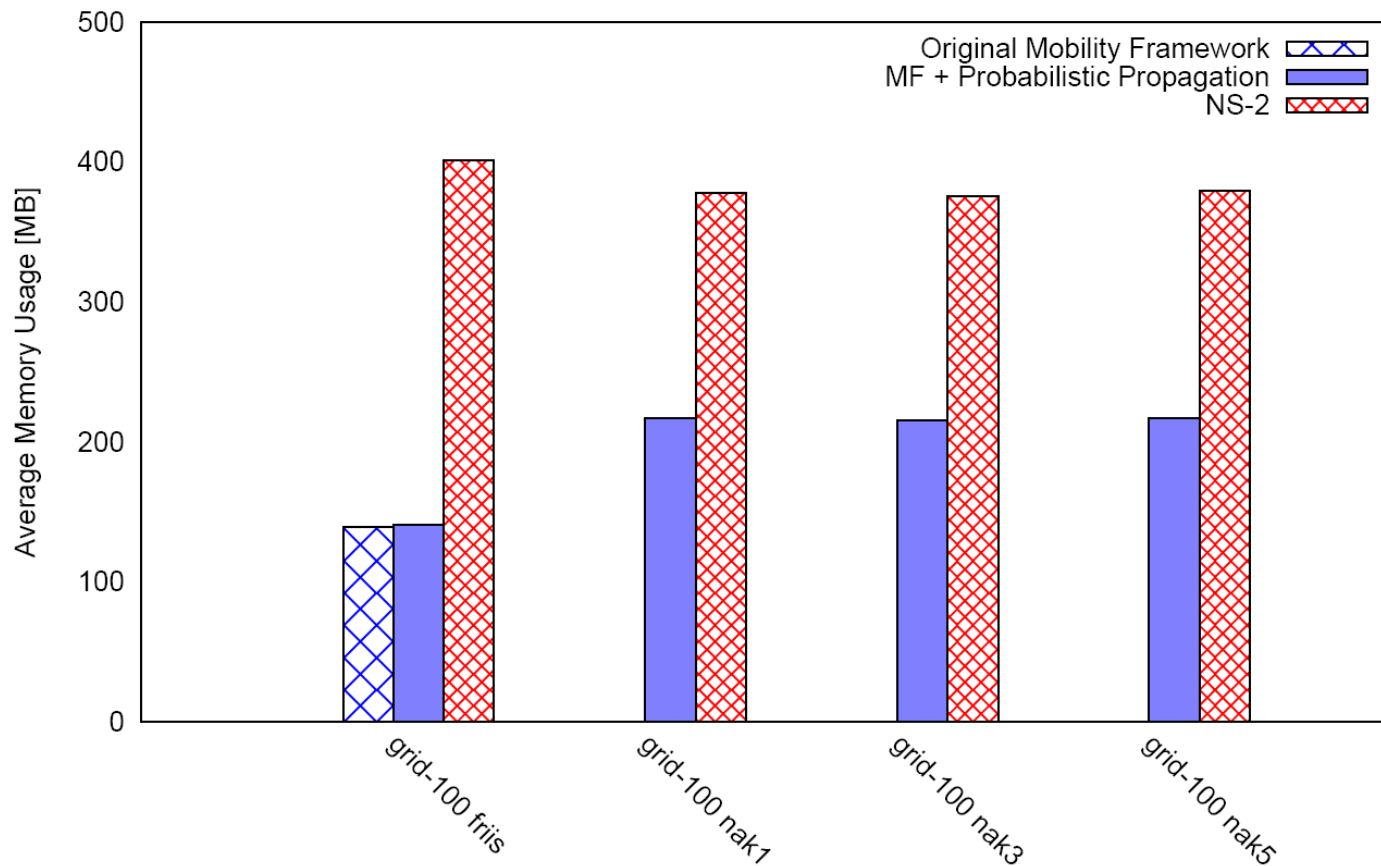
- Limitations
 - Proposed general solution to find MPD
 - Solution applied to Nakagami, $m=1$
- General setup
 - Topologies: chain, grid, random
 - Models: Free Space, Nakagami
 - Playground
 - ▶ 2000m x 2000m, torus enabled
 - ▶ Up to 1600 nodes and 100 senders
 - Fixed MPD for evaluation
 - ▶ Free Space 623m
 - ▶ Nakagami 1000m
- Cross validation
 - Comparison with NS-2
- Performance evaluation
 - Simulation speed
 - Memory usage

Cross Validation Check





- OMNeT++ MF faster than NS-2
- Nakagami causes more receive events



- OMNeT++ MF needs less memory
- Nakagami causes memory increase

- Introduced Probabilistic Wave Propagation Models to OMNeT++ Mobility Framework
 - Log Normal Shadowing, Rayleigh, Rice, Nakagami
 - Cross validation check with NS-2
 - Performance evaluation
- Tradeoff: Accuracy vs. Speed
 - General solution for max propagation distance (MPD)
 - Concrete solution for Nakagami, $m=1$
- Future Work
 - Max propagation distance for Nakagami, $m>1$
 - Analytical results for other models
 - Improved modeling for multiple interfering events
- Availability
 - Extension online: www.tm.uka.de/sne4omf
(Sensor Network Extensions for the OMNeT++ Mobility Framework)



- [Kotz2004] Kotz, D.; Newport, C.; Gray, R. S.; Liu, J.; Yuan, Y. and Elliott, C.: *Experimental evaluation of wireless simulation assumptions* In Proceedings of the 7th ACM international symposium on Modeling, analysis and simulation of wireless and mobile systems (MSWiM04), ACM Press, 2004, 78 – 82
- [Rappaport1996] Rappaport, T. S.: *Wireless Communications: Principles & Practise* Prentice Hall PTR, 1996
- [Nakagami1960] Nakagami, M.: *The m-distribution – A general formula for intensity distribution of rapid fading* Statistical Methods in Radio Wave Propagation, Pergamon, 1960