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On The Accuracy of IEEE 802.11g Wireless LAN Simulations Using OMNeT++

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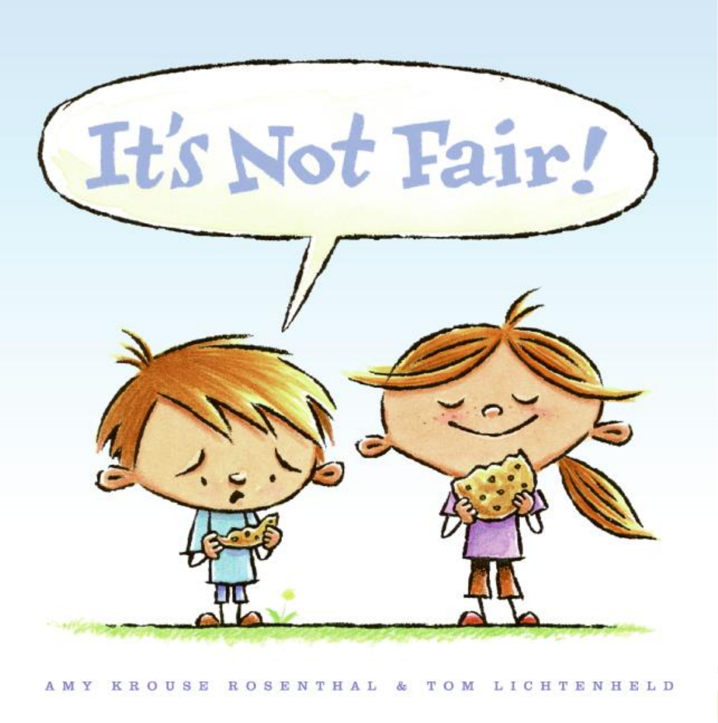
Motivation

- QoS and fairness evaluation in wireless networks
- Network measurements in the field of wireless networks
- Modeling of 802.11 DCF for Probabilistic Network Calculus
- Need for rare event simulations

What simulator is best ??



Outline

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- Motivation
- Background
  - IEEE 802.11 DCF random access procedure
  - Multiple access and inter-transmissions
- Measurement setup
- Measurements & Results
- Conclusions and future work

IEEE 802.11 DCF random access procedure

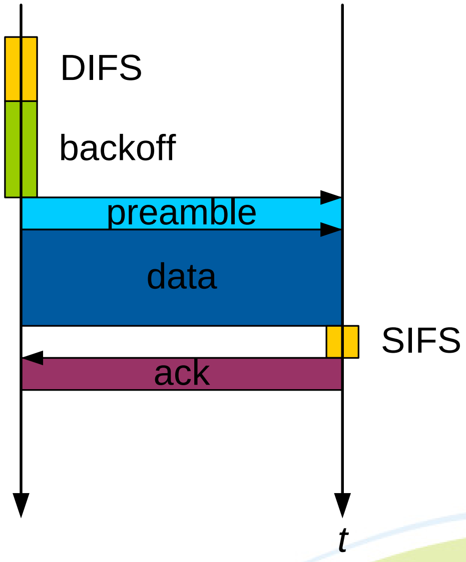
Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA)

Per-packet channel idle times

- Distributed Inter-Frame Space (DIFS)
- Random backoff duration
- Short Inter-Frame Space (SIFS)

Per-packet protocol overhead

- Preamble
- Acknowledgements

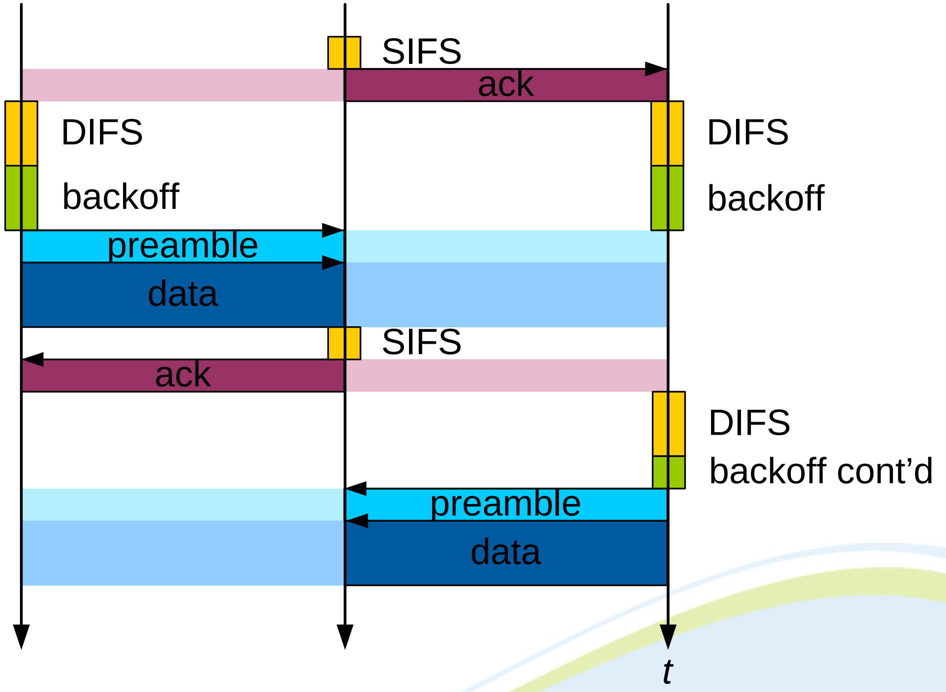


In case of IEEE 802.11g with 54 Mbps nominal capacity the attainable throughput with 1500 Byte packets is only 28 Mbps.

Multiple access and inter-transmissions

Countdown procedures at different stations are carried out simultaneously

- the station with the smallest backoff value finishes the countdown procedure first and transmits its packet
- other stations pause their countdown procedure and resume it afterwards
- each packet can be assigned one DIFS, SIFS, preamble, and ack.



If two or more stations start transmitting at the same time a collision occurs.

Multiple access and inter-transmissions

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Given a tagged stations transmits l packets we count the number of inter-transmissions by all other stations K

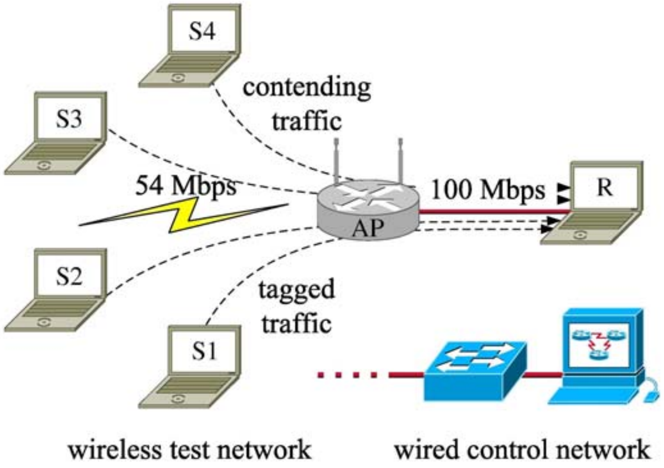
- Example: given station A and B transmitting at full speed may lead to the following packet order: a a b b a a b a b a b …..

Extending the model provided by Berger-Sabatel et al. [IEEE GLOBECOM, 2004], we can derive the conditional probability that a contending station (index 1) transmits k packets given a tagged station (index 2) transmits l packets

$$\mathrm{P}[K = k|l] = \mathrm{P}\left[\sum_{j=1}^{k} b_1(j) \leq \sum_{j=1}^{l} b_2(j) \quad \text{and} \quad \sum_{j=1}^{k+1} b_1(j) > \sum_{j=1}^{l} b_2(j)\right]$$

where $b_i(j)$ are i.i.d. backoff random numbers generated for packet j at station i.

Measurement setup

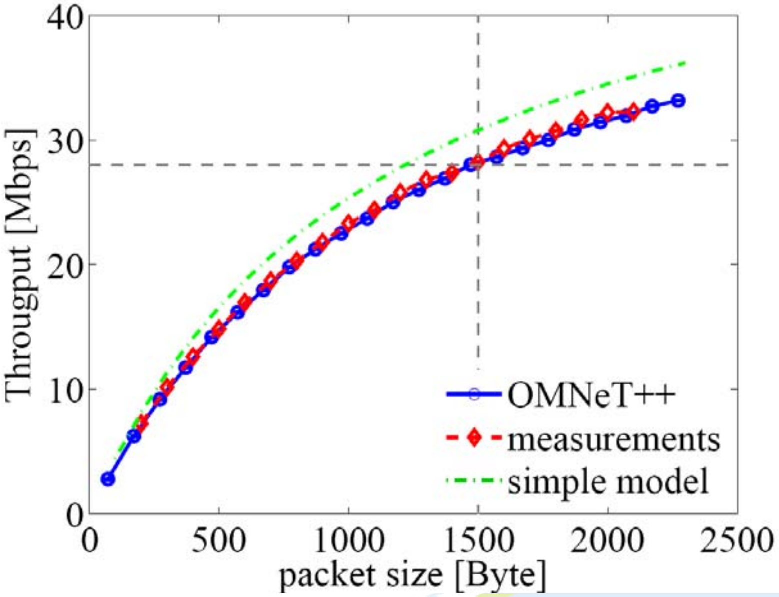


- Our measurement testbed is located in a shielded and anechoic room
- External influences are avoided, hence all contending stations are controlled
- All stations are connected to a separate wired control network
- Experiments are automated by script files (SSHLauncher, Python) and executed repeatedly for statistical analysis

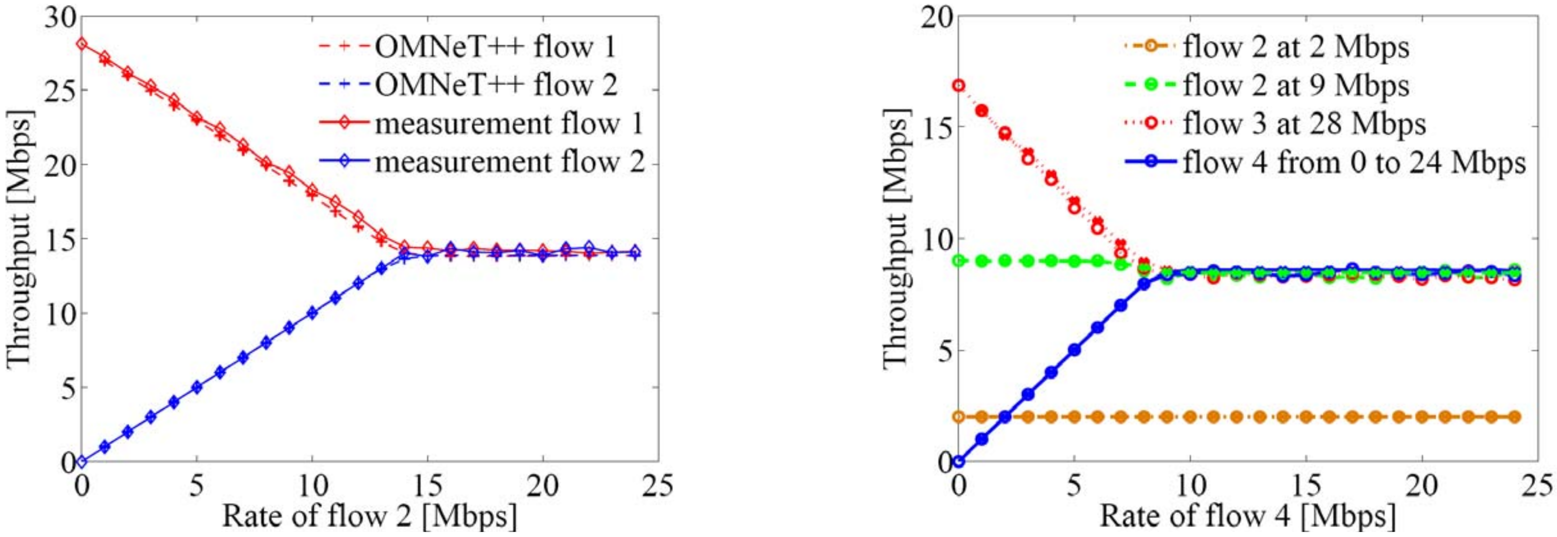
Protocol overhead

According to the protocol overhead, the achievable throughput in IEEE 802.11 strongly depends on the packet size.

- One station sending at full speed
- 25 Experiments
- 60 seconds for each experiment
- Confidence intervals are negligible at a confidence level of 0.95

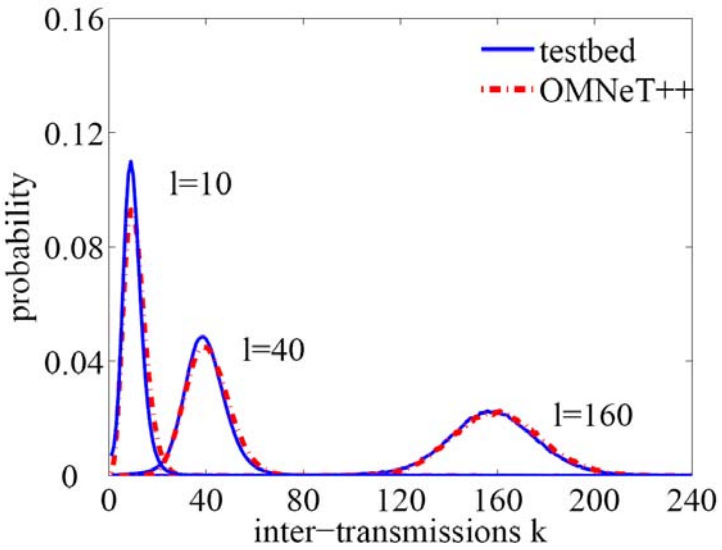


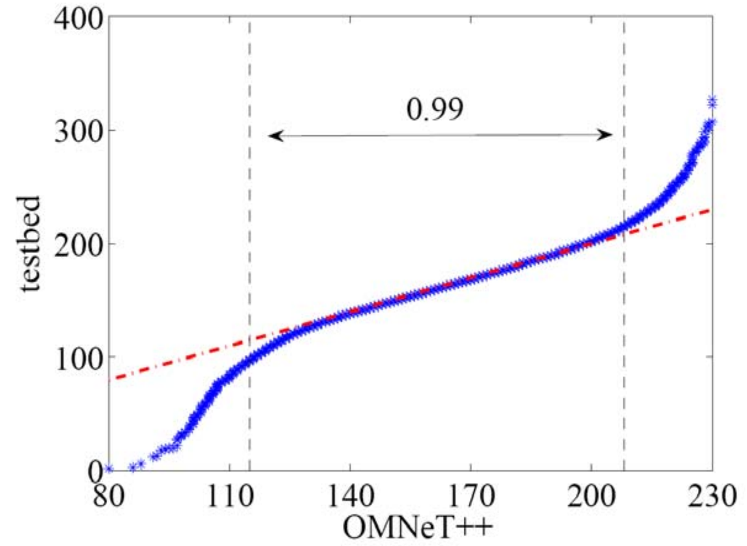
Long-term fairness



- Two, respectively four contending stations
- Packetsize of 1500 Byte
- 25 Experiments
- 60 seconds for each experiment
- Confidence intervals are negligible at a confidence level of 0.95

Packet intertransmissions

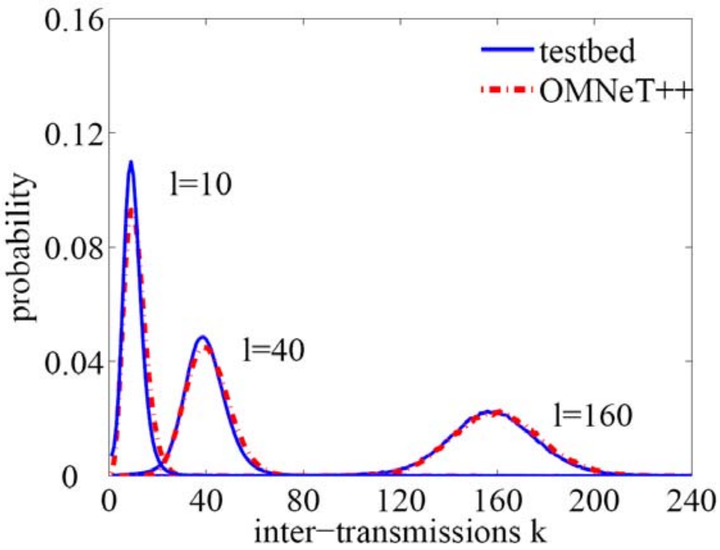


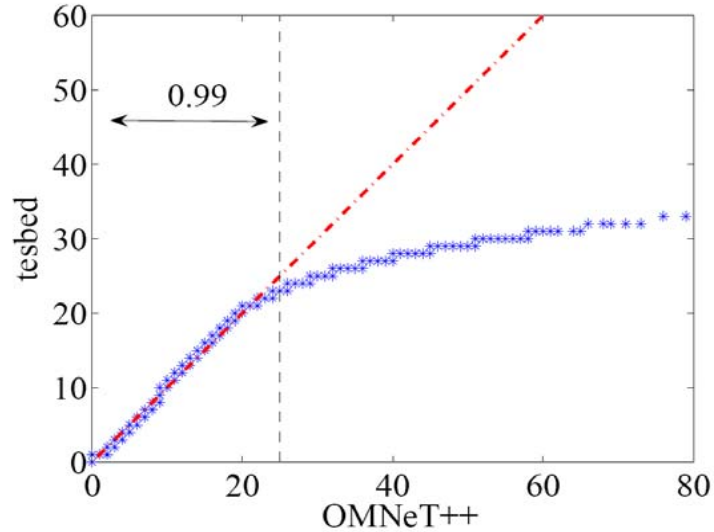


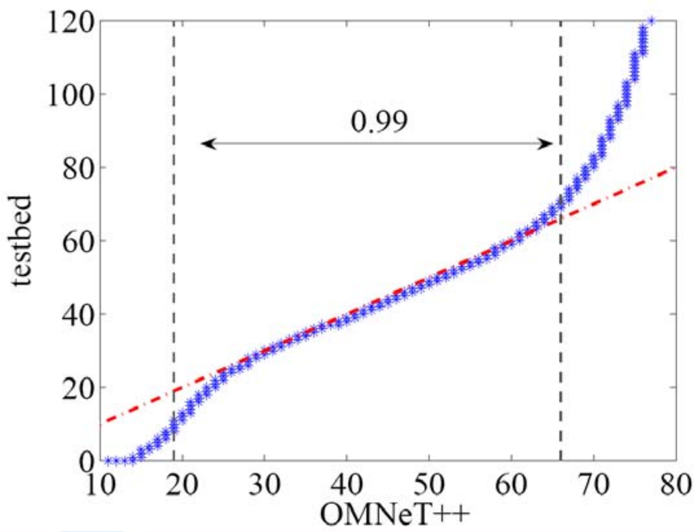
We count the inter-transmissions of two stations for comparison

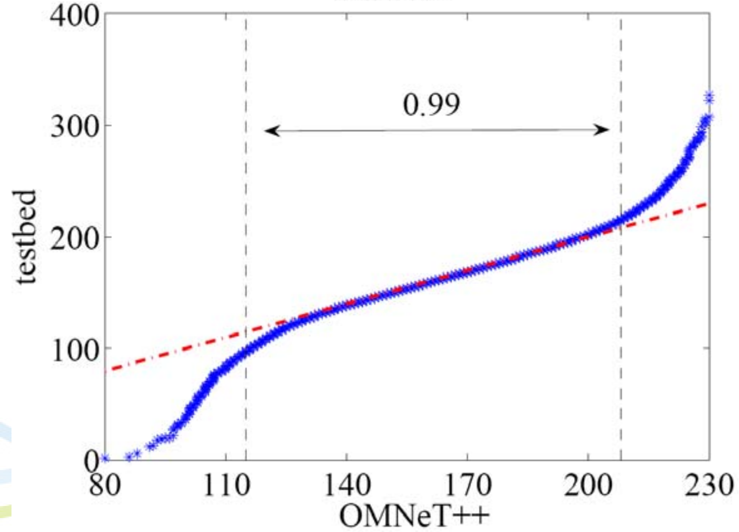
- The mass functions coincide almost with the testbed results
- q-q plots (l = 160) bring out the differences at the tail end of the distribution
  - 0.99 of the samples match well
  - At the tail end the testbed exhibits additional unfairness beyond OmNet++

Packet intertransmissions

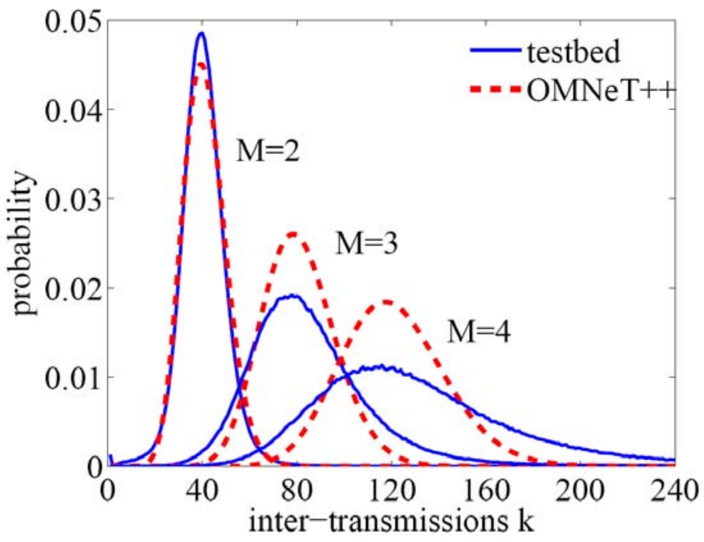


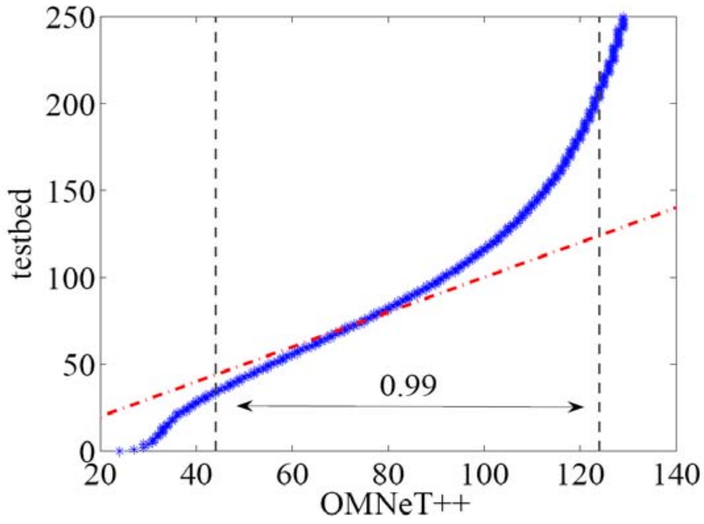






Packet inter-transmissions

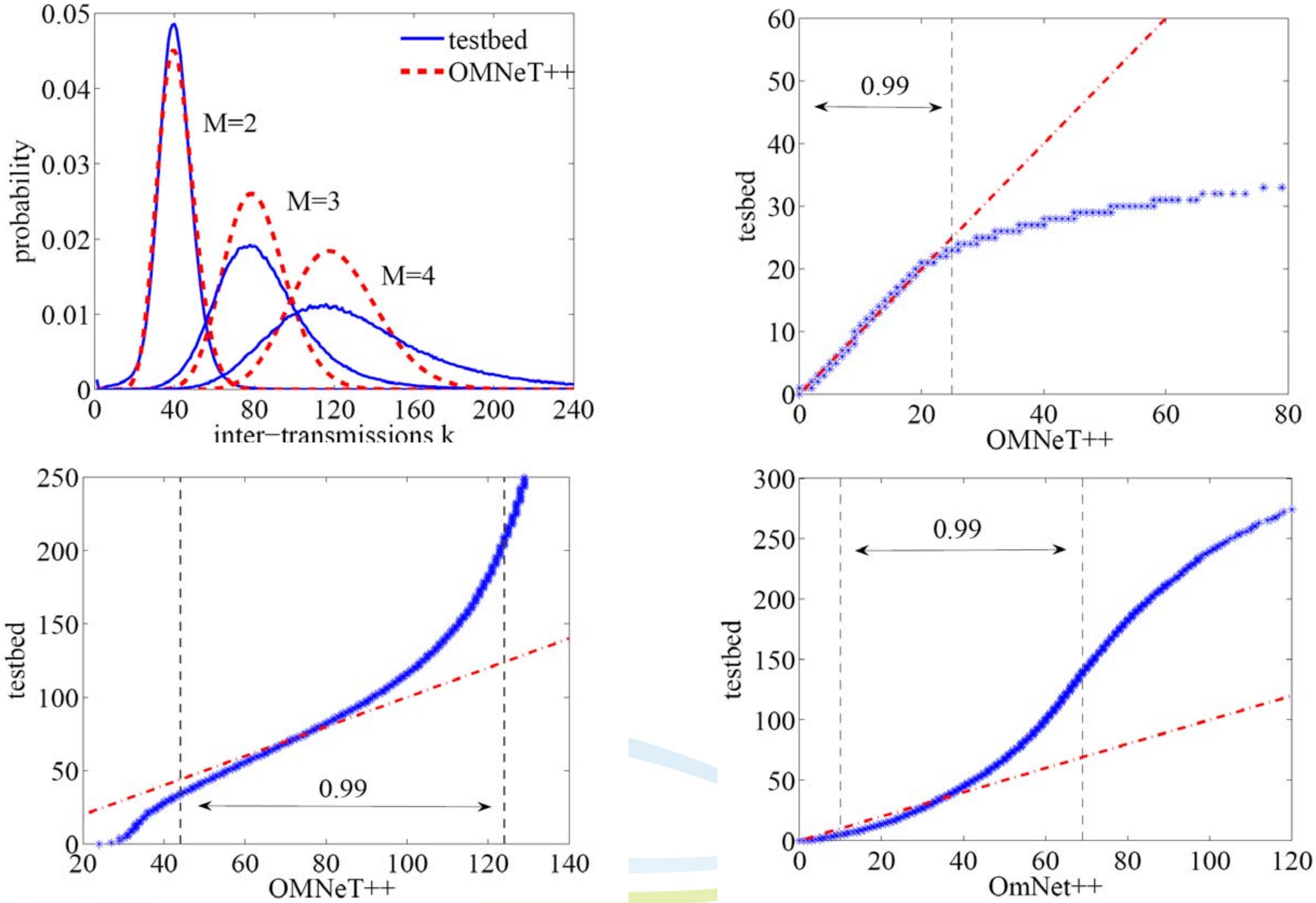




We count the inter-transmissions of two and more stations for comparison

- The mass function for two stations coincide almost with the testbed results, but differs for more than two stations
- q-q plots (M = 3) bring out the differences at the tail end of the distribution
  - At the tail end the testbed exhibits additional unfairness beyond OmNet++
  - The testbed exhibits additional unfairness for M > 2

Packet inter-transmissions



Conclusions and future work

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- We demonstrated that OMNeT++ works almost perfectly
  - OMNeT++ proved correct for averages over time
  - OMNeT++ predicts the majority of the samples correctly
  - Some inaccuracies regarding the distribution of inter-transmissions, hence fairness, especially for the more-than-two-node case

- Future work
  - OMNeT++ - Code review with respect to the 802.11 standard
  - Rerun the real-world experiments using different hardware
  - Develop and provide a standardized validation method for basic network functionalities, e.g. 802.11 DCF

Questions

Thank you very much for your attention …

Questions ??

Acknowledgements

- M. Bredel and M. Fidler: Understanding Fairness and its Impact on Quality of Service in IEEE 802.11. Technical report, arXiv:0808.3937v1, August 2008.
- I M. Bredel and M. Fidler: A Measurement Study of Bandwidth Estimation in IEEE 802.11 Wireless LANs using the DCF. Proceedings of IFIP Networking, Springer LNCS 4982, pp. 314 - 325, May 2008.

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