MesoNetHS: A Mesoscopic Simulation Model of a Router-Level Internet-like Network with High Speed TCP Replacements

MesoNetHS is a mesoscopic (medium scale) simulation model of a router-level Internet-like network with support for high speed TCP replacements. The model, written in SLX[1], facilitates investigation of global behavior through simulation of a network representing a single Internet Service Provider. MesoNetHS is uniquely positioned between microscopic models, which require hundreds of parameters to fully specify detailed behavior of individual network elements, and macroscopic models, which aggregate behavior of many network elements into abstract representations that may lose key interactions on fine spatiotemporal scales.

MesoNetHS assumes a three-tier hierarchy of routers (backbone, point-of-presence and access), while also supporting some heterogeneity, including: variations in speed among access routers and traffic sources, ability to connect access routers directly to backbone routers, and six classes of transport flow. Network links are simulated in detail only on the backbone, where propagation delays become important. The current model routes network traffic on static, shortest-path routes. Network traffic in MesoNetHS is supplied through simulated sources and receivers, which operate under connection-establishment and congestion-control procedures representing the Reno version of the transmission control protocol (TCP). MesoNetHS can also use congestion-control procedures representing high-speed TCP replacements (C-TCP, HS-TCP, FAST-TCP, S-TCP, or H-TCP). Each source cycles continuously among three steps: (1) think for some exponentially distributed time, (2) connect to a receiver with probabilities reflecting the network topology, and (3) transfer a web page of some Pareto distributed size. Size is increased for selected transfers to simulate users who decide to download a paper, image or music file from a web site.

Given a specified topology, MesoNetHS can be parameterized with a multiplier on propagation delays, queue limits and speeds for routers in each tier, average think period and file size (plus distribution shape), probability of a larger transfer and associated multiplier on file size. During simulation, model state is captured at each user-specified measurement interval, leading to time series for response variables. The current model records response variables at several levels, including: network wide, each router, and each flow class. Recorded responses include utilizations, queue sizes, losses, active and completed flows, retransmission rates, connection failures, throughputs, and rate of window increases, timeouts, and negative acknowledgments. MesoNetHS is also capable of logging detailed state changes and packet transfers for randomly sampled flows.

MesoNetHS is implemented as an agent-automata model, where every active element is updated at each time step. For a topology of 171 routers, 28 backbone links, 27,600 sources and 12,000 simultaneously active flows, MesoNetHS must update around 40,000 elements per time step, where some elements are updated multiple times to reflect speed differences. For such a topology, MesoNetHS executes about 10 times slower than real time, depending on the processor used. To date, MesoNetHS has been used to simulate network evolution over periods from 20 minutes to 17 hours.

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[1] SLX is a commercial simulation system available from Wolverine Software, see: http://www.wolverinesoftware.com.