Realistic Underlays for Overlay Simulation

Ingmar Baumgart, Thomas Gamer, Christian Hübsch and Christoph P. Mayer
[baumgart,huebsch,mayer]@kit.edu, gamer@tm.uka.de
**Motivation**

- **P2P networks** enable the flexible and scalable deployment of novel services
  - Popular examples: BitTorrent, Skype, Amazon´s Dynamo
- But: Behaviour of P2P networks is often complex and hard to predict
- **Simulation** helps to determine e.g. suitable protocol parameters
  - OverSim is a popular tool to simulate all kind of P2P networks
- P2P networks are usually **overlay networks**
  - Logical network on top of existing underlay network
  - Newer P2P protocols try to adapt the overlay topology to the underlay
    - Application Layer Multicast
    - Low latency DHTs
    - IETF ALTO Traffic Optimization
    - ...

→ To get accurate results we need realistic underlay models for OverSim!
OverSim: The Overlay Framework

Our overlay framework OverSim based on OMNeT++ provides:

- Support for simulation and real world applications
- Rapid development of new overlay protocols
- Scalability (>100.000 nodes) and flexibility due to a modular design

Several state of the art overlay protocols:
- Chord, Koorde, Pastry, Bamboo, Kademlia, Broose, Gia, VAST, QuON, Scribe, SimMUD, NICE

Several overlay applications:
- Generic DHT, i3, P2PNS, Gaming Application
Modular architecture

- **Layered architecture**
  - Underlying network
  - Overlay layer
  - Application layer

- **Consistent interfaces between layers**
  - **UDP/TCP** between network and overlay
  - **Common API** between KBR overlay and application

→ Exchange of one component is transparent to all other components
Classical OverSim underlay models

- **SimpleUnderlay**
  - Low computational overhead
  - Coordinate-based delays calculated from CAIDA/Skitter measurements
  - Logical access network

- **InetUnderlay**
  - Based on the INET framework
  - Complete IP stack is modeled
  - Backbone simulation
  - Extendable by INET framework models, e.g. 802.11
  
  \[ d_e = d_A + \frac{l_p}{b_A} + c \cdot \| A - B \|_2 + d_B + \frac{l_p}{b_B} \]

→ **Lacks support for a proper topology generator for realistic Internet topologies!**
ReaSE topology generator

- Internet-like topologies
  - Two hierarchy levels: AS level and router level
  - Differentiates between Transit AS and Stub AS
  - Additional hierarchy in the router level topology
    - Market demands like link costs result in hierarchical router topology

- Modelling of realistic background traffic
  - Reasonable mix of different kinds of traffic
    - Traffic profiles define flow behavior

- Related Work
  - Only state of the art generation topology generators relevant:
    - Degree-based graph model
      - TIERS, GT-ITM, BRITE are all based on obsolete models
    - Focus only on AS level topology
    - Often separate tools for topology generation and background traffic
Integration of ReaSE in OverSim

- Several modifications to ReaSE to generate OverSim compatible NED file
- In contrast to InetUnderlay the network contains only AS modules (so no routers and no overlay terminals)
- AS modules contain core routers, edge routers and overlay terminals
- Global TerminalConnector and RUNNetworkConfigurator modules parse the underlay topology, assign IP addresses and connect overlay terminals
- Optional ConnectionManager is used to generate background traffic
A quick look at simulation results…

- Network coordinate system Vivaldi with different underlay models

ReaSEUnderlay shows closest relative error results to real network measurements in PlanetLab
What is the best underlay model?

- **SimpleUnderlay**
  - Very scalable (up to 100,000 nodes)
  - Typical Internet end-to-end delays
  - Models only end systems (no overlay nodes in the network core)

- **InetUnderlay**
  - Models queuing effects in intermediate routers
  - Access to all models of the INET framework (e.g., 802.11)
  - Not possible to model the whole internet backbone on router level
  - Generates only basic random topologies

- **ReaSEUnderlay**
  - All benefits of the InetUnderlay
  - Realistic topologies based on real-world Internet observations
  - Also not possible to model the whole internet backbone on router level
Conclusion

- **OverSim** is a scalable and flexible P2P simulation framework
- **ReaSE** is a tool to generate realistic underlay topologies and background traffic based on Internet observations
- The integration of ReaSE in OverSim leads to a new **powerful underlay model**, which is especially useful for the evaluation of
  - Application Layer Multicast (ALM)
  - Network coordinate systems (e.g. Vivaldi)
  - Traffic Optimization (e.g. IETF ALTO)
- Disadvantage is the increased resource consumption…
  
  …choose your underlay model wisely!