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

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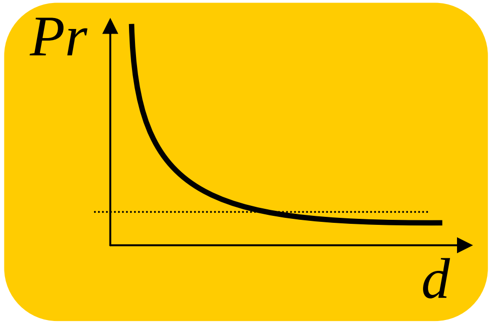
Why probabilistic models?

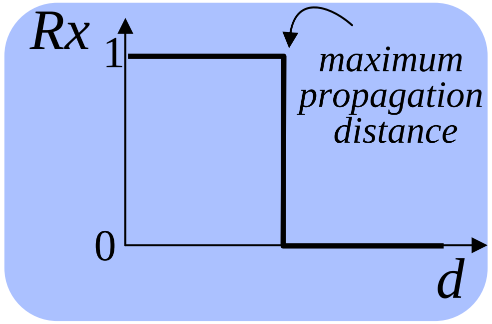
- Radio propagation models
  - Determine signal strength at receiving node
  - Simple deterministic models
    - Signal strength is a simple function of distance
- Consequences of deterministic models [Kotz2004]
  - A radio's transmission area is circular
  - All radios have equal range
  - If I can 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

How about Mobility Framework?

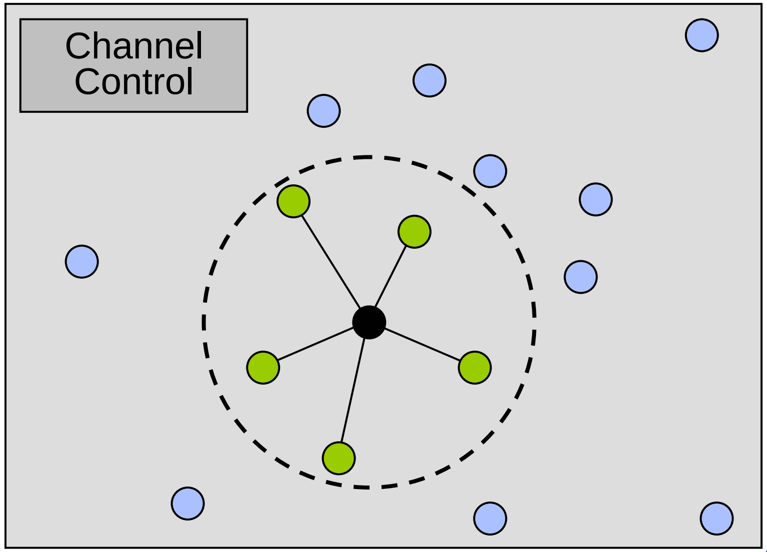
- Deterministic Free Space propagation model

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



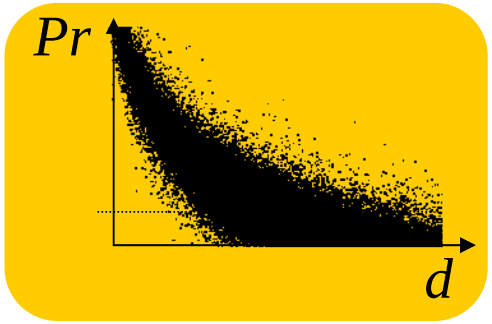


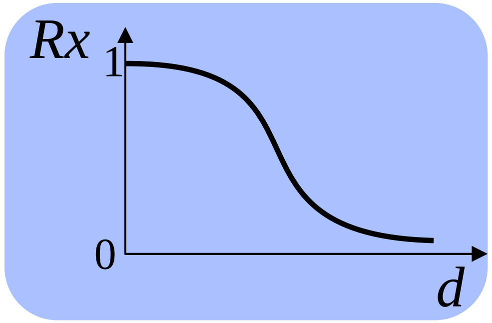
- All relevant rx events in unit disk graph
- Basis for MF Channel Control implementation
  - Connects nodes in max. propagation distance



Probabilistic Models

- General structure
  - Use deterministic path loss
    - Average reception power
  - Add probabilistic small scale fading
    - Characterized by some distribution
  - $\Pr_{Distr}(d;args) \sim Distr\left(\Pr_{\det}(d);args\right)$



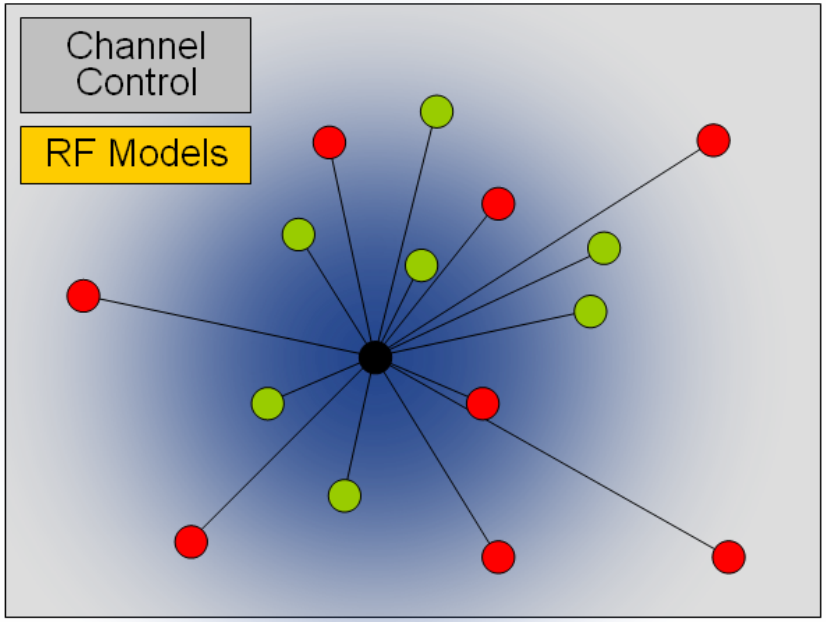


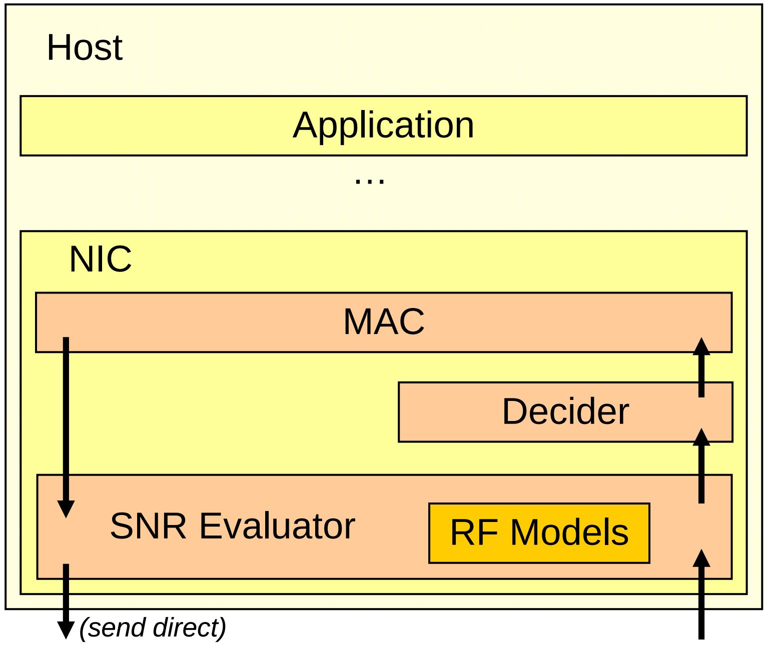
- Newly included models
  - Log Normal Shadowing
  - Rayleigh
  - Rice
  - Nakagami $\Pr_{Nak}(d;m) \sim Gamma\left(m, \frac{\Pr_{\det}(d)}{m}\right)$

[Nakagami1960] [Rappaport1996]

Integration into Mobility Framework

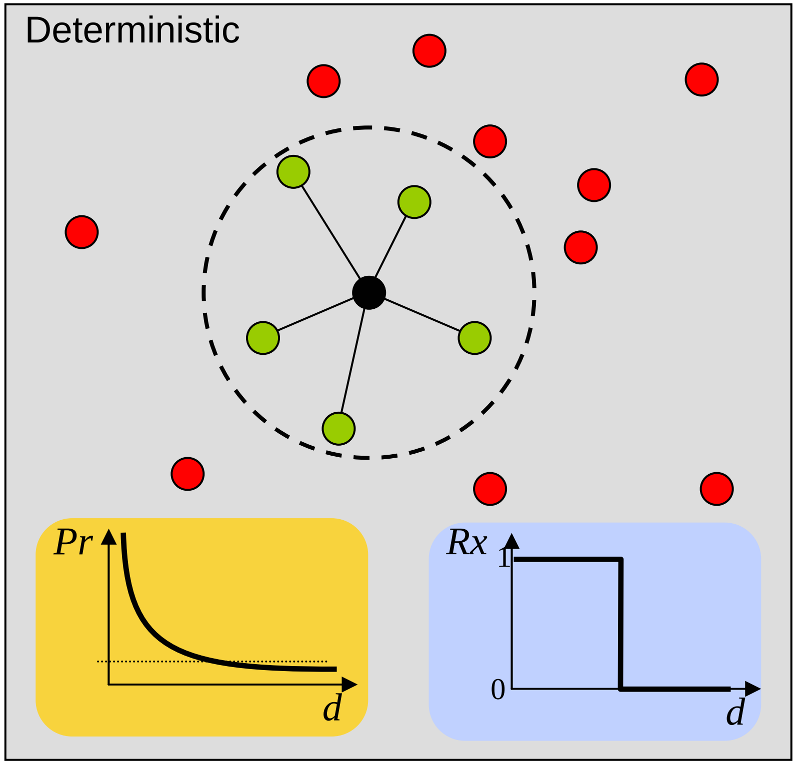
- Only ‚connected' nodes receive events
  - Channel Control cares about connections
  - Needs access to the RF module
- Calculate Pr(d) on each message arrival
  - RF Models needed in host module
  - SNREval keeps track of SNIR



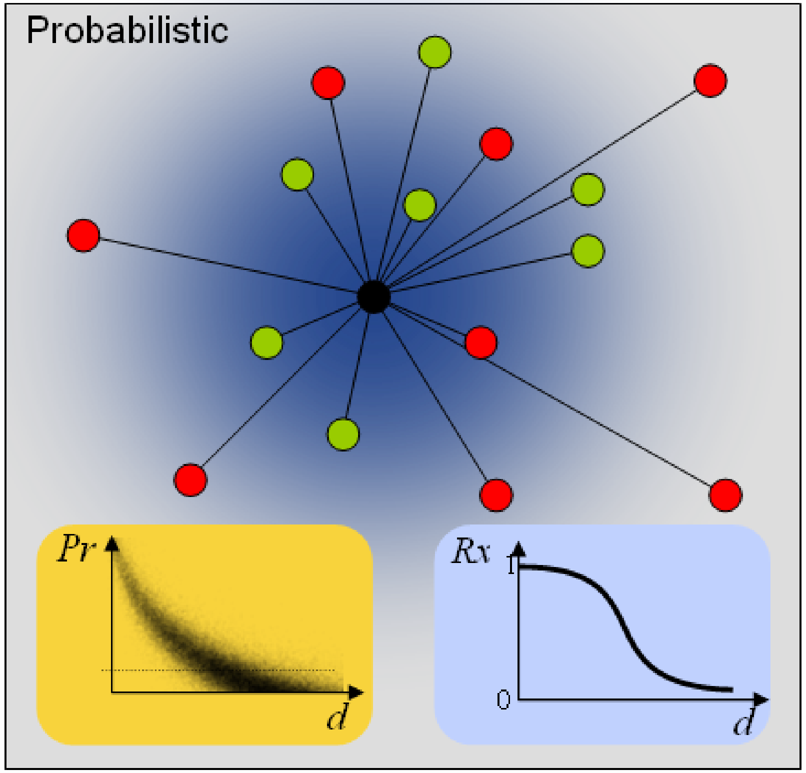


Consequences

- Rx Probability = {0, 1}
- Relevant events in max propagation distance
- $cost_{tx}$ ~ #nodes in ‘circle‘



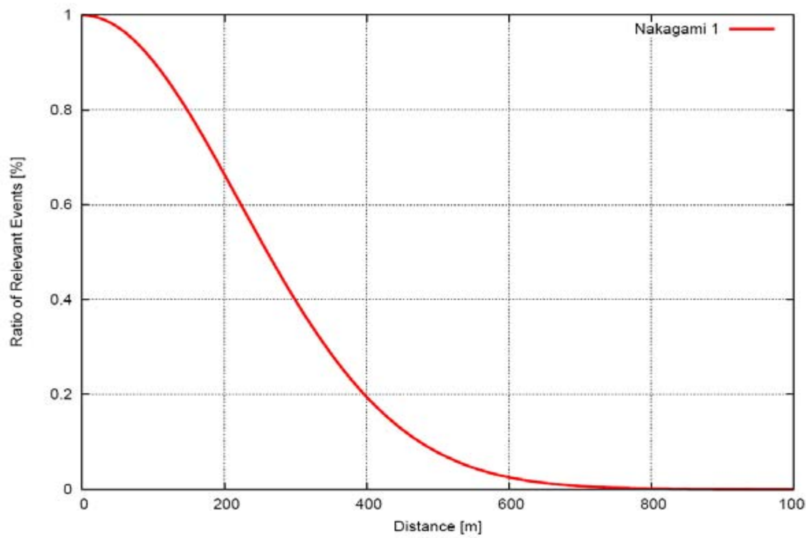
- Rx Probability != 0
- All events may be relevant
- All nodes have to be informed
- $cost_{tx}$ ~ #nodes in scenario



Tradeoff Accuracy vs. Speed

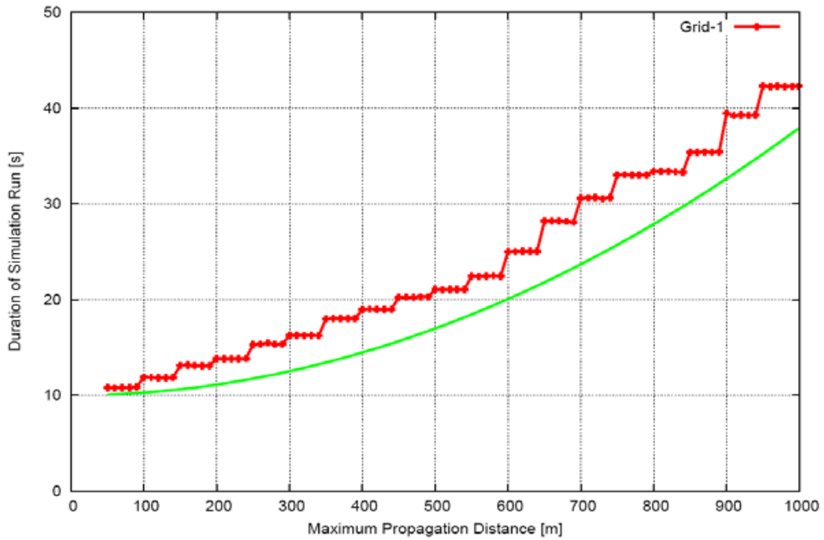
- Max propagation distance (MPD) is tradeoff parameter
  - Accuracy vs. speed of simulation
  - Large MPD ➔ slow but accurate simulation
  - Small MPD ➔ fast but inaccurate simulation

Relevance



Probability of relevant event wrt/ distance

Duration



Duration of simulation wrt/ MPD

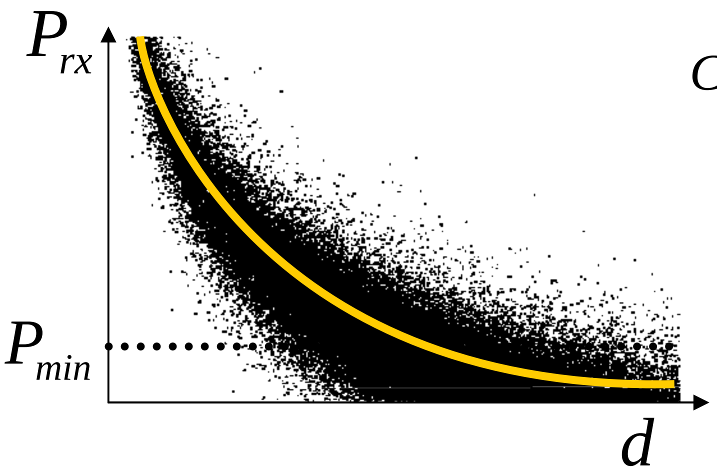
How to determine MPD (sketch)

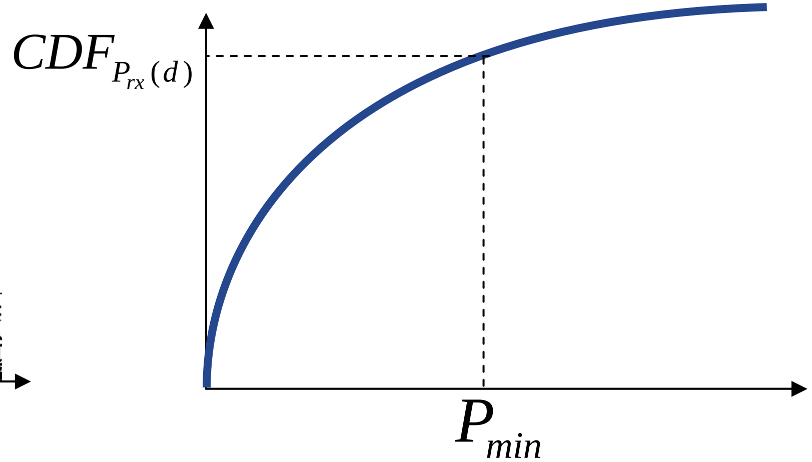
- Track one single event
- Node's goal
  - receive all relevant events
- Relevant event
  - $P_{rx}(d) > P_{min}$
- For which distance d holds:
  - Prob(relevant evt) < accuracy
  - $Prob(P_{rx}(d) > P_{min}) < accuracy$
- $P_{rx}(d)$ ~ probability distribution
- Cumulative densitiy function

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

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

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

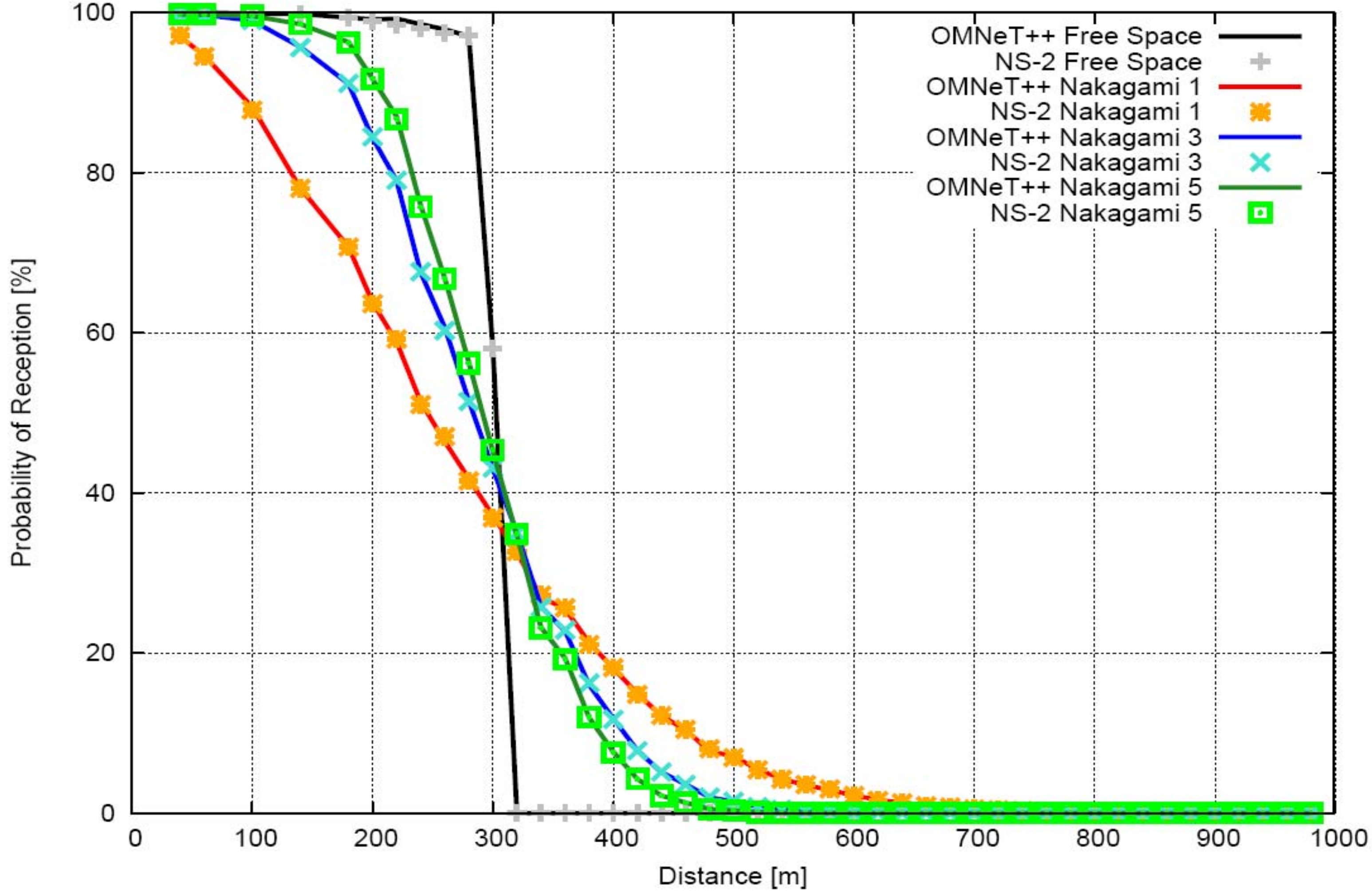




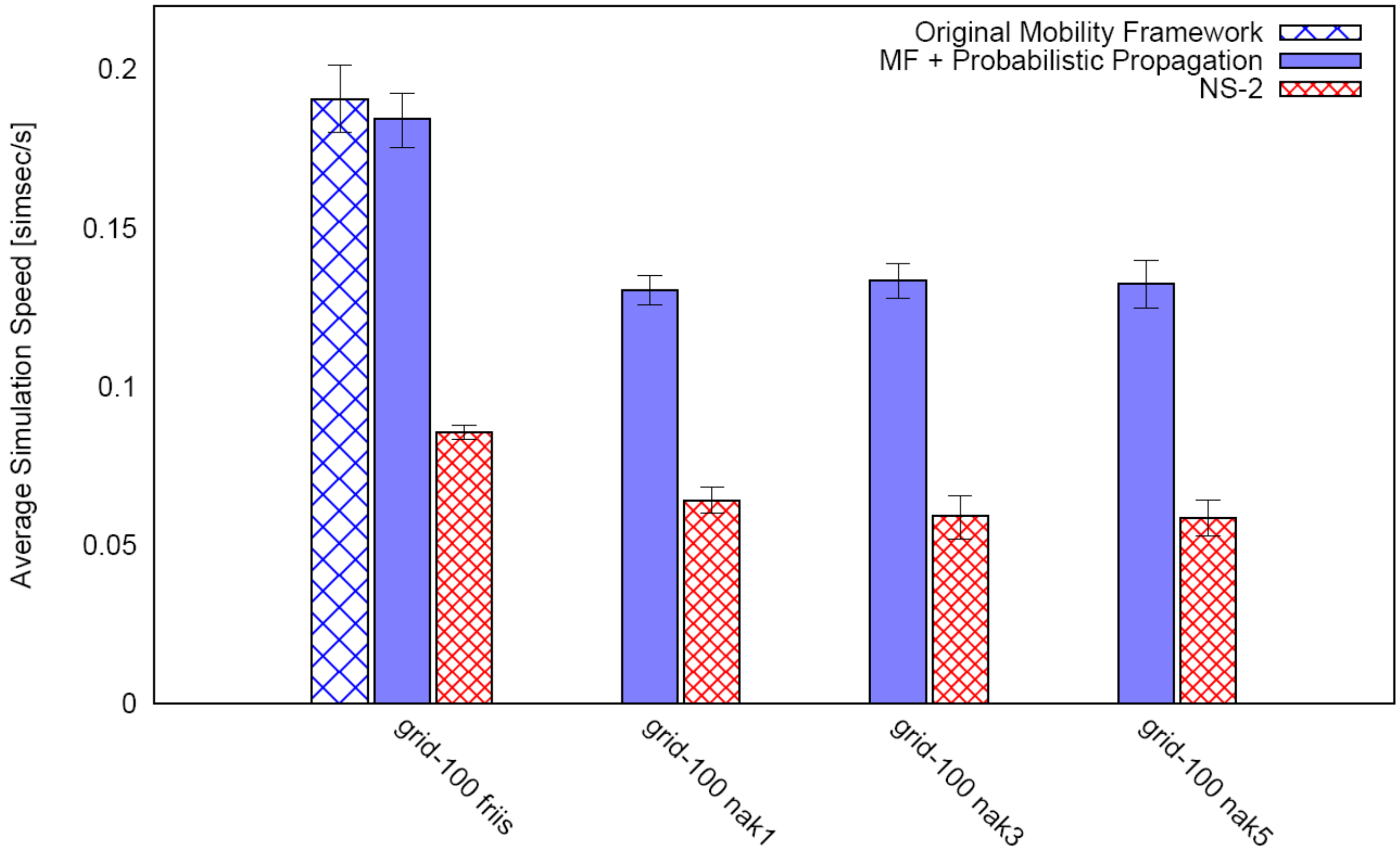
Simulation setup

- 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

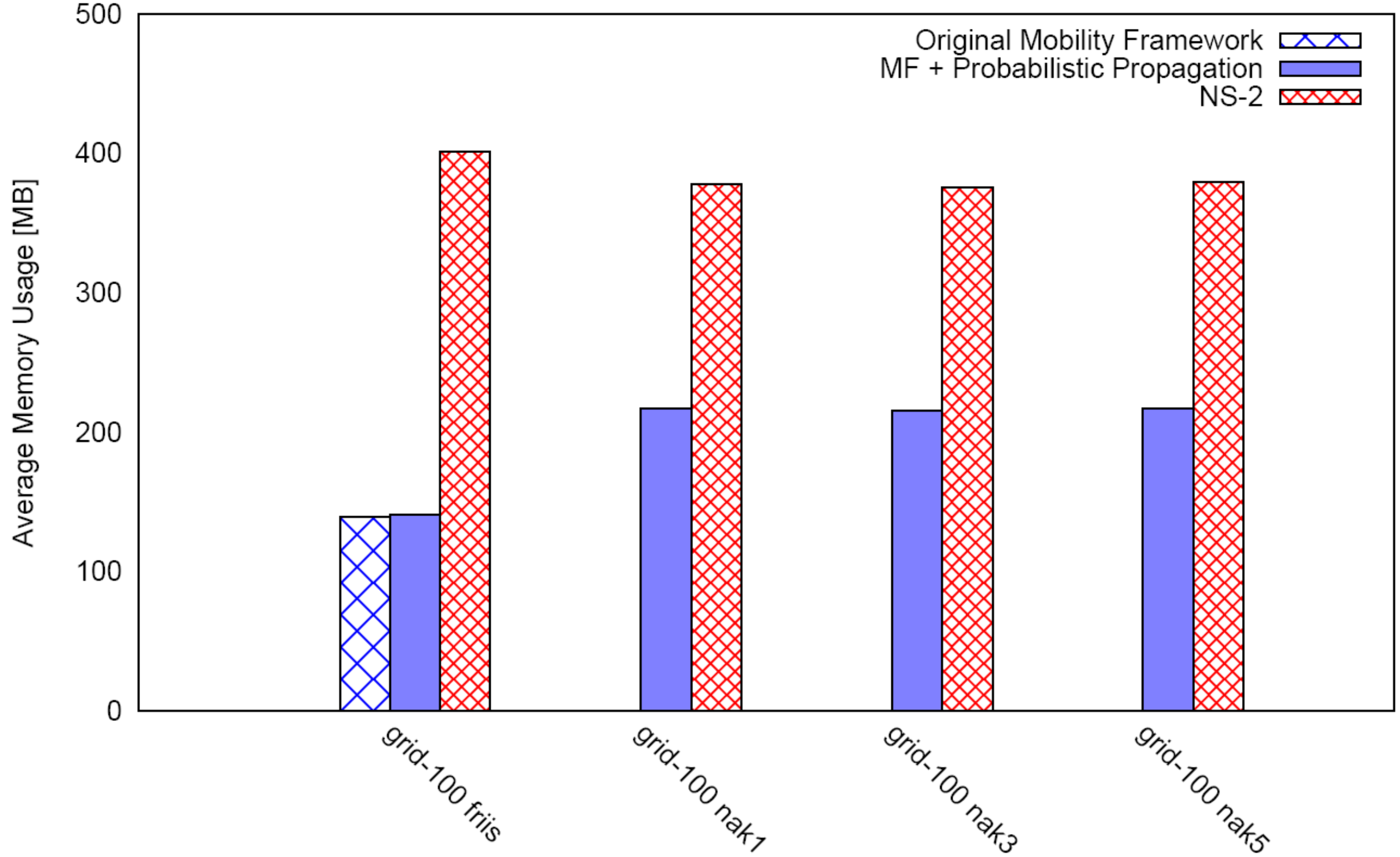


Performance Evaluation Speed



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

Performance Evaluation Memory



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

Summary and Outlook

- 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)

Literature

- [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