Experimental Validation of the ns-2 Wireless Model using Simulation, Emulation, and Real Network

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- Scientific contribution
  - Building a model from a real network
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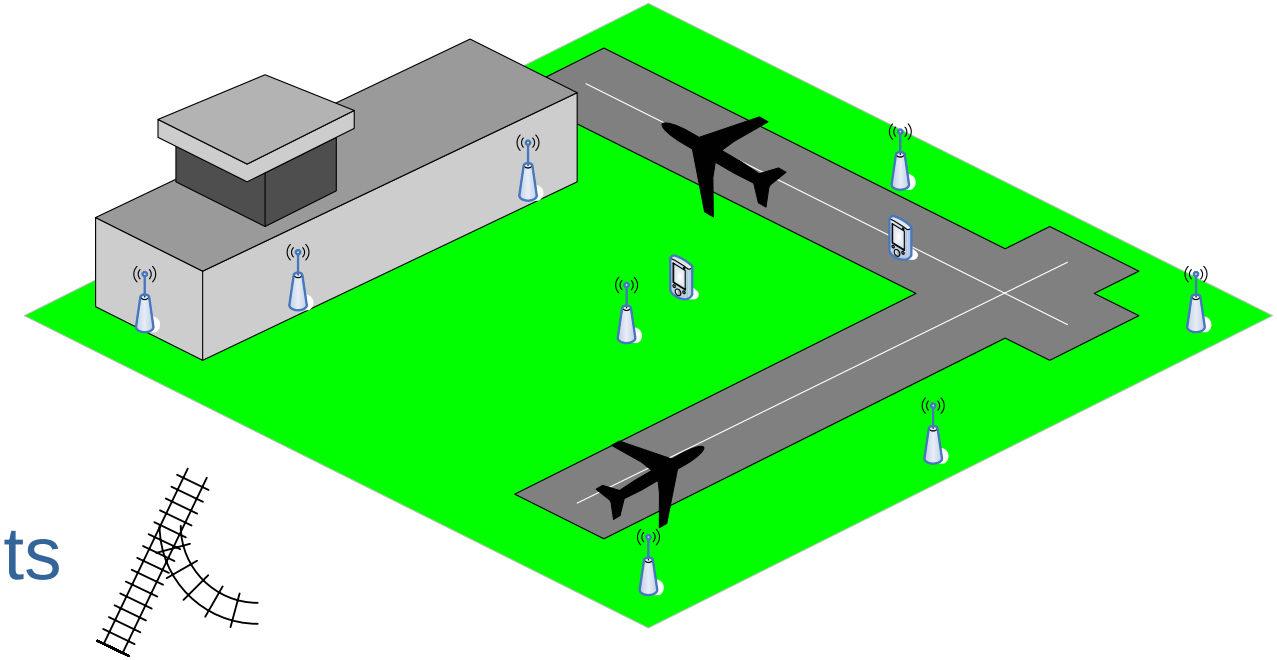
Application scenario

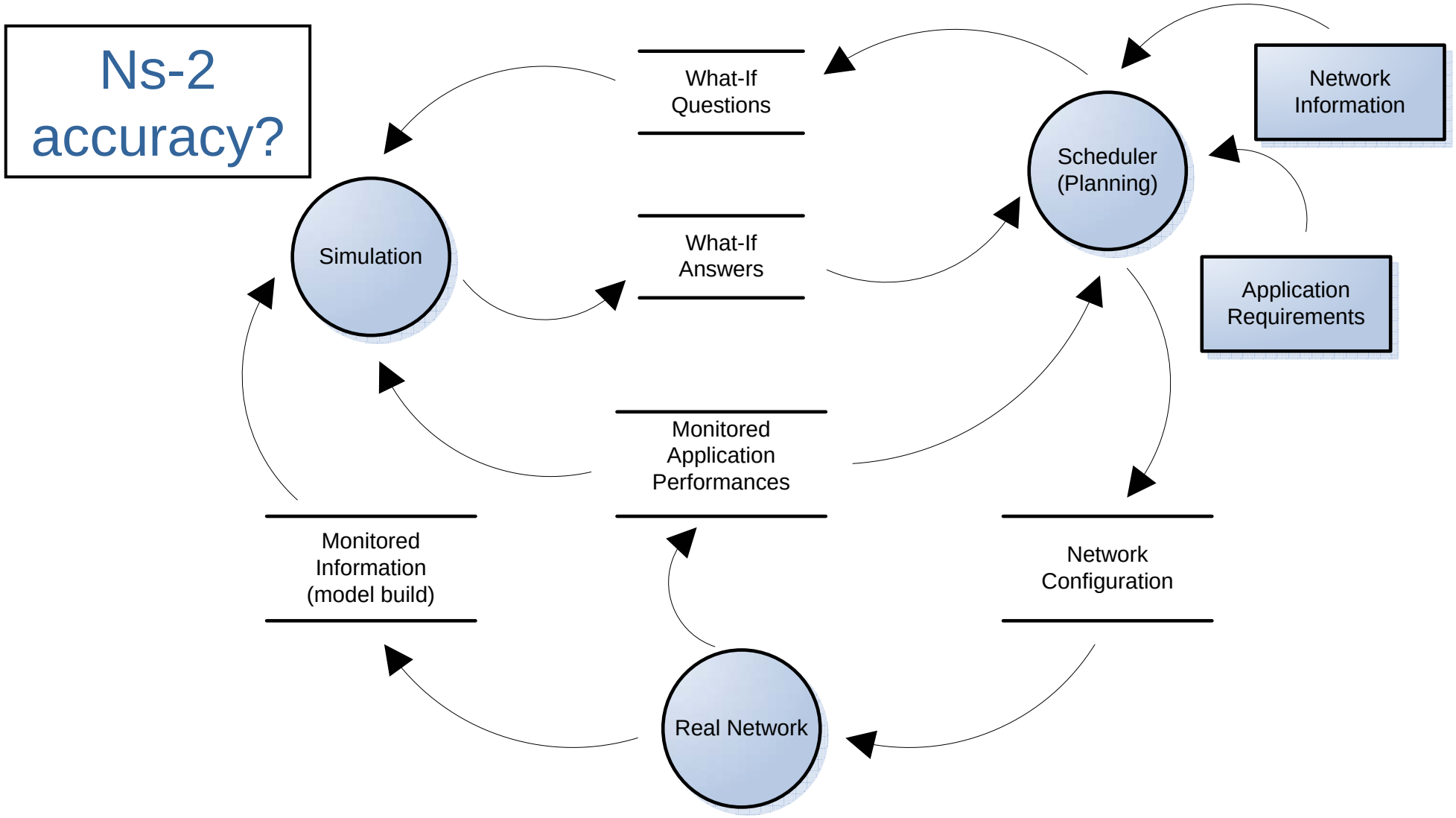
- Network needs
  - Coordination
  - Task scheduling / reporting
- Existing network
  - Wireless 802.11
  - Heterogenous
- Network requirements
  - Reliability
  - Quality of service
- Quality measures
  - Coverage
  - Latency
  - Packet drop



Wireless network: disadvantages

- Will the requirements be fulfilled?
  - After hardware change (mobile nodes/APs)
  - After software change (new application)
- Difficult question due to *unpredictability*
  - Signal fluctuations
  - Unknown topologies (communication / carrier sense)
  - Randomness in the CSMA method
  - Multiple use of bandwidth (mesh part)

Reality-driven simulation approach



Problem exposition

- What is the accuracy of ns-2?
  - How much do the application layer performances differ from reality?
  - Various simulation studies exist
  - Few real-world comparisons are available
- Importance (in our case)
  - Simulation results are used for real-world planning decisions

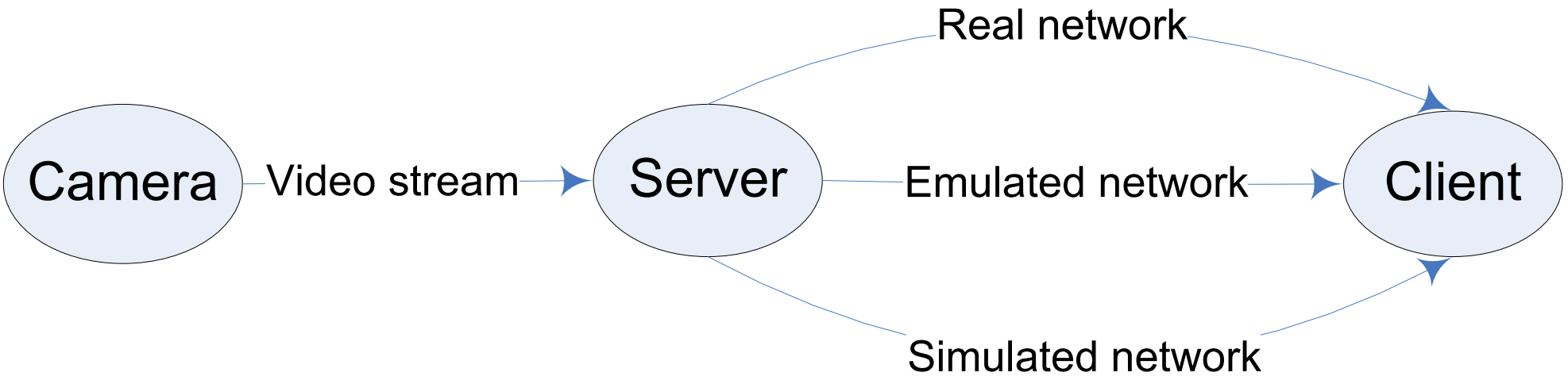
  => A level of consistency is required

Approach / contribution

- Network / Model building
  - Build typical wireless network (802.11g mesh)
  - Build manually a model (ns-2) of the real network
- Choose application-relevant quality measures
  - Topology mapping
  - Network latency
  - Packet delivery ratio
- Calibrate the model to the network
- Measure application performances (model, reality)
- Present results / differences

Experimental method

- Static network for the following reasons:
  - Start simple and add complexity incrementally
  - Mobility modelling adds additional error



Model building

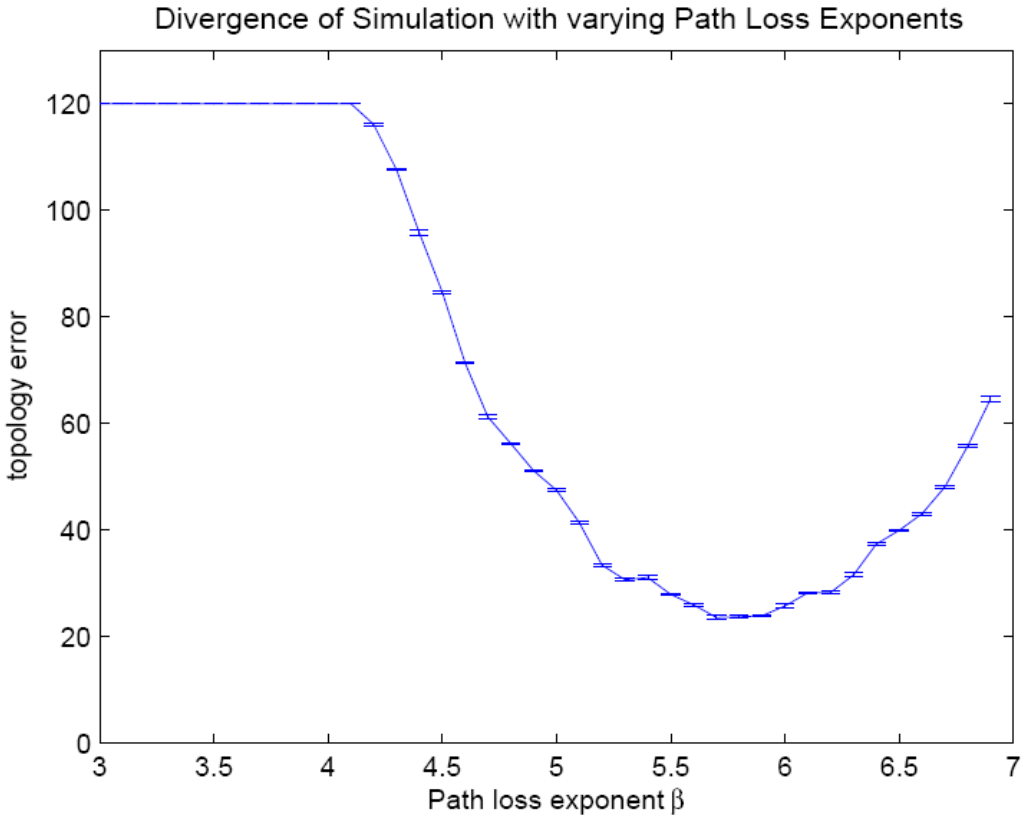
- Physical layer
  - The shadowing model of ns-2
  - Models large scale and small scale effects
- Data link layer
  - Fixed vs. adaptive data rate
  - Used fixed data rate observed from reality
- Routing layer
  - AWDS (Ad-hoc Wireless Distribution System – similar to OLSR)
  - Same implementation in ns-2 and reality (GEA)
- Application layer
  - Video streaming

Model calibration

- Ns-2 shadowing model

$$P(d) = P(d_0) - 10 * \beta * \log(\frac{d}{d_0}) - \mathrm{X}_\sigma$$

- Calibrate radio coverage
  - Path-loss exponent
  - Effect on upper layers
  - Local minimum is the optimal value



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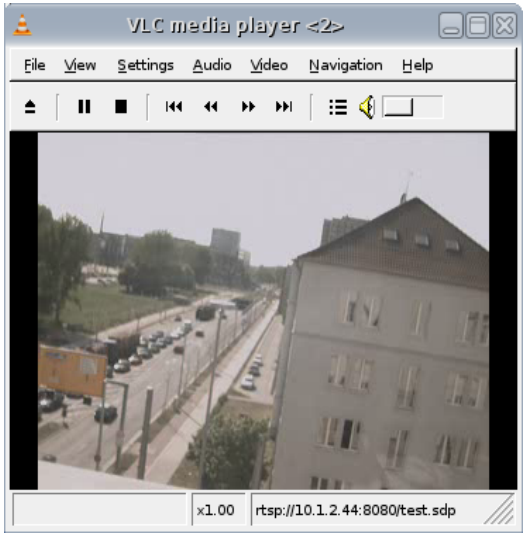
Experimental parameters/details

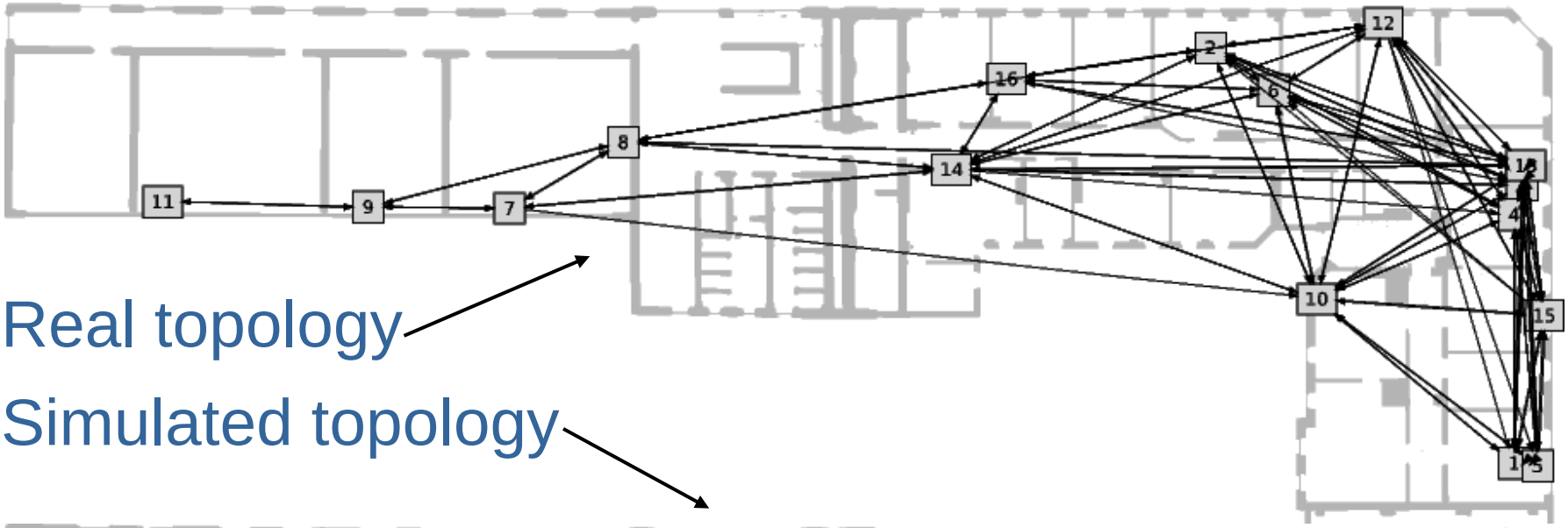
- Topology
  - Nodes: 14-16, hops: 1-4
  - Indoor environment
- Application load
  - 2-3 min streaming -> 2500-4000 packets
  - Packet-by-packet in the simulation
- Used hardware/software
  - Modified APs (embedded Linux)
  - Web camera
  - Laptops as end stations
  - VLC video streaming software



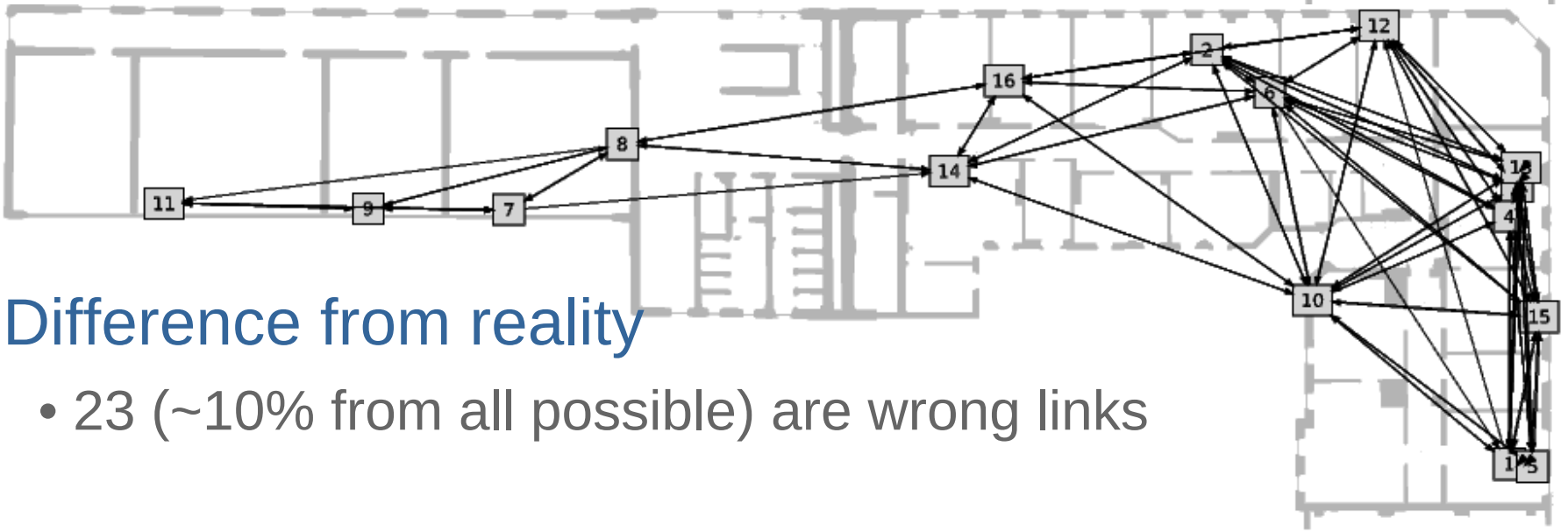
Measurement methods

- Coverage
  - Similarity of network topologies
  - Information from routing layer state
- Packet latency
  - Packet dump for transmission/arrival timestamp
  - Identical data stream (Gigabit Ethernet) for reference
- Packet delivery ratio
  - Derived from packet dumps

Results: network topologies



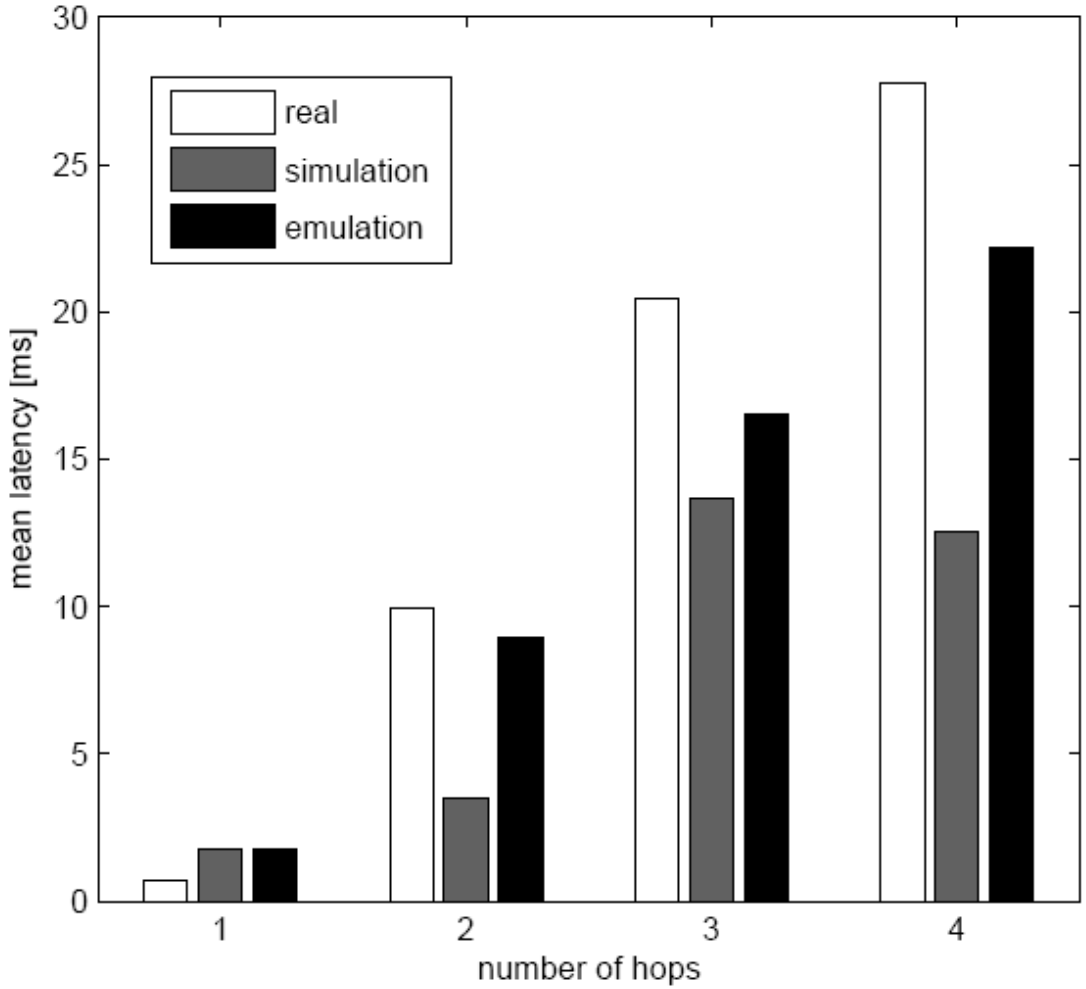
- Real topology
- Simulated topology



- Difference from reality
  - 23 (~10% from all possible) are wrong links

Results: network Latencies

- Difference from reality
  - 57% from the real latency
- Discrepancy factors
  - Static data rate
  - Runtime delays (OS) not modelled
  - Topology differences



Results: packet delivery ratios

Hop count	Real	Simulation	Emulation
1	100 %	99.70 %	100 %
2	99.86 %	99.74 %	100 %
3	99.86 %	99.78 %	99.80 %
4	98.73 %	99.58 %	99.73 %

- Difference from reality
  - 0…1%
- Reasons for high accuracy
  - Link quality filtering (routing layer)
  - Up to 4 retransmissions on the unicast routing paths

Conclusions

- Condition for realistic simulation
  - Model calibration
- Accuracy depends on measure
  - Delivery ratios: 0…1% difference
  - Coverage / topologies: 10% difference
  - Network latency: 57% difference
- Additional investigations for more accurate simulations
  - Use of non-homogenous fading models
  - Use dynamic data rate models

Outlook

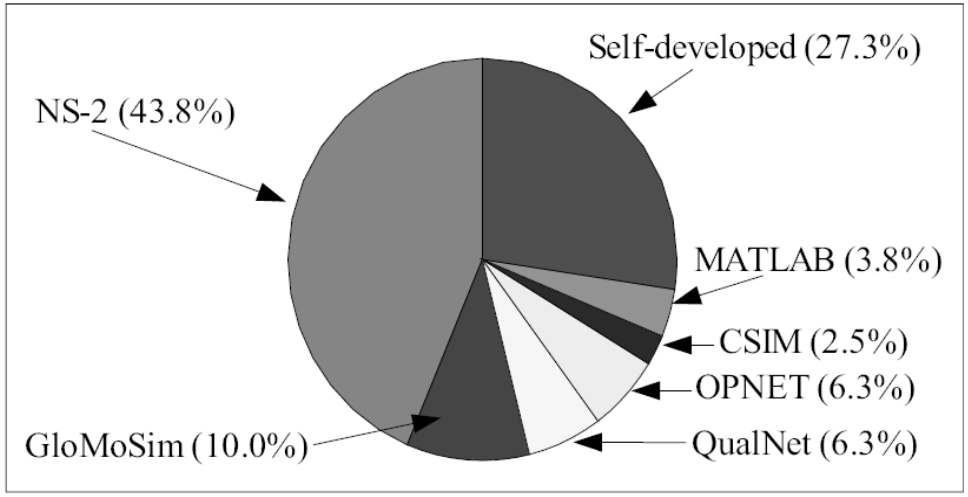
- Feedback-controlled Simulation model
  - Start with physical layer
  - Add upper layers
  - Ns-2, Ns-3, vs. OPNET Modeler?
- Applications
  - Wireless network coverage planning
  - Automated WLAN Localization
  - Reliability and QoS planning

Thank you!

Questions

Network simulation usage

- Wireless network simulation is widely used*
  - Survey of MANET research
  - 151 papers from ACM MobiCom 2000-2005
  - 76% use simulation
- Used simulation tools



* Source: Kurkowski, “MANET simulation studies: the incredibles”, ACM SIGMOBILE Mobile Computing and Communications Review, vol. 9, 2005.

Experimental setup (detail)