Simulation Software:
Omnet++ GTNetS GlomoSim / QualNet

Holger Füßler

Course overview

1. Introduction	7. NS-2: Fixed networks
2. Building block: RNG	8. NS-2: Wireless networks
3. Building block: Generating random variates I and modeling examples	9. Output analysis
4. Building block: Generating random variates II and modeling examples	10. OPNET Modeler / CN “Praktikum”
5. Algorithmics: Management of events	11. Other Network Simulators
6. NS-2: Introduction	12. Trends, Simulation lifecycle, summary

Simulation software and tools

- … where simulation meets software technology
  - How to build models and run simulations ***conveniently***.

General-purpose programming language

Simulation package (language and/or simulator)

Packaging standard elements of DES

- **Criteria:**
  - General capabilities (flexibility, available models, re-use, …)
  - Hardware/software considerations
  - Graphical facilities
  - Statistical features
  - "Learning curve", documentation, support
  - Output reports and plots

Choice of simulation software

- So far we know ns-2 / OPNET / BirdySim ☺ and some ‘toy example’ (simlib)
  - What do you like about ns-2?
  - What do you dislike?
- Many more options:
  - CSIM: C-based simulation package (http://www.atl.external.lmco.com/proj/csim/)
  - JSIM: Java-based simulation package (http://chief.cs.uga.edu/~jam/jsim/)
  - OMNeT++
  - GTNetS
  - GloMoSim / QualNet
  - …

Today:

- OMNeT++ / GTNetS / QualNet

Lecture overview: OMNeT++

- **OMNeT++ overview**
- **Concept**
- **Architecture / Steps to follow**
- **Simulator internals**
- **Example**
- **Existing modules**
- **Differences with ns-2**

OMNeT++

- **Open-source, generic simulation framework -- best suited for simulation of communication networks, multiprocessors and other complex distributed systems** **(further examples: queuing systems, hardware architectures, server farm, business processes, call centers)**
- **C++ based simulation kernel plus a set of libraries and tools (GUI and command-line)**
- **Platform: Unix, Windows**
- **Being developed at BUTE (Technical University of Budapest), CVS at Uni Karlsruhe**
- **Contributions from worldwide**
- **Active user community (mailing list has about 240 subscribers)**

Concept

Separation of concerns:

simulation = sim. program + experiments

model parameters, batch vs. GUI execution, sequential vs parallel execution, analysis of results

simulator + model

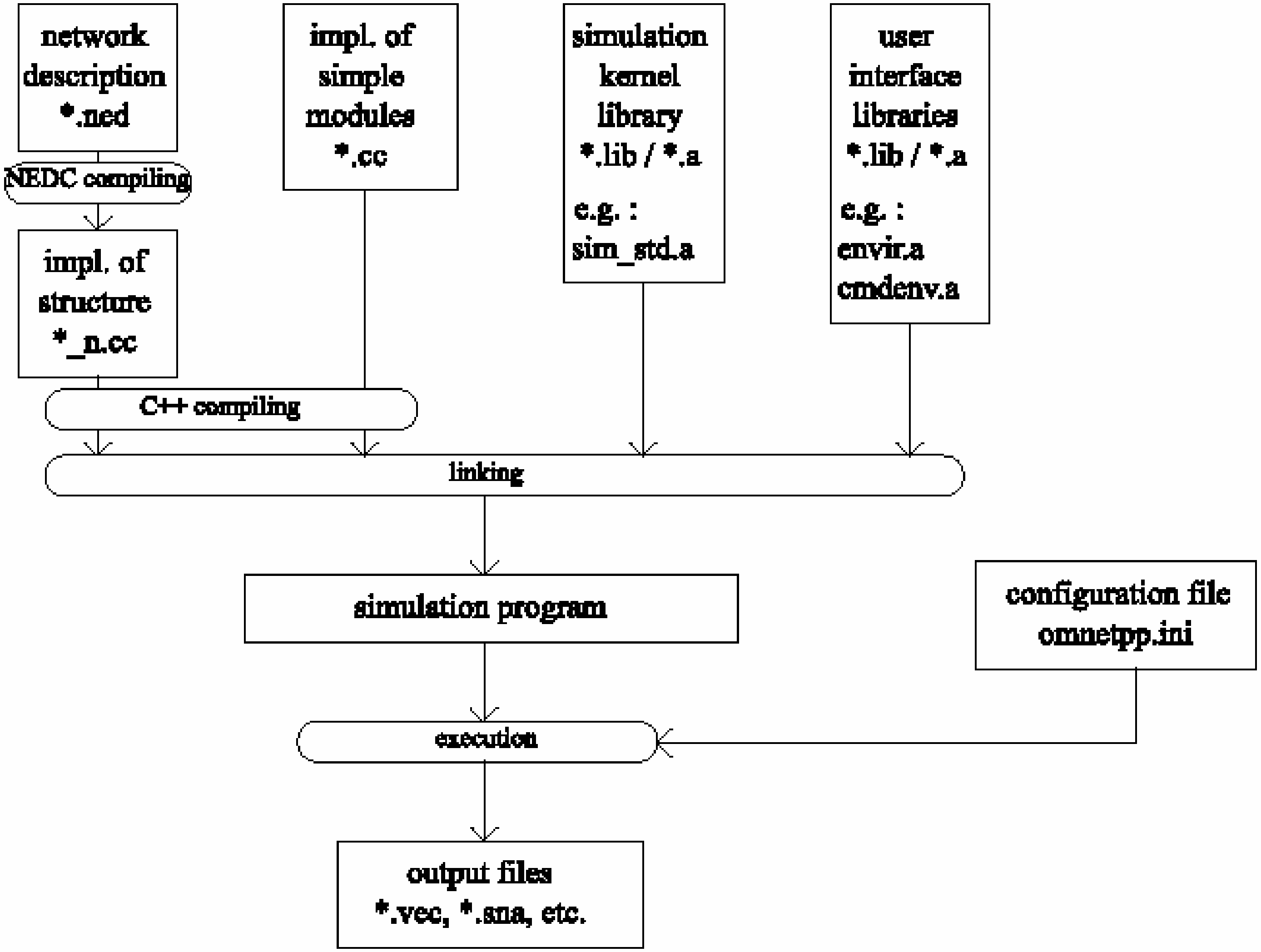
framework of generic services & tools

'topology' + behaviour

NED language, graphical editor

expressed in C++, using the simulation library

Architecture



Steps to follow

1. Map your system into a set of communicating modules
2. Use NED (or GNED) to define the model's structure
3. Using C++, describe the active components of the model as concurrent processes
4. Provide a suitable configuration file containing options of OMNeT++ and parameters to your model
5. Build the simulation program and run it
6. Analyze results written into output vector files.

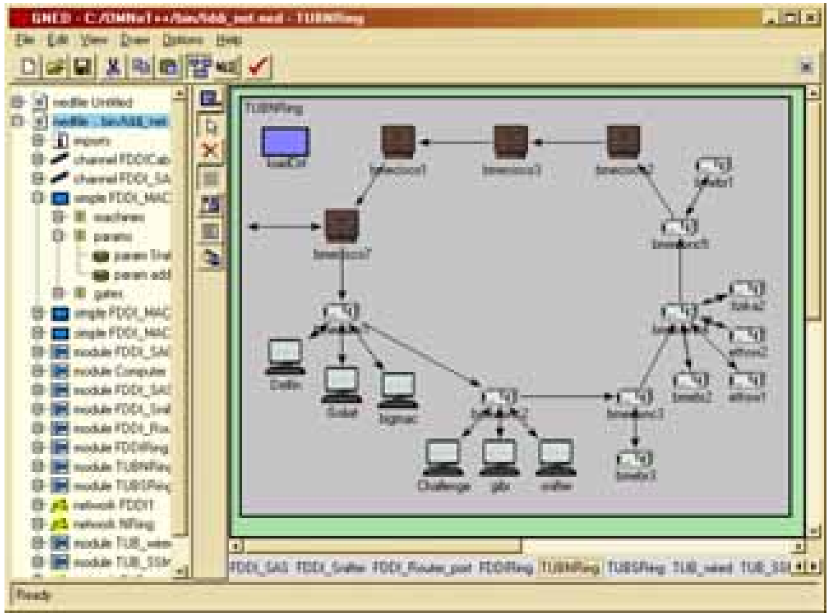
Defining the topology

» **NED – Network Description Language**

- **declares simple modules with their interfaces**
- **defines compound modules (submodules, interconnection)**
- **defines the network as instance of a module type**

» **GNED -- Graphical Network Editor**

- **works directly with NED files**
- **two-way tool: you may edit in NED sources or graphical view – they are automatically kept consistent**



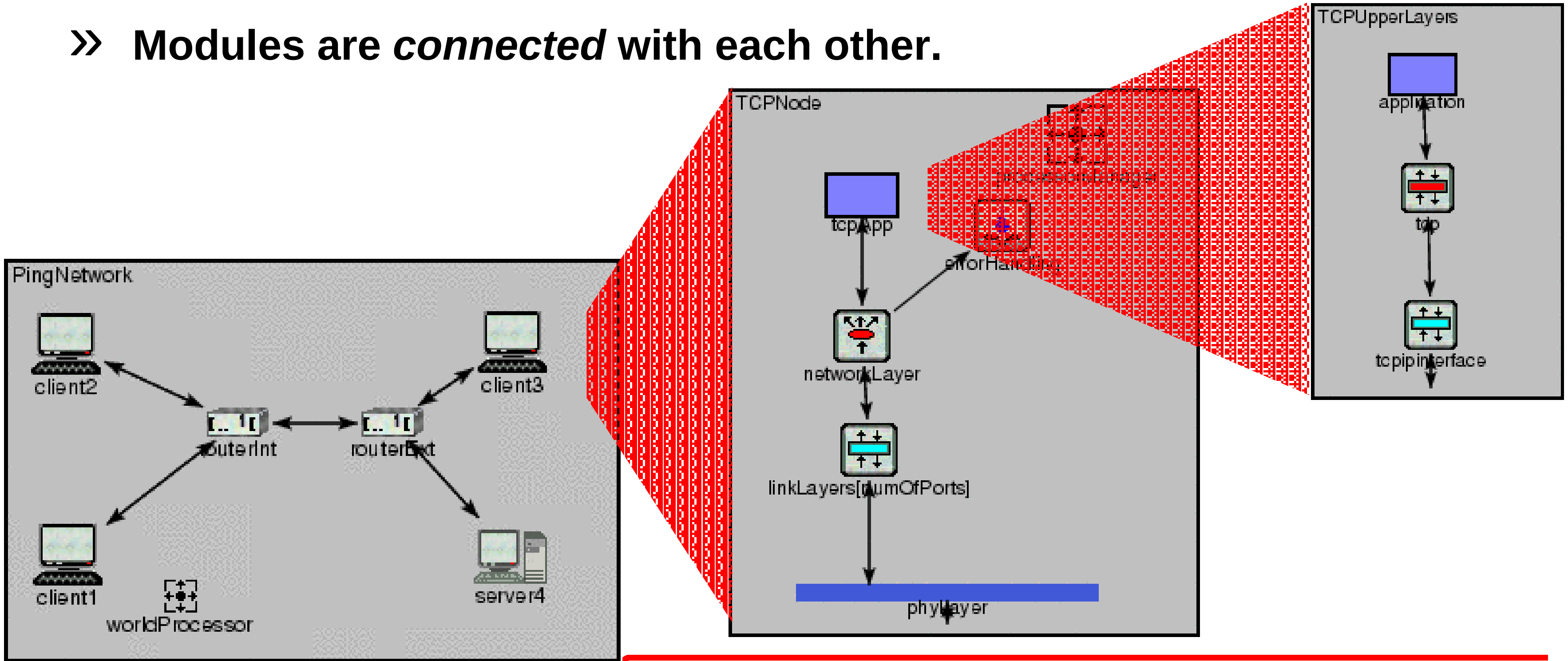
Model structure

Component-oriented approach (Hierarchically nested modules):

» **The basic building block is a simple module (programmed in C++).**

» **Simple modules can be grouped to form compound modules.**

» **Modules are *connected* with each other.**



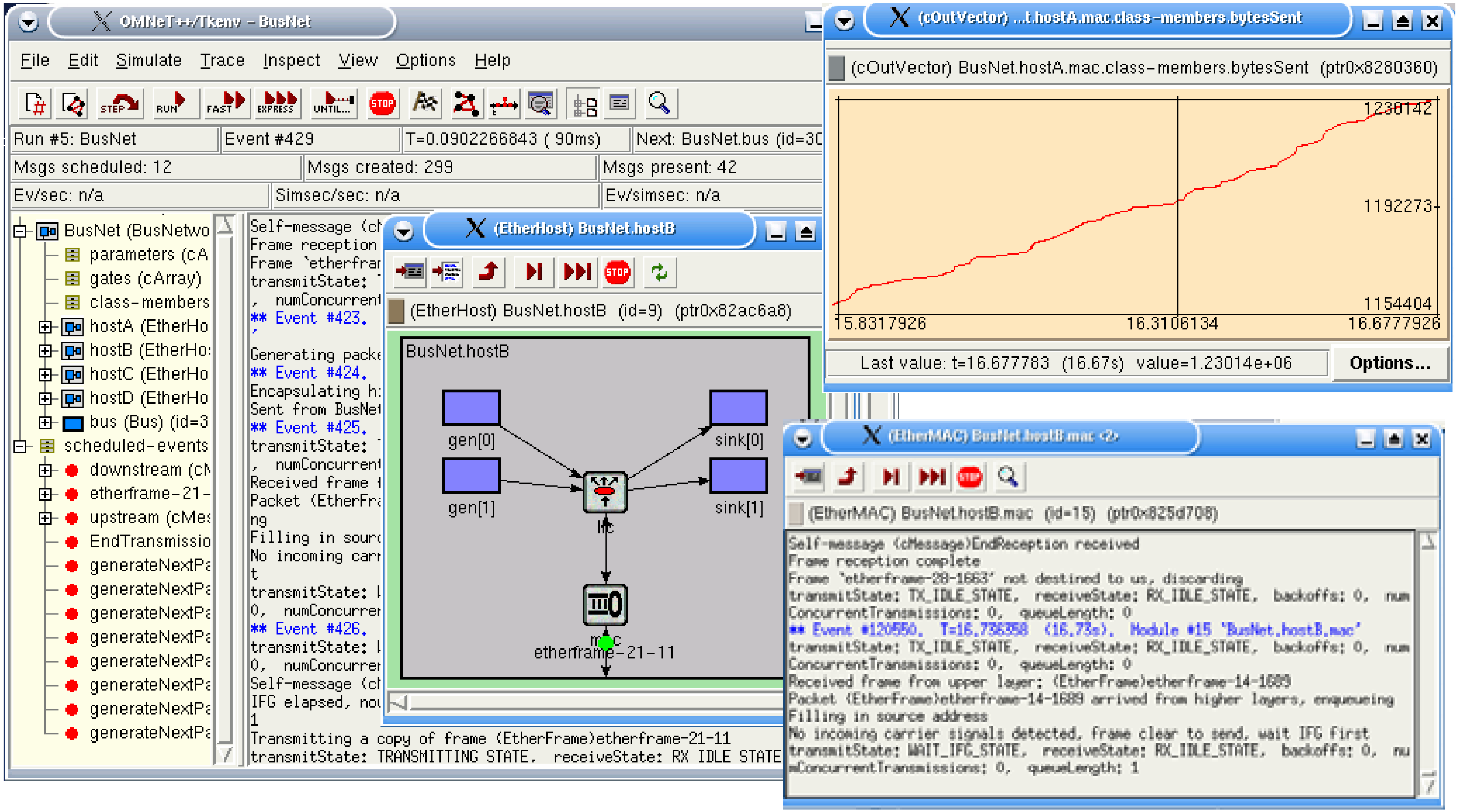
Defining the behaviour

- **Behaviour is encapsulated in simple modules, C++.**
- **A simple module:**
  - **sends messages, reacts to received messages**
  - **collects statistics**
- **Gates are the input and output interfaces for messages.**
- **Connections (links) are established between modules, characterized by:**
  - **Propagation delay**
  - **Bit error rate**
  - **Data rate**

Simulation library

- **Simulation class library covers commonly needed functionality, such as:**
  - ***random number generation***
  - ***queues and other containers***
  - ***support for topology discovery and routing***
  - ***recording simulation results (output vectors)***
  - ***statistics collection and estimation (histograms, etc)***

The GUI

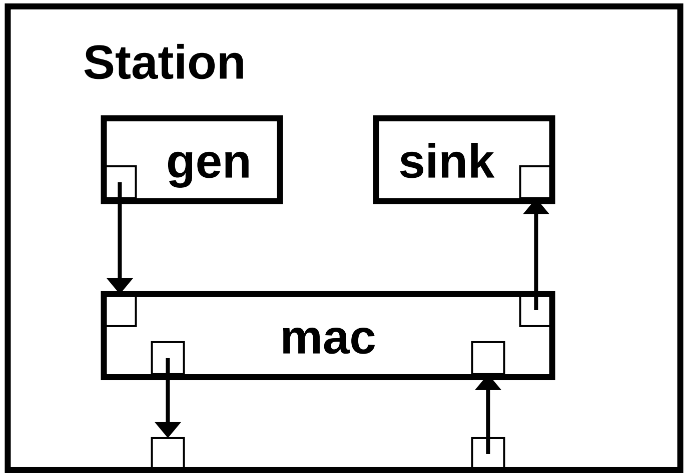

OMNeT++/Tkenv - BusNet
File Edit Simulate Trace Inspect View Options Help
STEP RUN FAST EXPRESS UNTIL... STOP
Run #5: BusNet
Event #429
T=0.0902266843 (90ms)
Next: BusNet.bus (id=30
Msgs scheduled: 12
Msgs created: 299
Msgs present: 42
Ev/sec: n/a
Simsec/sec: n/a
Ev/simsec: n/a
BusNet (BusNetwo
parameters (cA
gates (cArray)
class-members
hostA (EtherHo
hostB (EtherHo
hostC (EtherHo
hostD (EtherHo
bus (Bus) (id=3
scheduled-events
downstream (cM
etherframe-21-
upstream (cMes
EndTransmissio
generateNextPa
Self-message (cl
Frame reception
** Event #423.
Generating packe
** Event #424.
Encapsulating h
Sent from BusNet
** Event #425.
transmitState:
Received frame
Packet (EtherFra
Filling in sourc
No incoming carr
** Event #426.
Self-message (cl
IFG elapsed, no
Transmitting a copy of frame (EtherFrame)etherframe-21-11
transmitState: TRANSMITTING STATE, receiveState: RX IDLE STATE
(EtherHost) BusNet.hostB
(EtherHost) BusNet.hostB (id=9) (ptr0x82ac6a8)
BusNet.hostB
gen[0]
gen[1]
sink[0]
sink[1]
mac
etherframe-21-11
(cOutVector) ...t.hostA.mac.class-members.bytesSent
(cOutVector) BusNet.hostA.mac.class-members.bytesSent (ptr0x8280360)
1238142
1192273
1154404
15.8317926
16.3106134
16.6777926
Last value: t=16.677783 (16.67s) value=1.23014e+06
Options...
(EtherMAC) BusNet.hostB.mac <2>
(EtherMAC) BusNet.hostB.mac (id=15) (ptr0x825d708)
Self-message (cMessage)EndReception received
Frame reception complete
Frame 'etherframe-28-1653' not destined to us, discarding
transmitState: TX_IDLE_STATE, receiveState: RX_IDLE_STATE, backoffs: 0, numConcurrentTransmissions: 0, queueLength: 0
** Event #120550. T=16.736358 (16.73s). Module #15 'BusNet.hostB.mac'
transmitState: TX_IDLE_STATE, receiveState: RX_IDLE_STATE, backoffs: 0, numConcurrentTransmissions: 0, queueLength: 0
Received frame from upper layer: (EtherFrame)etherframe-14-1689
Packet (EtherFrame)etherframe-14-1689 arrived from higher layers, enqueueing
Filling in source address
No incoming carrier signals detected, frame clear to send, wait IFG first
transmitState: WAIT_IFG_STATE, receiveState: RX_IDLE_STATE, backoffs: 0, numConcurrentTransmissions: 0, queueLength: 1

Running under the GUI

» Run or single-step the simulation
» Monitor state of simulation and execution speed
» Examine model object tree
» Explore modules and see message flow
» Examine scheduled events
» Trace what one module is doing
» Step to next event in a module
» Look at state variables and statistics
» Find out pointer values for C++ debugging (gdb)
» Look at results being recorded

Simple example

» **Station:**



Submodels can be connected to each other or to parent module

Simple definition in NED

```
simple MAC
parameters: address;
gates:
in: from_higher_layer, from_network;
out: to_higher_layer, to_network;
endsimple
```

A compound model

```
module Station
   parameters: mac_address;
gates:
   in: in; out: out;
submodules:
   mac: MAC
        parameters:
        address=mac_address;
   gen: Generator;
   sink: Sink;
connections:
   mac.to_network --> out,
   mac.from_network <-- in,
   mac.to_higher_layer --> sink.in,
   mac.from_higher_layer <-- gen.out;
endmodule
```

Existing modules

- **Simulation Models TCP/IP networks:**
  - **IPSuite**
  - **IPv6Suite**
- **LAN/MAN protocols:**
  - **Ethernet**
  - **FDDI**
  - **Token Ring**
- **Wireless LAN protocols:**
  - **802.11**
  - **Hiperlan/2**
- **Mobility and ad-hoc frameworks:**
  - **Mobility Framework**
  - **An AODV framework**

OMNeT++ vs NS-2 (seen from OMNeT's perspective)

	OMNeT++	NS-2
Flexibility	Generic simulation framework	Good for IP networks
Topology Description	NED or GUI	OTcl
Model Management	Models independent of simulation kernel	Monolithic
Hierarchical Models	Hierarchical module structure	"Flat" models
Debugging	Tkenv	None
Models Available	Few computer systems	Rich in communication protocols
Scalability	Limit is the virtual memory of computer	Some problems in large networks
Parallel Simulation	PDES: Parallel Discrete Event Simulation	Developed in Georgia Tech
Embeddability	Simulation kernel can be embedded in other applications	None

References

- **Home page: www.omnetpp.org**
  - **Downloadable**
  - **Tutorials (M/M/1 queue!)**
  - **Manual**
  - **Mailing List**
  - **Models**
  - **...**
- **Commercial version also exists: www.omnest.com**

GTNetS – The Georgia Tech Network Simulator

- **complete new design (pure C++)**
- **main design goals: scalability, performance**
- **Download:**
  http://www.ece.gatech.edu/research/labs/MANIACS/gtnets.htm
- **a lot of protocols as network primitives (802.3/11 / IP / TCP)**
- **primitives for statistics generation / tracing**
- **natural support for distributed execution**
- **Mobility: RWP / specified waypoint**
- **Radio Channel Modelling: ?**

The GTNetS Process

Develop Model in C++ (Algorithms)

↓

Write int main() yourself

↓

compile and link against GTNetS object files

↓

run

GTNetS – Discussion

- pure C++
  - IMHO very nice
  - BUT: have to provide Functions for reading scenarios etc.
- potentially a lot faster than ns-2
- BUT: lots of people still focus on ns-2 → newer protocols available, more used means usually mor debugged

References - GTNetS

Download:

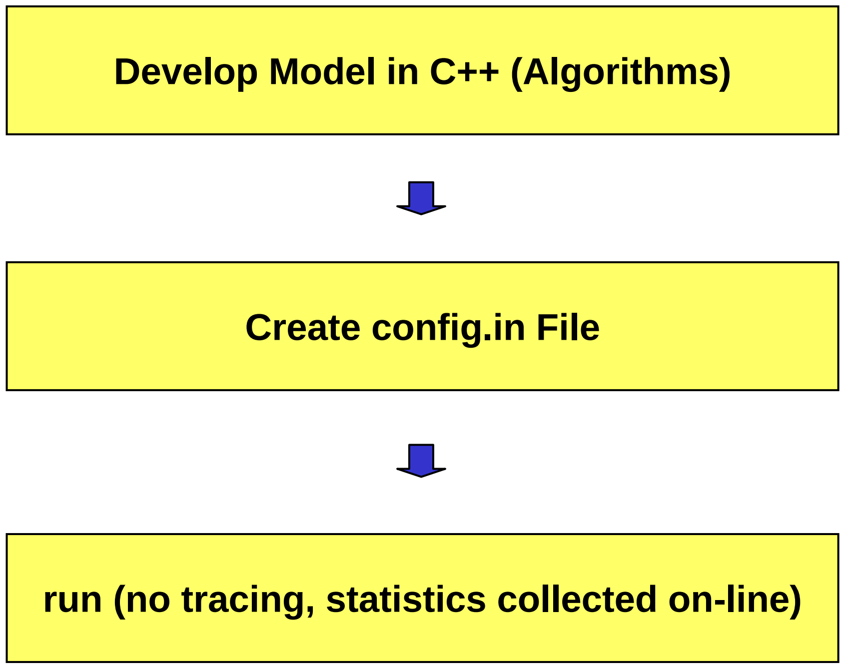
http://www.ece.gatech.edu/research/labs/MANIACS/gtnets.htm

» **Riley, George F. : “The Georgia Tech Network Simulator”, p. 5-12, In Proc. of SIGCOMM 2003, Karlsruhe, Germany**

GlomoSim / QualNet

- C++ / ParSec (language for description of parallel processes)
- ParSec has to be installed separately (bad license for commercial use)
- QualNet is commercial spin-off, GlomoSim free but no longer maintained

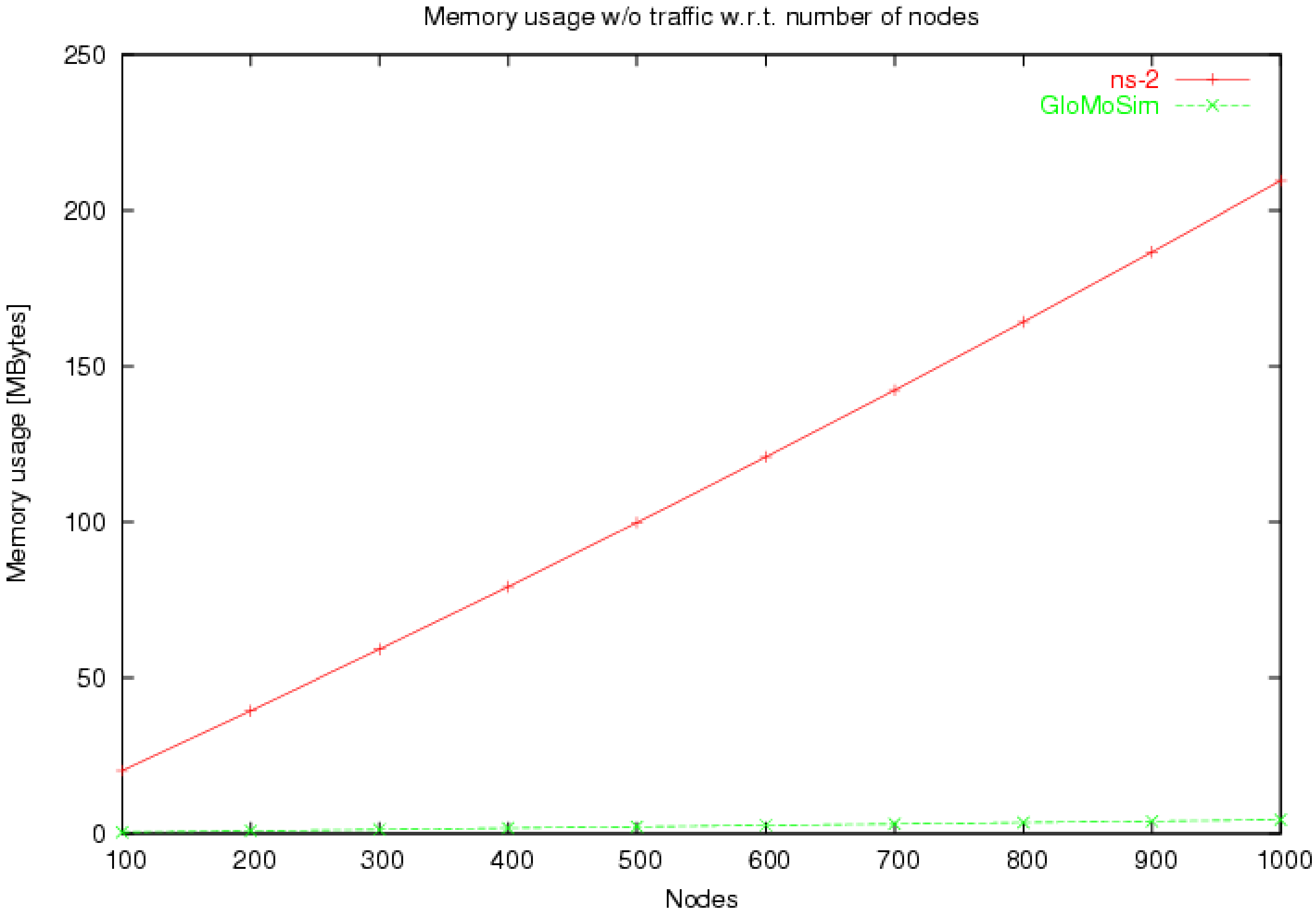
The GlomoSim / QualNet Process



GlomoSim / QualNet - Discussion

- » **Strengths:**
  - **Ad-Hoc Networking (routing etc.)**
  - **Radio Channel Modeling (Directional Antennas)**
  - **a lot of nodes possible**
- » **Weaknesses:**
  - **needs PARSEC**
  - **licensing, sourcing (QualNet) / up-to-dateness (GlomoSim)**
  - **tracing (for debugging)**

GlomoSim vs. ns-2 – Memory Scalability



References – GlomoSim / Qualnet

- **GlomoSim:** http://pcl.cs.ucla.edu/projects/glomosim/
- **QualNet:** http://www.scalable-networks.com

Wrap-Up – Which Simulator should I use?

- **Criteria re-visited:**
  - **General capabilities (flexibility, available models, re-use, …)**
    - **which specific problem / class of problems do I want to tackle?**
    - **which orders of magnitude for simulation size?**
  - **Hardware/software considerations**
    - **which OS is available / needed?**
    - **which compilers etc.?**
  - **Graphical facilities**
    - **educational / scientific purpose?**
  - **Statistical features**
    - **tracing vs. inline statistics**
  - **“Learning curve”, documentation, support**
    - **how many languages do I have to learn?**
  - **Output reports and plots**
  - **What do the others in my community use?**