AN INTEGRATED APPROACH TO NETWORK SIMULATION

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Proactive Network Management

- **There are three methods for obtaining predictive data about networks:**
  - **analytical modeling**
  - **monitoring/ measurement**
  - **simulation**
- **Each of these methods offers significant advantages and disadvantages.**
- **Increasingly, hybrid approaches are being developed which seek to maximize these advantages while maintaining model fidelity.**

Analytical Modeling

- **Analytical methods offer important performance advantages over simulation.**
- **Unfortunately, analytical modeling using conventional queuing theory does not provide high fidelity network models in most cases.**

  Some types of network activity are accurately modeled using Poisson processes.

  Other network activities are more accurately represented by hyperexponential distributions,

  and still others are not easily characterized by standard distribution functions (Paxson 95).

- **Where analytical models accurately represent a network component, this is usually the most computationally efficient representation.**

Network Monitoring

- **Many networks of interest are already constructed and in use. Intuitively, the best way to check the operation and performance of a network is to observe and measure the results. There are two major drawbacks to this approach:**

  1. This is not predictive, as past performance provides no clues on how the network will react to previously unseen changes.

  2. Experimenting on an operational network is very risky since the experimental changes may produce unforeseen problems.

- **Network monitoring provides the measurements that may determine the face validity of the simulation.**

  However, this requires the desired configuration to be already installed and operational.

Network Simulation

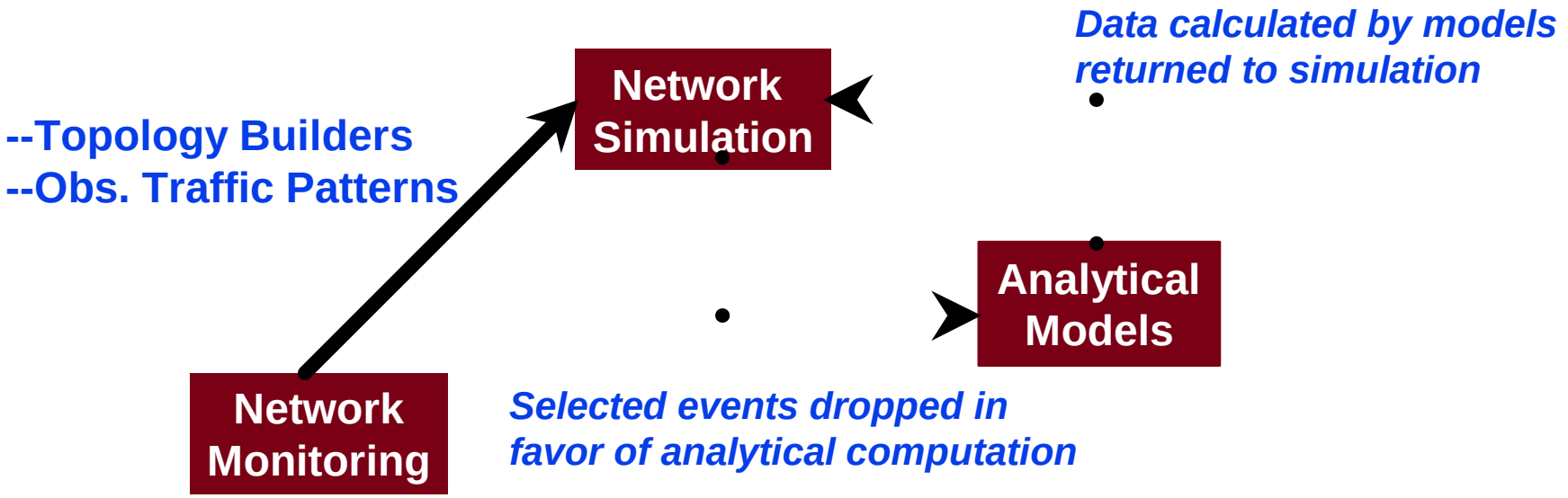
- **Through the use of network simulation, modifications to existing networks can be tested for performance and cost effectiveness before they are implemented.**
- **In order to create an accurate network model, the performance of the existing network must be understood.**
- **Additionally, after modifications are made based on results from the model, the network manager must be able to verify that the changes had the desired effect.**

Challenges

- **Simulation offers a viable method for network design. The three major challenges in network simulation are:**
  - **fidelity**
  - **performance**
  - **validation**
- **Large, high fidelity, network simulations can be difficult to construct and have unusable long run times.**
- **Model validation of unimplemented networks is also challenging.**

An Integrated Approach

- **An integrated approach using analytical modeling, monitoring and reusable network objects ameliorates some of the challenges associated with network simulation.**



Integrated Monitoring

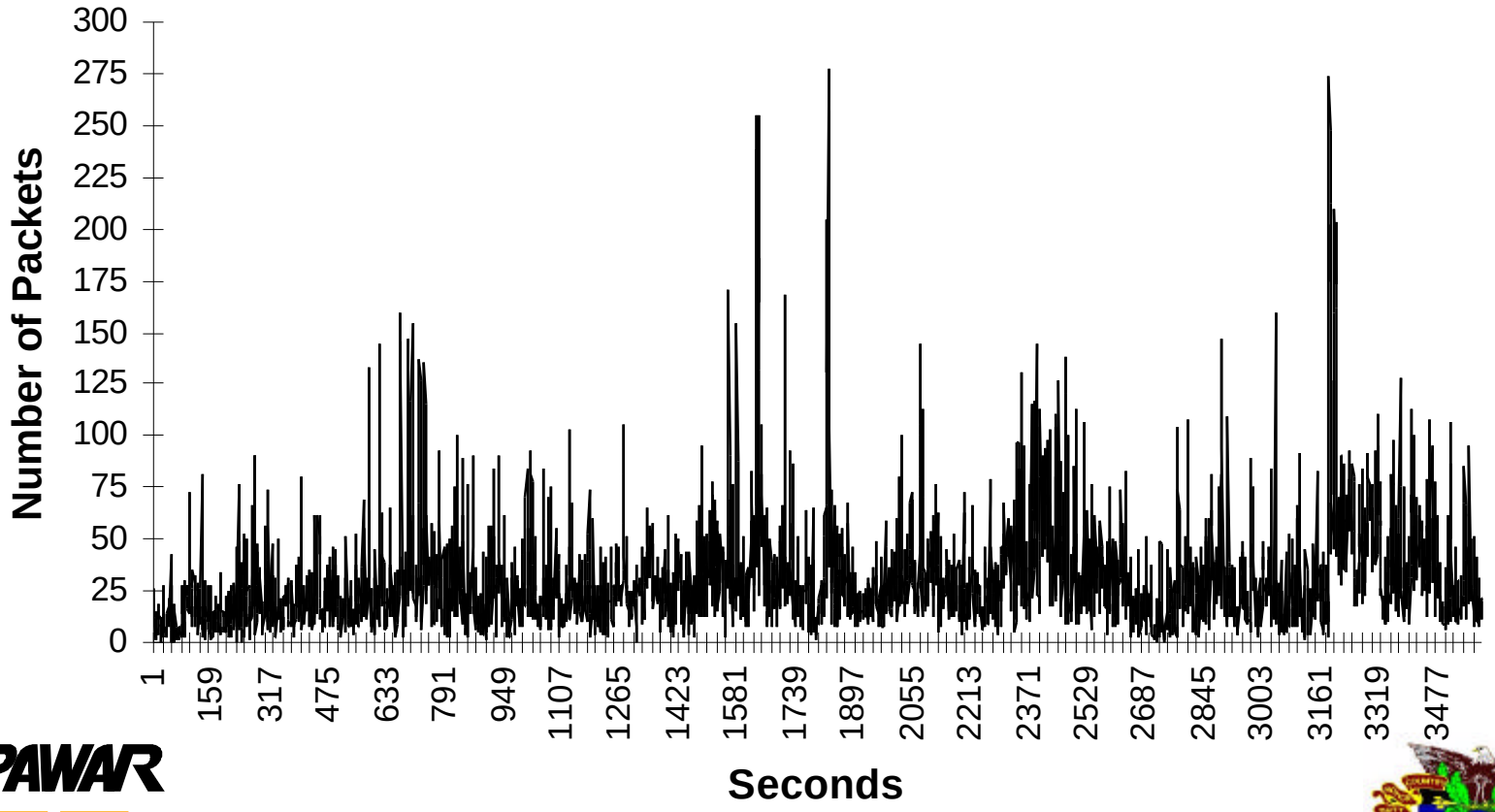
- **Network monitoring provides the inputs, the reality checks and the verification and validation capability for analytical modeling and network simulation.**

- **For a non-trivial network, it is critical to determine precisely what to measure. Commonly used measures for aggregate data are:**
  - » **throughput**
  - » **link utilization**
  - » **end-to-end delay**

That which is monitored improves!

Aggregated Traffic Data

Total Packets Transmitted



Simulating Network Traffic

- **For detailed traffic studies, it is desirable to capture the following information about each packet:**
  - » **Source**
  - » **Destination**
  - » **Time Sent**
  - » **Time Received**
  - » **Packet Length**

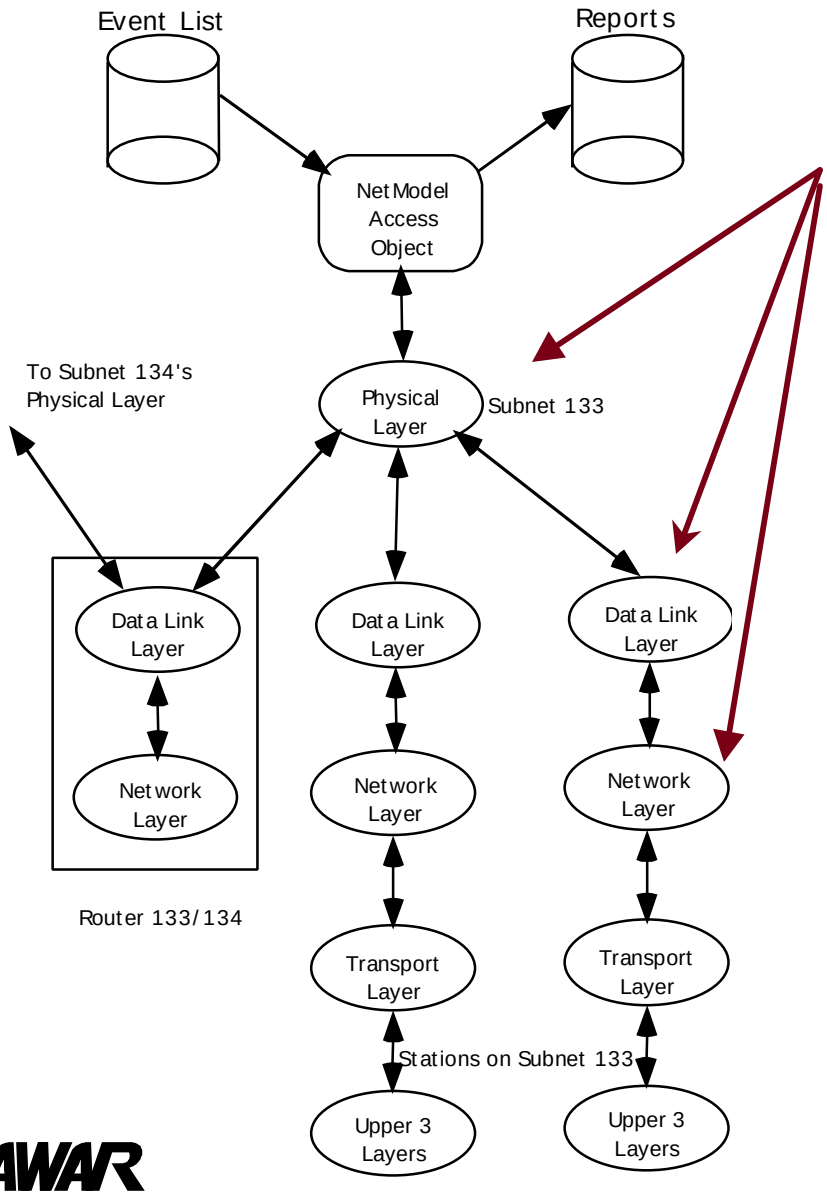
- **(Terplan 92) observes that network simulation models are very sensitive to:**
  - **Workload descriptions**
  - **Network configuration**
  - **Software environments**

Operational Use of Network Simulation

- **Network configurations can be exercised with event lists generated from historical traffic (workload) data.**
- **Predictive data about the effects of configuration changes can be made based upon known usage.**
- **Predicting future workloads is much more difficult.**
- **How precisely accurate the traffic generators must be depends upon the fidelity needs and operational requirements of the simulation.**

Simulation Performance

- A simulation, which takes one hour to run one second of simulation time, is rarely of operational use.
- This is a major issue in limiting the level of detail, which can be modeled in a large network.
- Implementing simulation models at the packet level with a millisecond time resolution poses major challenges.
- In the domain of computer networks a second is an eternity. A great deal can happen between one second and the next.



Multilevel network simulation

Network protocol layers

Multiresolution simulation

Time resolution
Traffic resolution

SPAWAR

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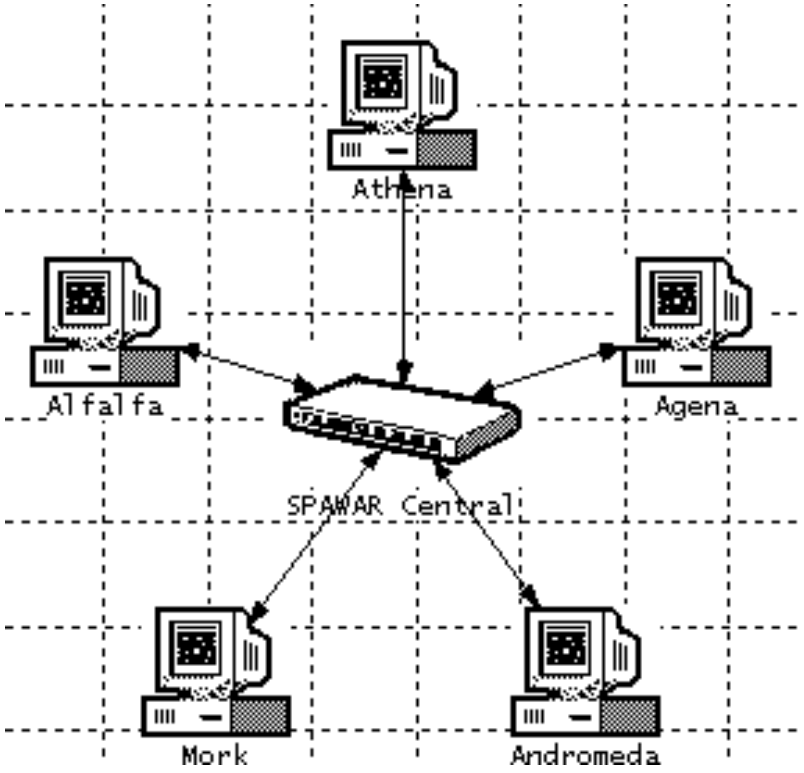
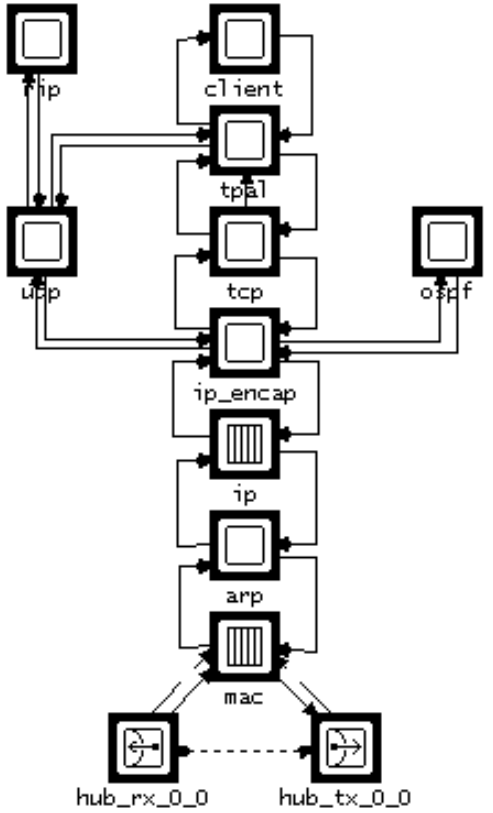
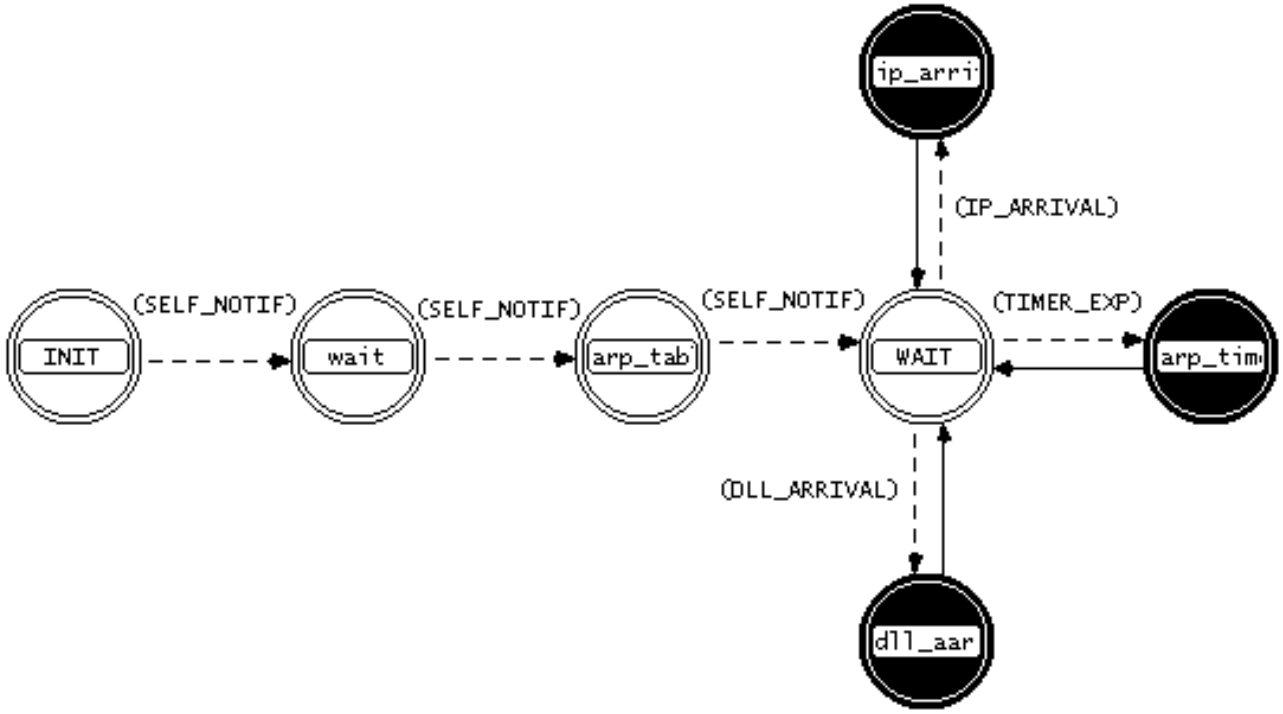
Multilevel Simulation





Multilevel Simulation

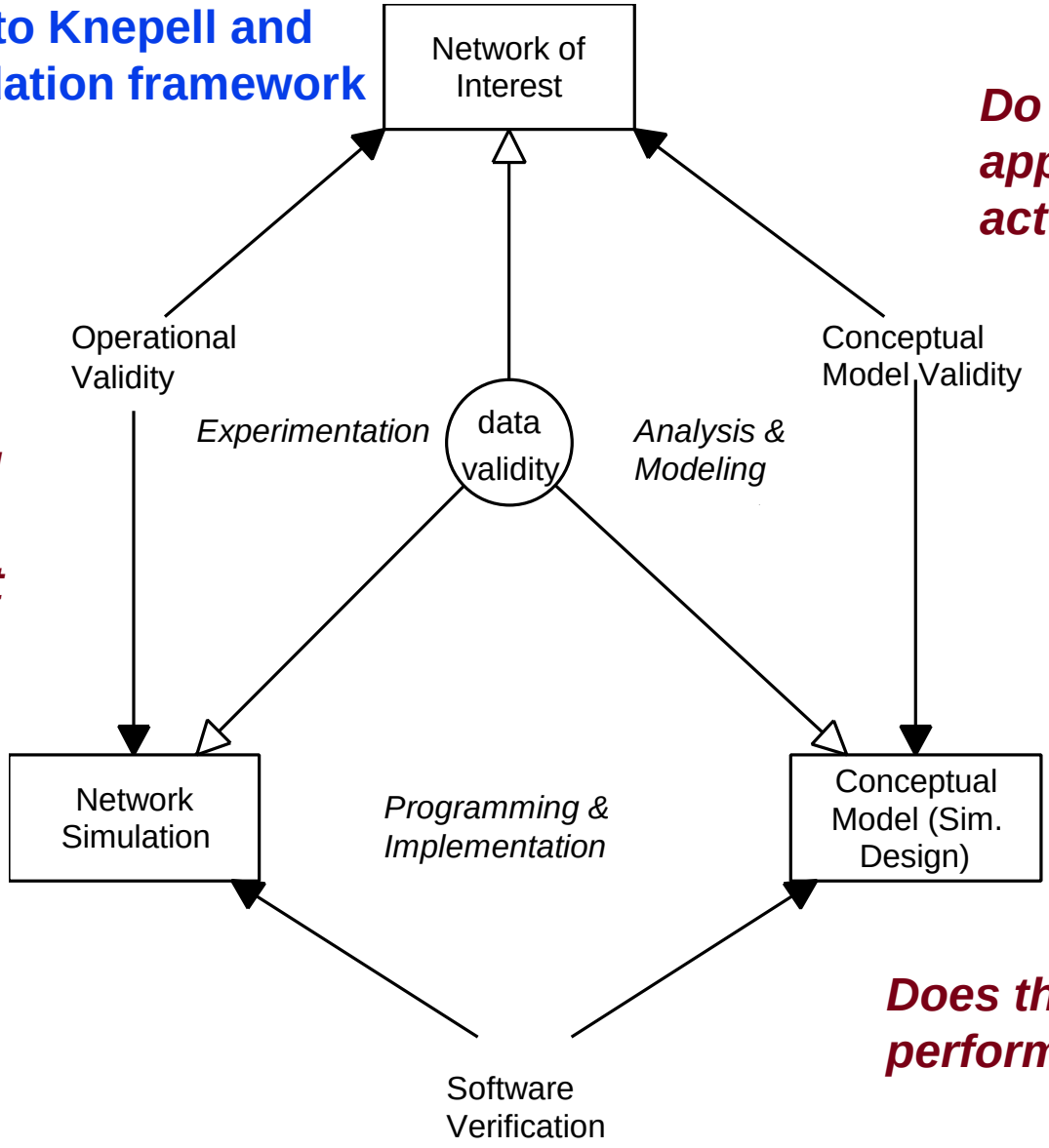


V&V Terminology

- **A model is *valid* if it can produce the outputs, which are equivalent to the ones, which would be observed given the same inputs in the environment being modeled.**

- **The term *verification* describes the activity of insuring that a particular implementation faithfully satisfies the requirements of a specification over a given range of inputs.**

A modification to Knepell and Arangno's validation framework



Do the predicted approximate the actual results?

Does the model implementation correctly reflect the network?

Does the software perform correctly?

Simulation Validation

- **Non-validated simulations may produce subtly erroneous data.**
- **Since simulation is the only tool that is really scaleable to handle large networks, validating a large network simulation is not easy.**
- **We recommend individually monitoring manageable parts of the network and using that as input to validate your simulator.**
- **If the expected and the actual data check out, then the simulator can be used to forecast topology/equipment changes and upgrades with some confidence.**

Conclusions

- **Network simulation is a tool to eliminate much of the uncertainty involved in LAN planning and management.**
- **Future networks with higher speed and greater bandwidth may require even higher levels of precision.**
- **As new networking technologies are introduced, there is little reason to expect a significant reduction in complexity.**
- **An integrated approach to network simulation has the best chance of scaling up to meet the challenges of these new technologies than any single methodology.**