Invited Talk at the Universidad de Castilla-La Mancha

Multi-Path Transport with OMNeT++ and the INET Framework

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Multi-Homing and Multi-Path Transport

- **Multi-Homing**
  - Multiple interfaces (addresses)
  - **Redundancy** → Communication even when some paths fail

- **Multi-Path Transport**
  - Also utilise paths *simultaneously* → better throughput
  - **MPTCP**: Multi-Path TCP
  - **CMT-SCTP**: Concurrent Multi-Path Transfer for SCTP

Hot topic in research and standardisation!

SCTP: Stream Control Transmission Protocol
TCP: Transmission Control Protocol

Redundancy is expensive!
Multi-Path Transport with MPTCP and CMT-SCTP

- Subflow ↔ path
- Fairness
  - Paths may overlap (fully or partially)
- Scheduling
  - Different path characteristics
    - Bandwidth
    - Latency and jitter
    - Packet loss

Complex system → analyses are necessary!
OMNeT++ and the INET Framework

- Simulations? → OMNeT++ and INET Framework!
  - Well-known Open Source network simulation framework
  - Initial SCTP model (without CMT-SCTP) already available

- Goal: state-of-the-art SCTP model
  - Particularly: with CMT-SCTP, of course!

SCTP Project at Universität Duisburg-Essen

https://www.uni-due.de/~be0001/sctp/
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The CMT-SCTP Model

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Stream Control Transmission Protocol (SCTP)

- Defined in RFC 4960
- Choose one “primary path” per direction for payload transport
- Other paths are just backups → redundancy only
Concurrent Multipath Transfer for SCTP (CMT-SCTP)

- Defined in draft-tuexen-tsvwg-sctp-multipath
- All paths can be used for payload transport
- Scheduler makes choices (not defined how to do this → implementer!)
The SCTP Model in OMNeT++ (1)

- SCTP in OMNeT++
  - State-of-the-art SCTP model
  - SCTP protocol extensions

- Open Source
  - SCTP model is included in the INET framework!

https://inet.omnetpp.org
The SCTP Model in OMNeT++ (2)

- SCTP, according to RFC 4960
- All relevant protocol extensions (RFCs + Internet Drafts):
  - Partial Reliability (PR-SCTP)
  - Dynamic Address Reconfiguration ("Add-IP")
  - Chunk Authentication
  - Stream Reset
  - Packet Drop Reporting
  - Selective Acknowledgement (SACK) Immediately
  - ...
- Added for CMT-SCTP:
  - CMT-SCTP, of course
  - Non-Renegable Selective Acks (NR-SACK)
  - + lots of bug fixes
Overview:
The Modified IPv4NetworkConfigurator

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A Multi-Homed Network: How to make use of the redundancy?

- Example: how to route from A to B?

  - "Classic" routing: just one route (the cheapest) from A to B
  - Routing requirement: create separate networks with own routes
    - E.g. A1 → B3, A2 → B2, A3 → B1
The Modified IPv4NetworkConfigurator - An Auto-Configurator for Multi-Homed Networks

How to set up multi-homed networks easily?

- IPv4NetworkConfigurator
  - Automatic configuration of IP addresses and routing tables
  - Links belong to a network
    - NetID: the network identifier
    - Special NetID “0”: all networks
  - Dijkstra algorithm is separately applied on each network
- Not yet adapted to IPv6 → to do
Overview:
The NetPerfMeter Application Model

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NetPerfMeter –
The Multi-Protocol Network Test Application Model

- NetPerfMeter model
  - Throughput measurements
  - Application delay measurements
  - Multi-protocol support
    - SCTP (of course)
    - TCP
    - UDP
  - Sender options
    - Saturated ("as much as possible")
    - Non-saturated ("frame rate / frame size")
Putting Everything Together: A Running Example!

- Get the sources (for current version):
  - `git clone https://github.com/dreibh/inet.git td-inet`
  - `cd td-inet`
  - `git checkout td-netperfimeter-for-integration`

- Build:
  - Currently with OMNeT++ 5.1pre3
  - `make makefiles && make`

- Run the example
  - `cd examples/sctp/advancedmultipath/`
  - `./run`

- See `advancedmultipath.ned` and `omnetpp.ini` for configuration and parameters!

Note: This is not the upstream INET repository!
NetPerfMeter –
The Real Multi-Protocol Network Test Application

• NetPerfMeter Model ↔ NetPerfMeter Application
  – Real application for Linux, FreeBSD, etc.
  – Supports transport protocols of underlying operating system:
    • Linux → Linux MPTCP, SCTP (without CMT, yet), DCCP, TCP, UDP
    • FreeBSD → SCTP (inclusive CMT), TCP, UDP
  – Allows for comparison of real-world measurements and simulations
    • Same parameters and application behaviour!
• NorNet Core slivers have NetPerfMeter already pre-installed!

See https://www.uni-due.de/~be0001/netperfmeter/ for details!
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Requirement for Parameter Studies

Parameter studies need a lot of runs ...

- We have a pool of PCs for student exercises
  - Can we make use of these resources when not otherwise used?

- Reliable Server Pooling (RSerPool)!
  - Reference implementation RSPLIB
  - + A simple distribution application
  - + A collection of scripts

- Interesting fact:
  - RSerPool (RFC 5351-5356) uses SCTP
  - A good stress test for RSerPool + SCTP implementations!

https://www.uni-due.de/~be0001/rserpool/
Simulation Processing Tool-Chain (SimProcTC)

See https://www.uni-due.de/~be0001/omnetpp/ for details!
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Conclusions

- OMNeT++ and INET Framework
  - Powerful and easy to use network simulation framework
  - Open Source
- Multi-path transport
  - CMT-SCTP
  - NetPerfMeter application model
  - Allows for comparison to real network measurements → **NorNet testbed**!
- Future work
  - Contribution of missing parts into upstream INET framework project
  - (most improvements are already there!)
  - MPTCP model? → work at University of Duisburg-Essen/HAW Hamburg!
Thank you for your attention!
Any questions?

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Literature
Literature (1)


Literature (2)


