Approaches for Evaluating the Application Performance of Future Mobile Networks

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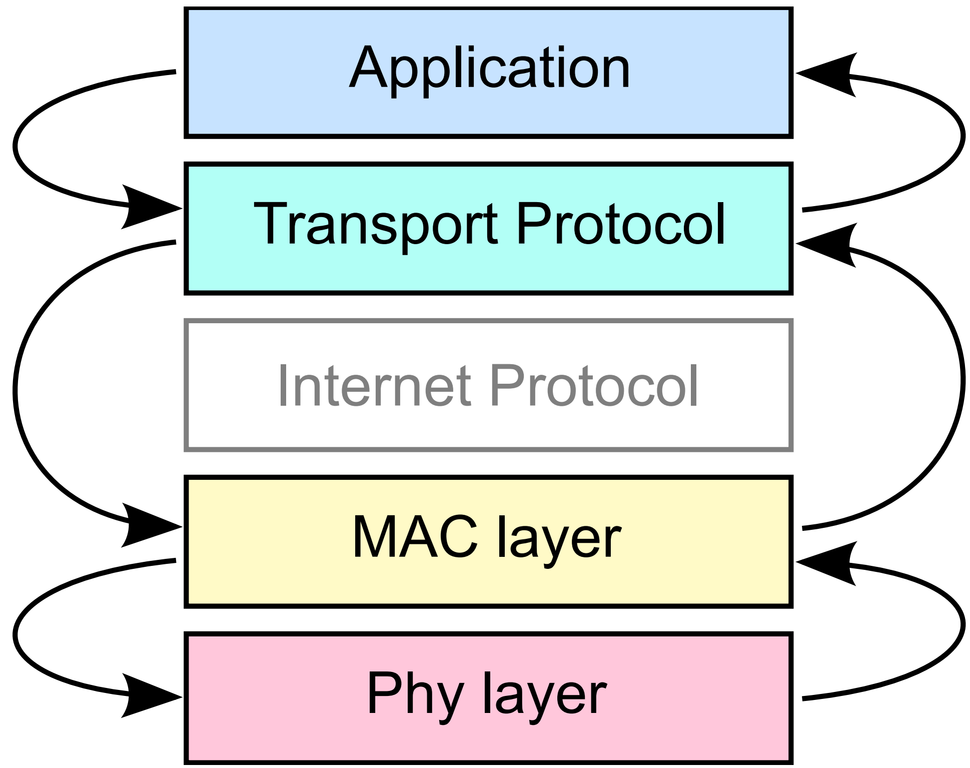
Motivation



Subject of evaluation

Algorithms and techniques in the Phy and MAC layers

Metric

- Achievable application performance
- Difficult to derive from average delay & throughput

→ Models required for evaluation

Feedback to lower layers

- Object sizes transmitted by applications
- Effects from parallel TCP connections
- Queues running empty

see also: Muhammad Amir Mehmood, Cigdem Sengul, Nadi Sarrar and Anja Feldmann, 2011, Understanding Cross-Layer Effects on Quality of Experience for Video over NGMN

C. M. Mueller, 2011, Analysis of interactions between Internet data traffic characteristics and Coordinated Multipoint transmission schemes

Problem

Cross-Layer evaluation required

How to bring network simulation
and real world protocols / applications together?

Approaches (1/3)

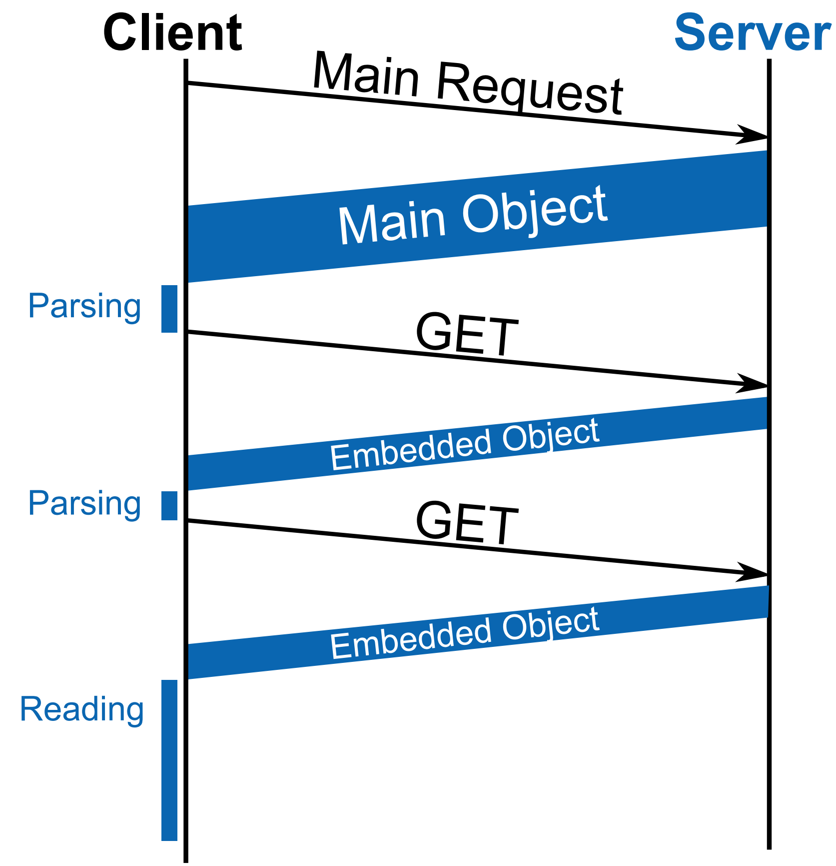
Model all components

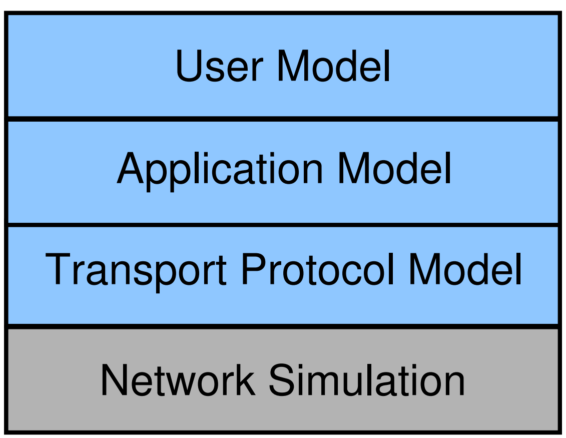
Simulation models for Applications and Transport Protocols

- TCP models:
  various implementations
- Application models:
  e.g. NGMN web model (on the right)

→ complicated algorithms

→ models usually simplified — still realistic?





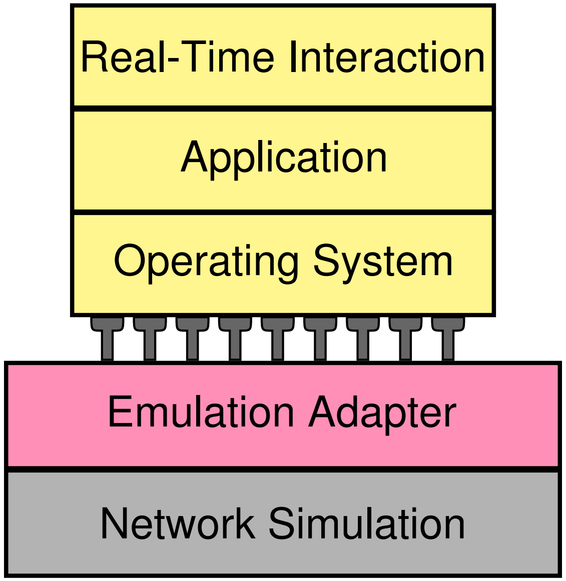
Approaches (2/3)

Bring the network simulation into a lab setup

Real-Time Emulation

- Build up lab setup with real computers
- Connect real network devices to simulated network
- Optionally communicate with the real internet

→ Requires fast (abstract) simulation models



Slowed Emulation

- Decelerate the computers' clock speed to gain time for emulation

→ Requires special setup & synchronization

Approaches (3/3)

Bring real code into the Simulation

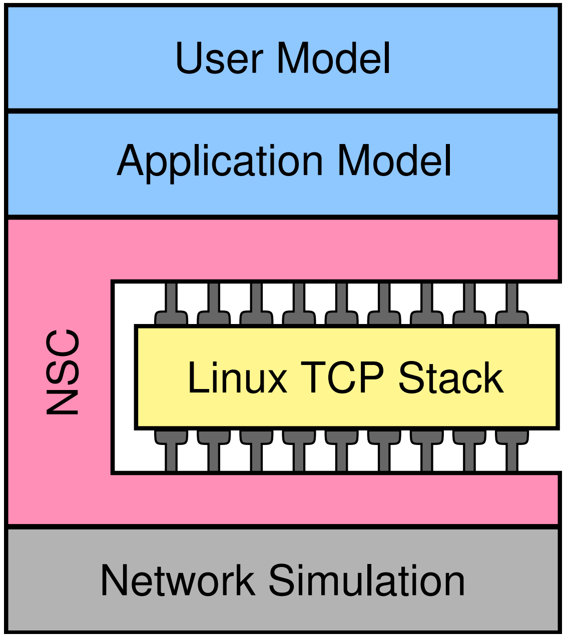
Example: Network simulation cradle

- Linux kernel code is modified by partly automated scripts
- TCP stack can be loaded as shared library into ns-2
- Clocks of the kernel are driven by the simulation

→ Adapts to the speed of the simulation

→ Authentic protocol behavior

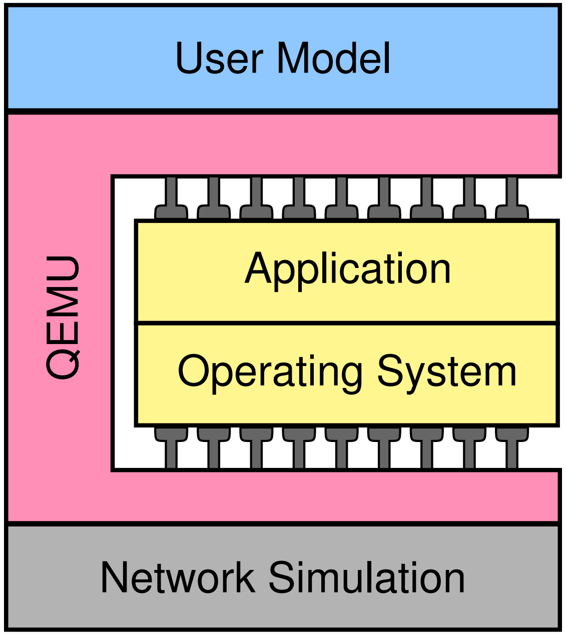
→ The chosen interface makes it difficult to port a new linux kernel



Our Approach

Existing IKR Simulation Ecosystem

- IKR SimLib → fixed network simulation
- IKR RadioLib → radio transmissions (LTE)
- IKR EmuLib → real time emulation
- IKR nscadapter → wrapper for the NSC
- **QEMU simulation adapter**



Main Idea

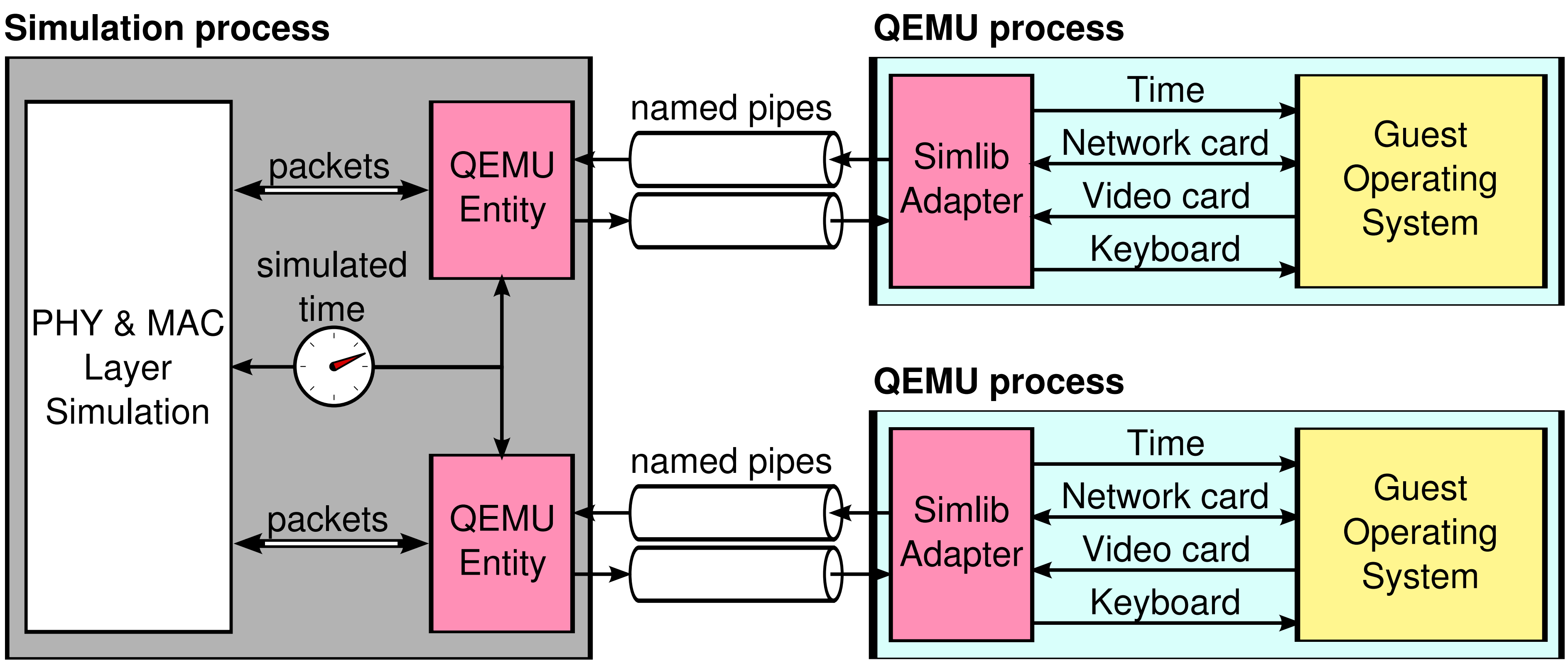
- Use Computer Virtualization as interface between simulation and real code
- Let virtual clock be driven by the simulation

Our ambition

- Easy handling (hundreds of simulations)
- No special requirements for hardware etc.

→ **Possible to perform simulations on a standard computer cluster**

Architecture



→ **Independent processes communicating via pipes**

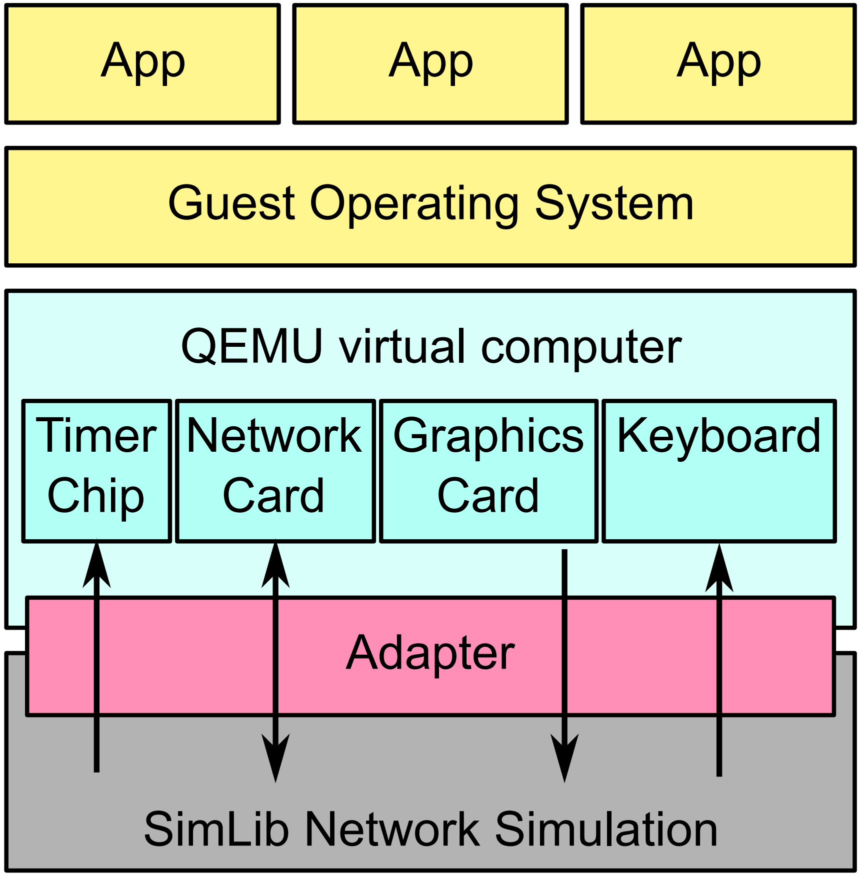
QEMU as interface between Simulation and OS

Virtual Computer as Interface

Operating system and applications
do only see the virtual computer

→ No modifications required

→ Easy to install new applications / OSs



Modifications inside QEMU

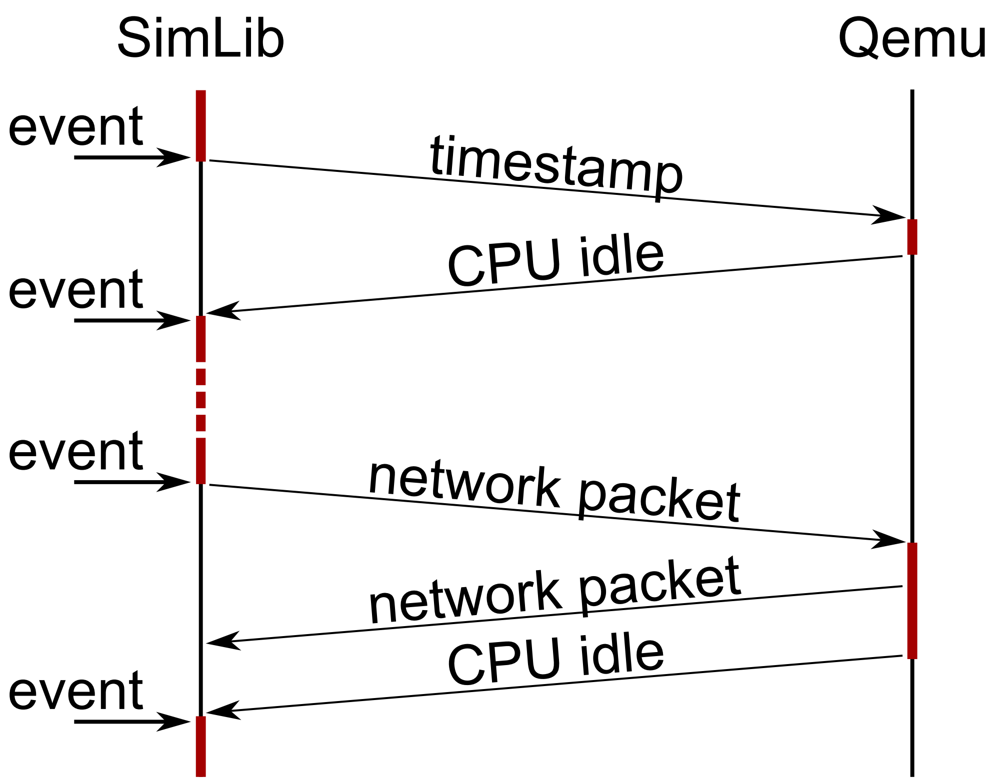
- Layered architecture: QEMU consists of device emulations and backends
- Our adapter provides additional backends, emulation layer remains unchanged
- We have modified the QEMU main loop to support a shared control flow

Control Flow

Interaction of SimLib and QEMU

- Either the simulation or one single QEMU instance executes at a time
- Timer events correspond to events in the simulation calendar
- Calculations inside the virtual computer are performed in zero simulated time

  → follows paradigm of event-driven simulation
- Virtual computer can spend nearly infinite time for computations



→ **Virtual computer is not restricted by host CPU power**

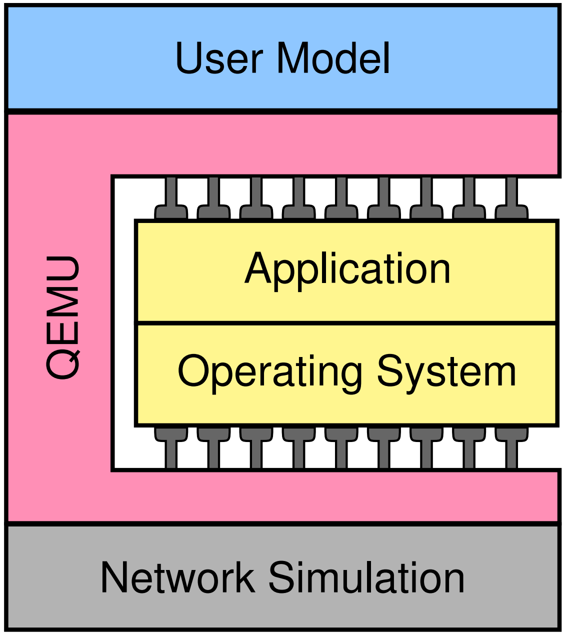
→ **Strictly synchronous interaction**

User Model and Metrics

User Models

- Interactive use not desired and not possible

→ Automatic user models required
(e.g. stochastic reading time)



Subjective Metrics

- Record and play back screencast
- Compare different parametrizations

Objective Metrics

- Automatically analyze screenshots
  (e.g. determine if pixels change)
- Investigate network packets
  (e.g. first and last packet of a TCP session)
- Modify applications to print their state
  in a machine-readable format

Scalability

Memory

- Overhead of emulator and adapter: negligible
- Small operating system without GUI:
  32MB per instance
- Modern operating system with graphical applications:
  at least **512MB per instance**
- Requirements can possibly be reduced
  with Linux Kernel Samepage Merging (KSM)

Processing Power

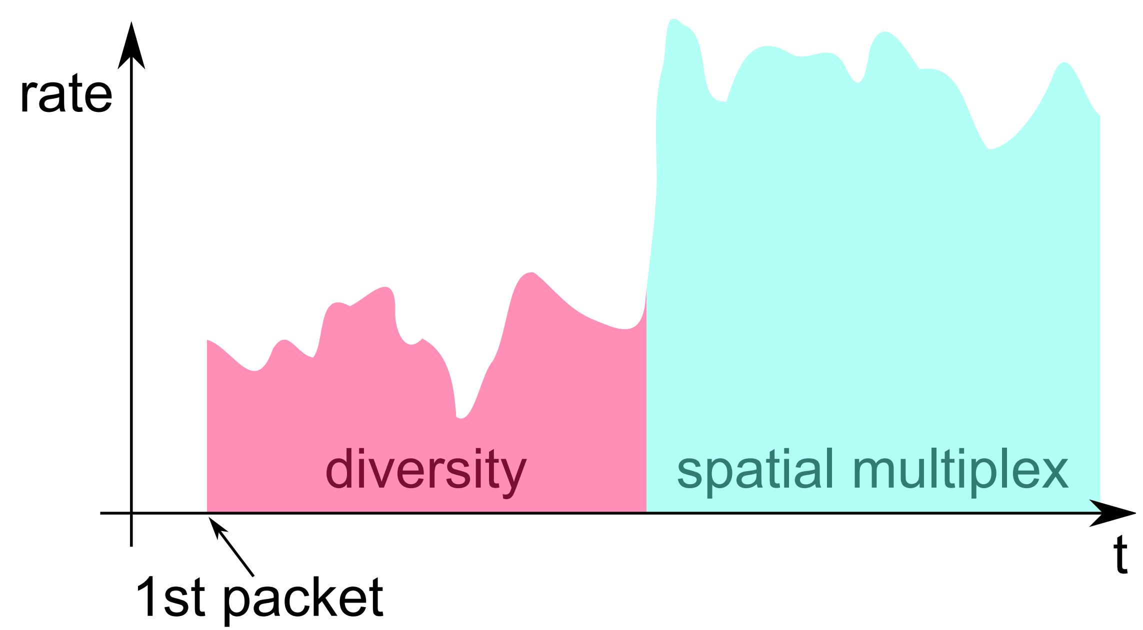
- High CPU load: User space QEMU about factor 10 slower than host computer
  - Example: booting Ubuntu Maverick takes about 15 minutes
- Low CPU load: About factor 10 faster than real time
- Typically no CPU-intensive applications on the virtual computer
- Simulated time spans have to be large to capture the upper layer effects

→ **Complex Phy models become the limiting factor**

Usage Scenarios (1/2)

Link layer evaluation of a complex MIMO setup scheme

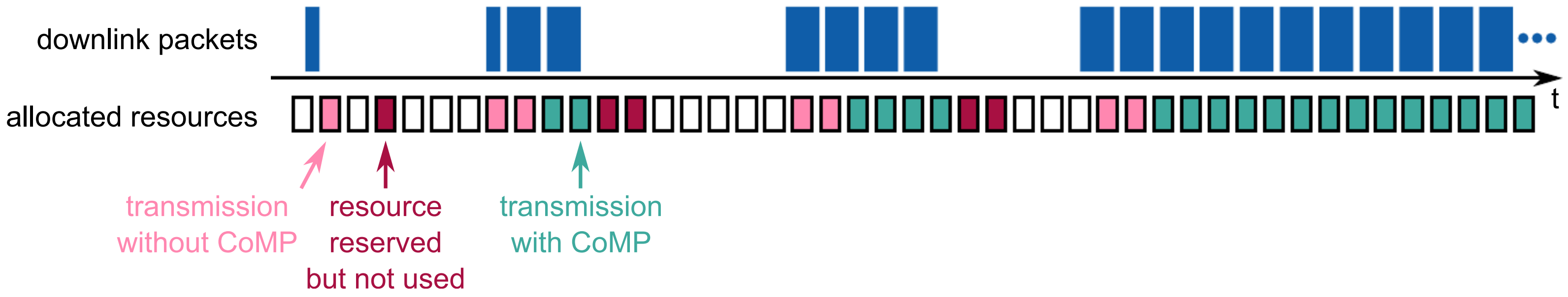
- Focus: Influence of setup time on application performance
- Moderately abstract Phy model
- Application: Web browser loading a single web page
- Metric: Time it needs to load the web page
- Multiple drops to achieve statistically valid results
- Simulated time: 15 seconds



Usage Scenarios (2/2)

Evaluation of a coordinated scheduling algorithm

- Focus: Interactions between coordination and TCP control loops
- Abstract Phy model
- Application: Simplified → TCP downloads only
- Stochastic models for reading times and web object sizes (including heavy tail)
- Metric: Object finish times, miscoordinated frames
- Simulated time: 2 to 8 hours



Summary & Conclusion

Summary

- Cross layer evaluation required
- Modelling of all effects is difficult
- Using real code is often easier
- Presented architecture allows to use OSs and applications without modification

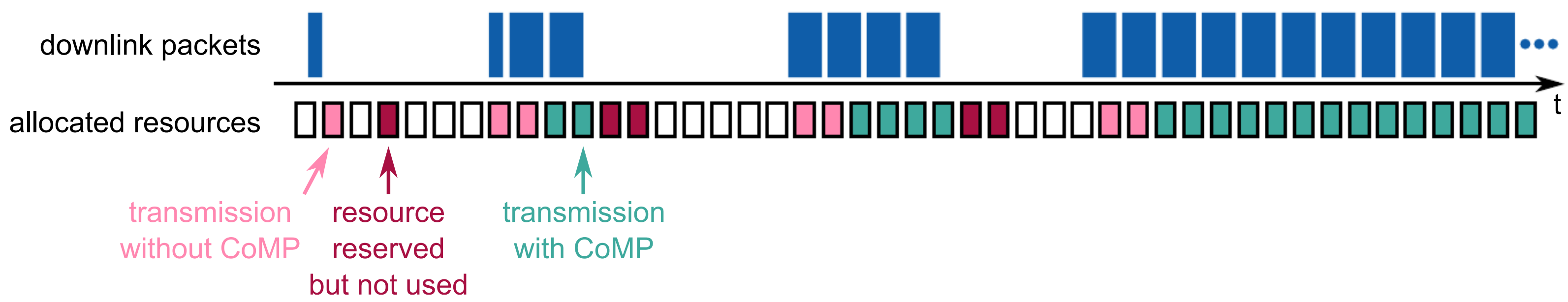
Conclusion

- Easy to try new applications — just install on the virtual computers
- Easy to use new kernel versions
- Also nice for demonstration!
- Abstract Phy models still required because of long simulation time spans

Motivation — Example

A simple CoMP setup scheme

- Assuming a non-negligible communication delay between cells
- CoMP setup is started when first package arrives
- Packets are transmitted without CoMP until setup has been completed
- When the queue runs empty, the reserved resources have to be freed



Influencing factors

- TCP behavior
- Parallel TCP connections used by the Browser
- Interactive web applications requesting small objects

see also: C. M. Mueller, 2011, Analysis of interactions between Internet data traffic characteristics and Coordinated Multipoint transmission schemes

Modelled Processing Power

How many clock cycles per timer tick?

- Emulator has overhead → typically slower than host
- We slow down the virtual clock anyway
  → arbitrary time for computation available

How much processing power do we want?

- Exact counting of instructions is not possible with QEMU
- End device not in the focus of our evaluations

→ Model (nearly) infinite processing power

Problem: infinite loops

- Example: Linux kernel calibrating bogomips
- QEMU has to return control flow eventually
- We use a variable time-out, e.g. max. 1s CPU time per 1ms tick