Networks 2008 - October 2, 2008

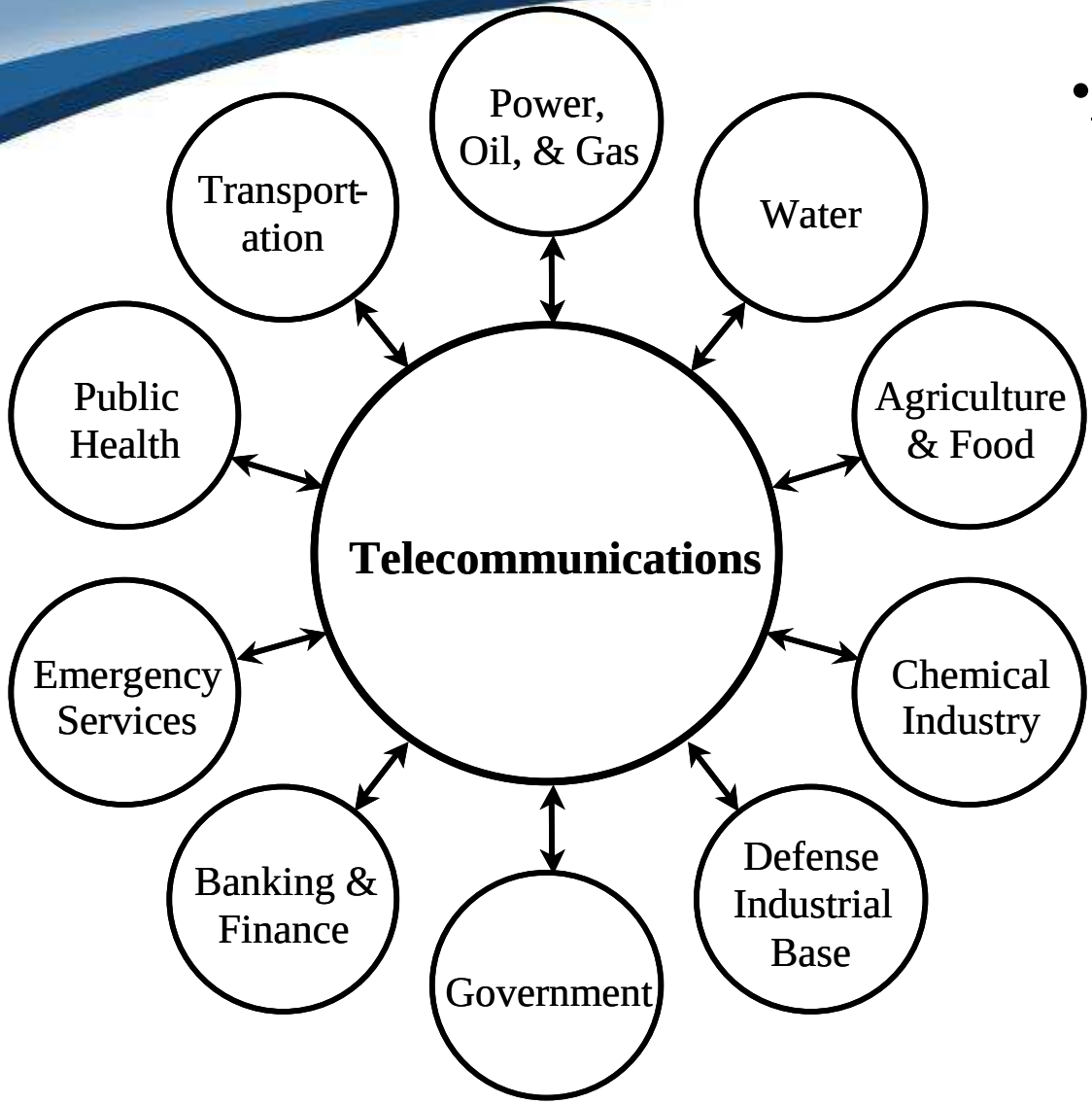
NETWORK CAPACITY ANALYSIS USING DYNAMIC SIMULATION

Dr. Gerard O'Reilly

LGS, Bell Labs Innovations

Subsidiary of Alcatel-Lucent

Critical National Infrastructures Dependency on Telecommunications



- Simulation Approaches

✓Call-by-call model (Discrete event based)

✓Dynamic Simulation (Time based)

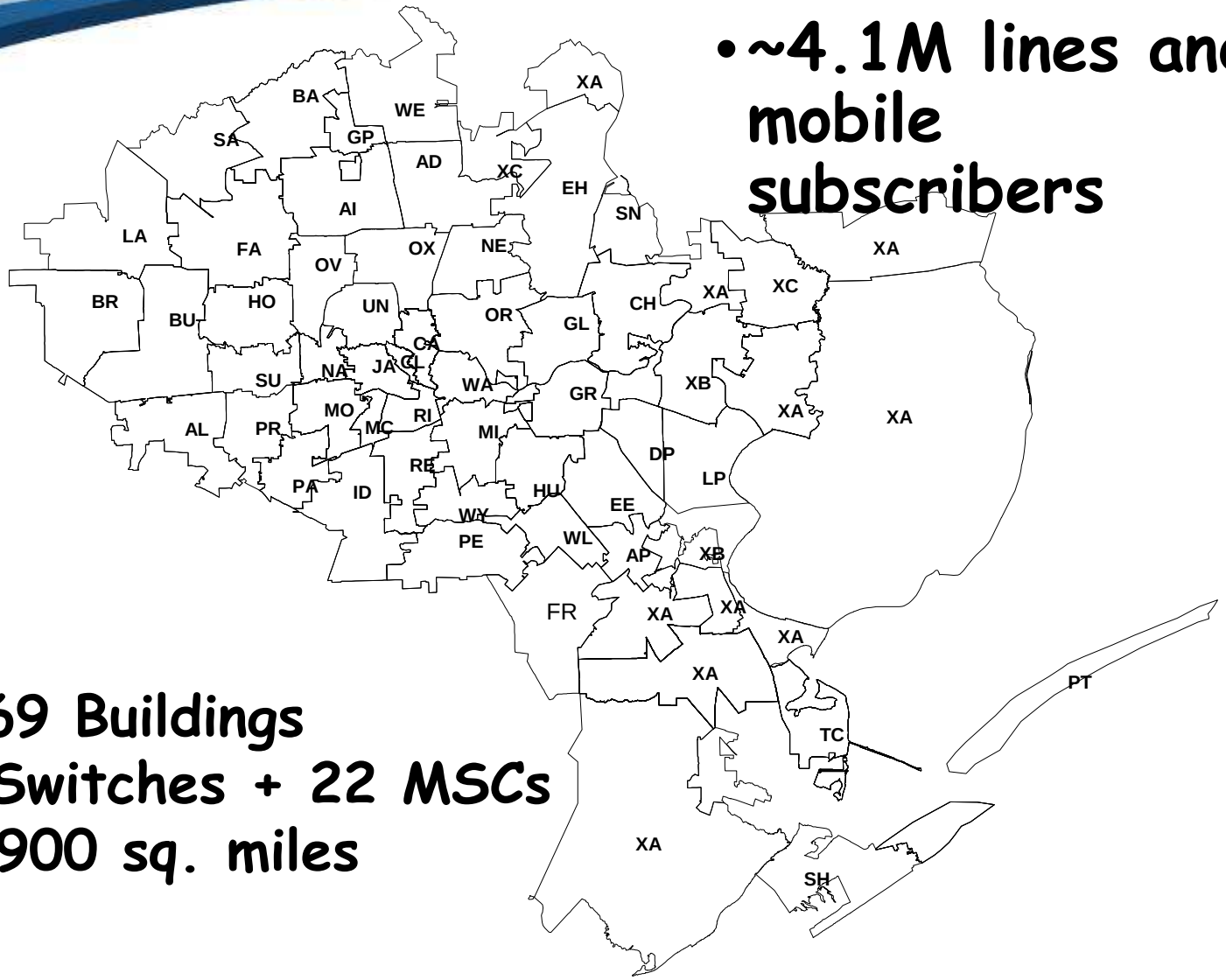
System Dynamics (SD) Models

- Time based
- Stocks and flows
- Several commercial-off-the-shelf (COTS) software tools are available:
  - Vensim: www.vensim.com.
  - Powersim: www.powersim.com
  - Stella™ and iThink™: www.hps-inc.com

➔Using Vensim, we apply SD approach to telecom modeling and cross-infrastructure studies.

➔Here we use SD for capacity planning.

Houston/Galveston Wire Centers



- ~4.1M lines and mobile subscribers

69 Buildings
78 Local Switches + 22 MSCs
~1900 sq. miles

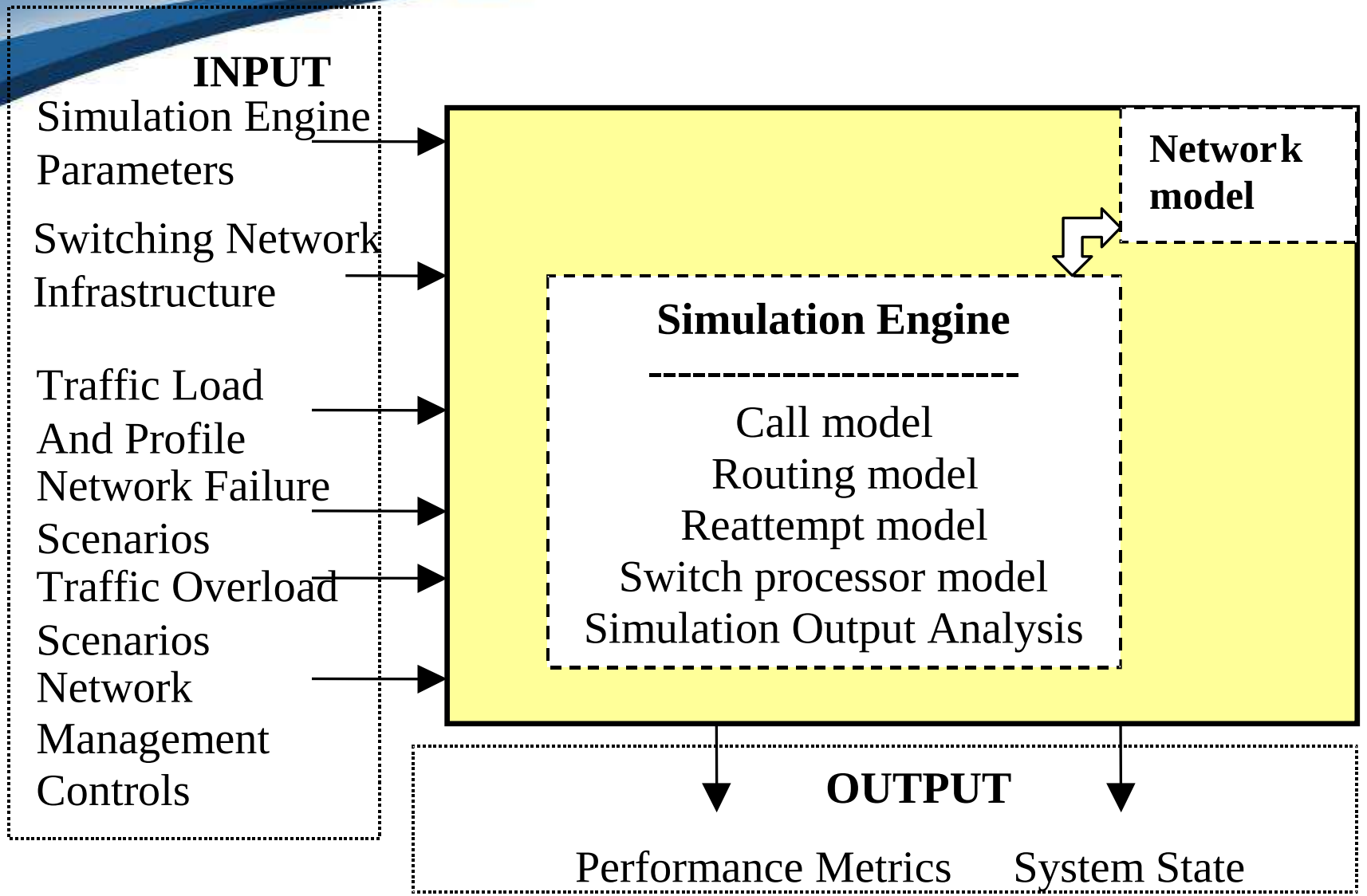
Models at various levels of aggregation

- Discrete Event Call-Level Model – (N-SMART custom software)

- Commercial-off-the-shelf (COTS) dynamic simulation software (Vensim)
  - Nodes and Links - Individual Buildings and Trunk groups
    - Similar to N-SMART
    - Simulate calls in bulk across individual buildings and trunk groups (stochastic)
    - Run time in Vensim is too slow given trunk group modeling between nodes
  - Nodes Model - Individual Buildings
    - Simulate calls in bulk across individual buildings (stochastic)
    - Using multiple equations (one for each node) approach, but lose trunk group level
  - Aggregate Network Model
    - √ Treat "network" as two whole networks (one for wireline and one for wireless), e.g. for metro area of millions of wireline and wireless subscribers
    - √ Simulate calls and re-attempts in bulk for the network and allow flows across networks (stochastic)
    - √ Results are a good match to Discrete Event Simulations

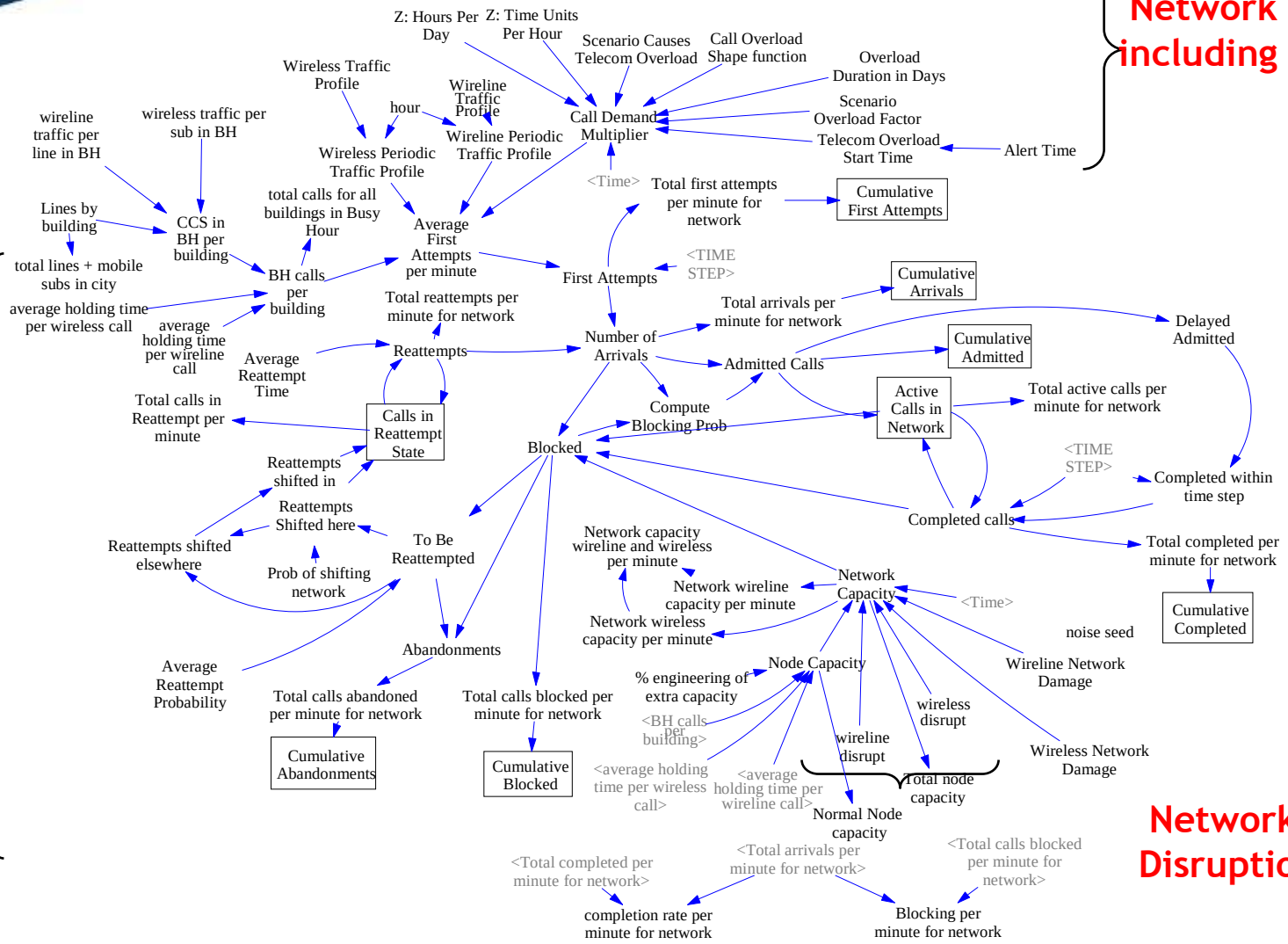
N-SMART Telecommunications Simulation Components

Network Simulation Modeling and Analysis Research Tool



Dynamic Simulation Model of Wireline and Wireless Networks

Metropolitan network with millions of lines + mobile subscribers



Network Demand including overload

Stochastic Simulation over all buildings

Network Disruption

Aggregate Model – example equations

wireline

- Completed calls [L] =

  RANDOM BINOMIAL(0, 1e+009 ,

  1-EXP(-TIME STEP /average holding time per wireline call),
  Active Calls in Network [L] - Completed within time step [L],
  0 , 1 , 0) + Completed within time step [L])

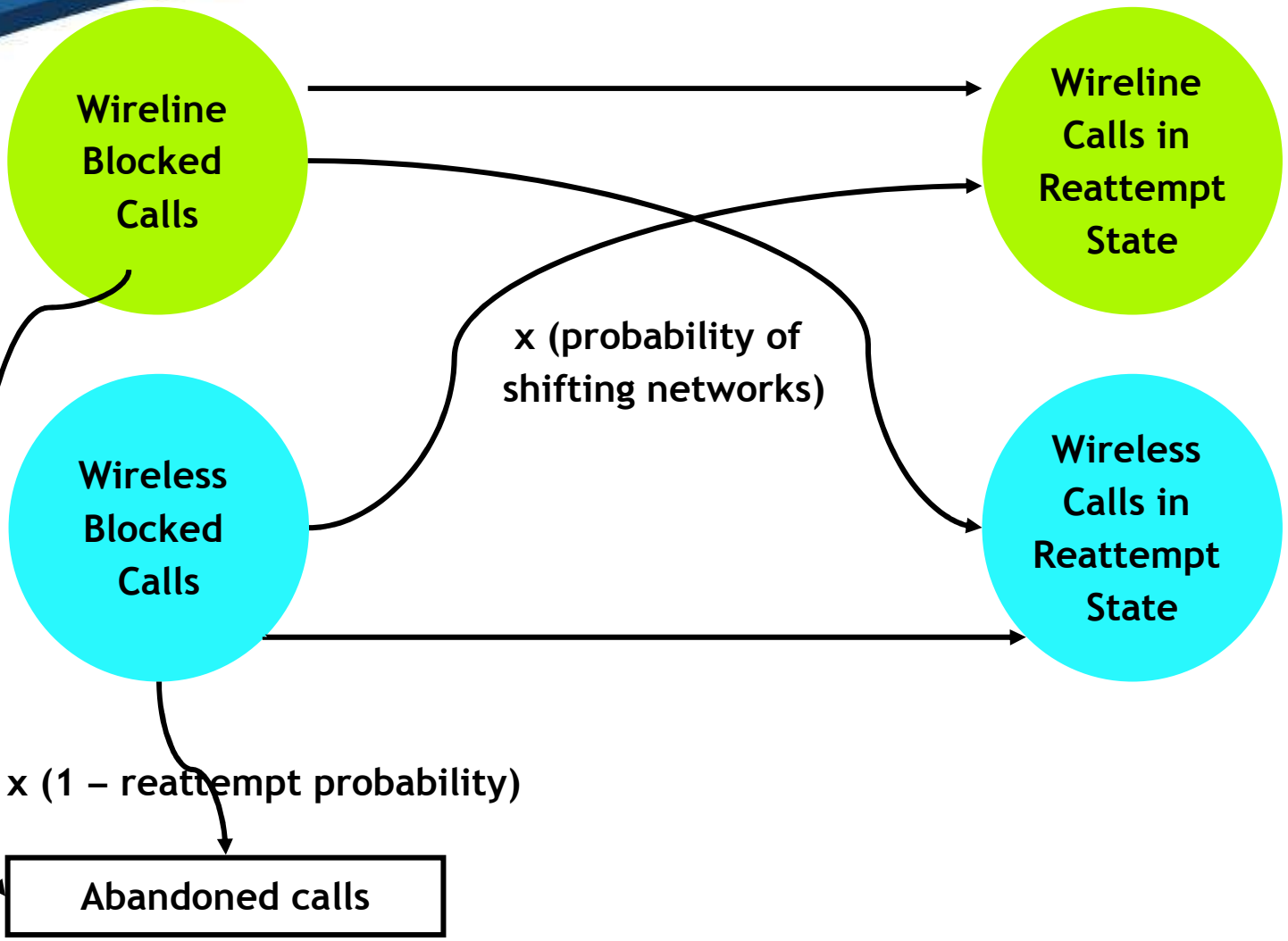
wireless

- Completed calls [S] =

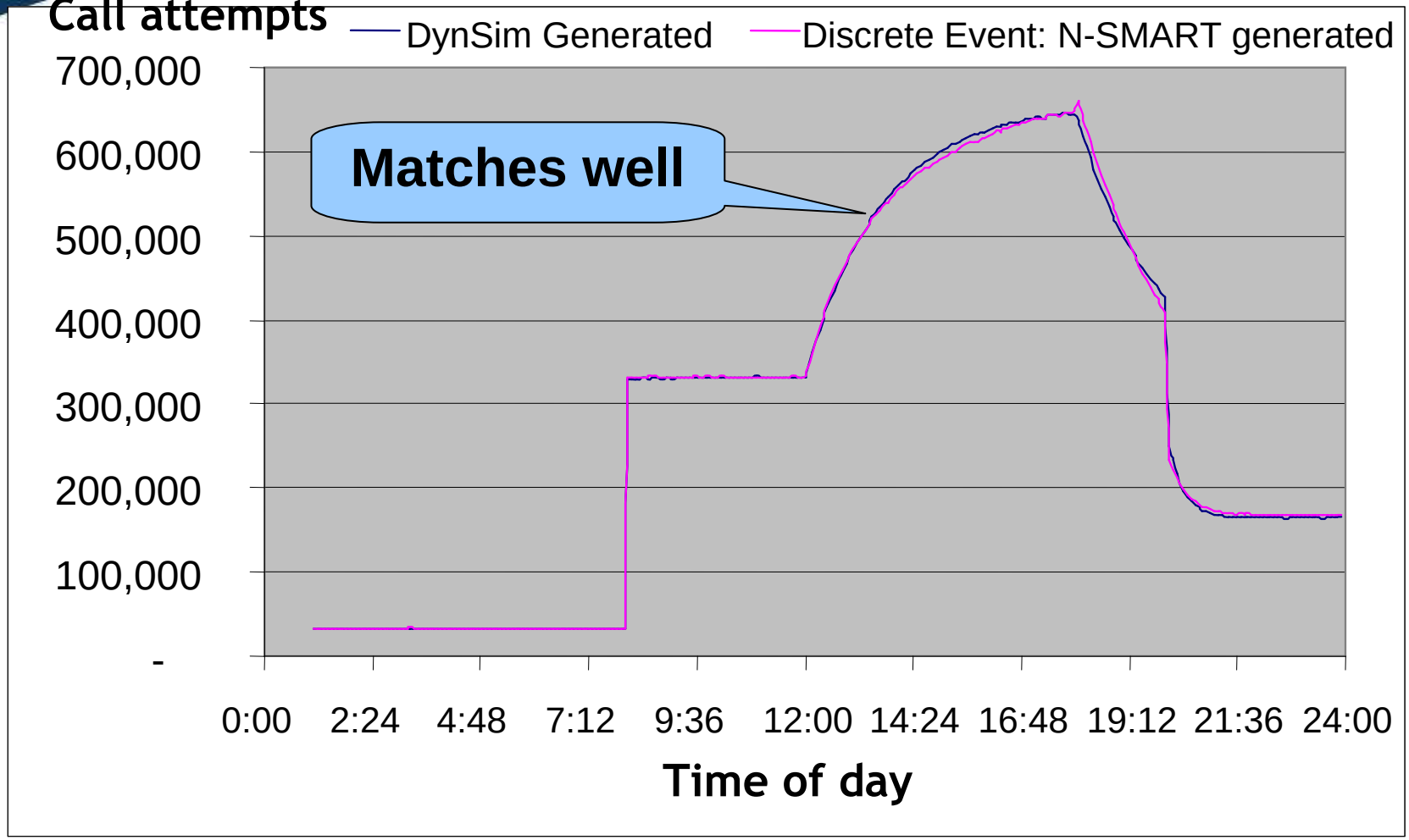
  RANDOM BINOMIAL(0, 1e+009 ,

  1-EXP(-TIME STEP /average holding time per wireless call),
  Active Calls in Network [S] - Completed within time step [S],
  0 , 1 , 0) + Completed within time step [S])

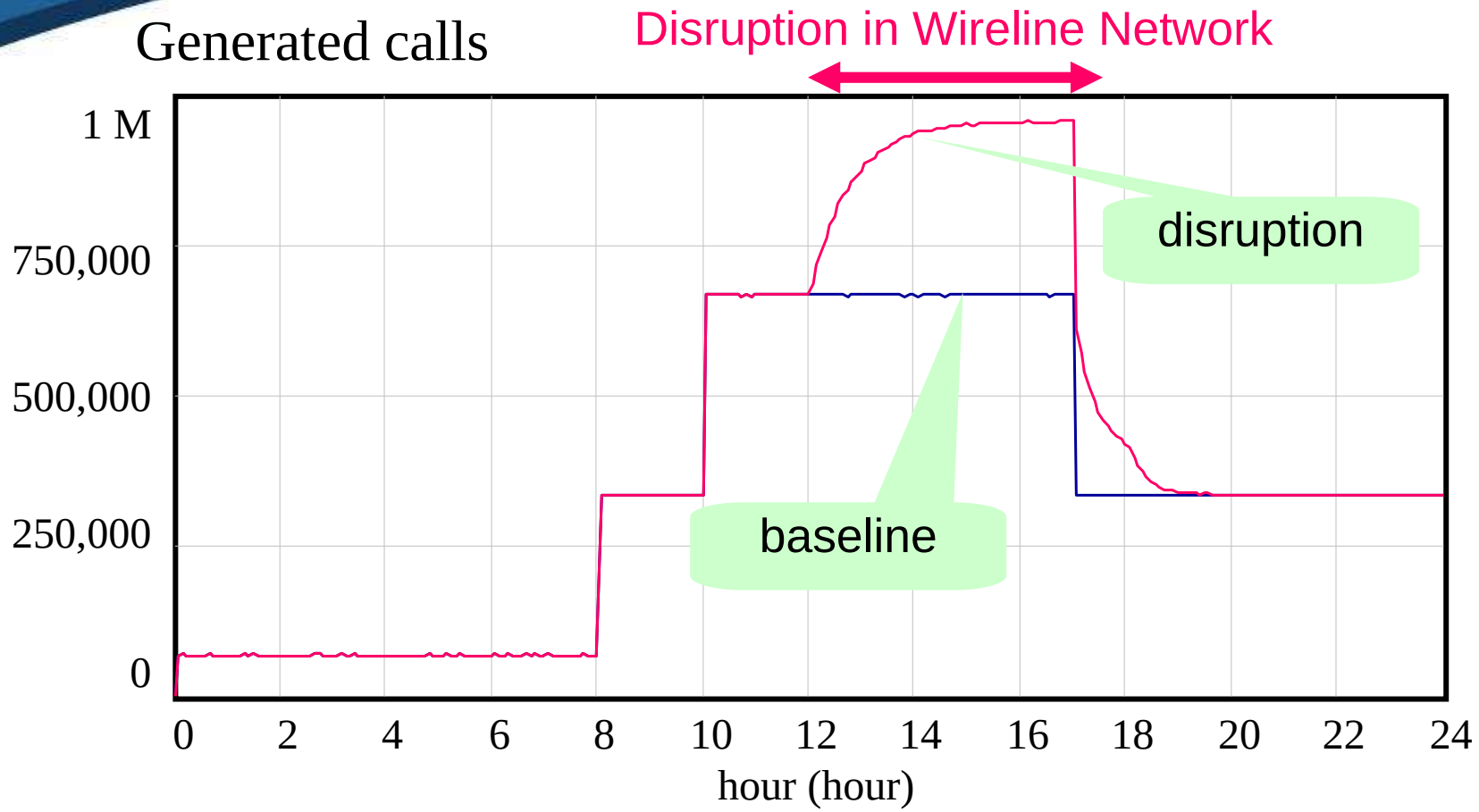
Shifting of disrupted calls between wireline and wireless networks



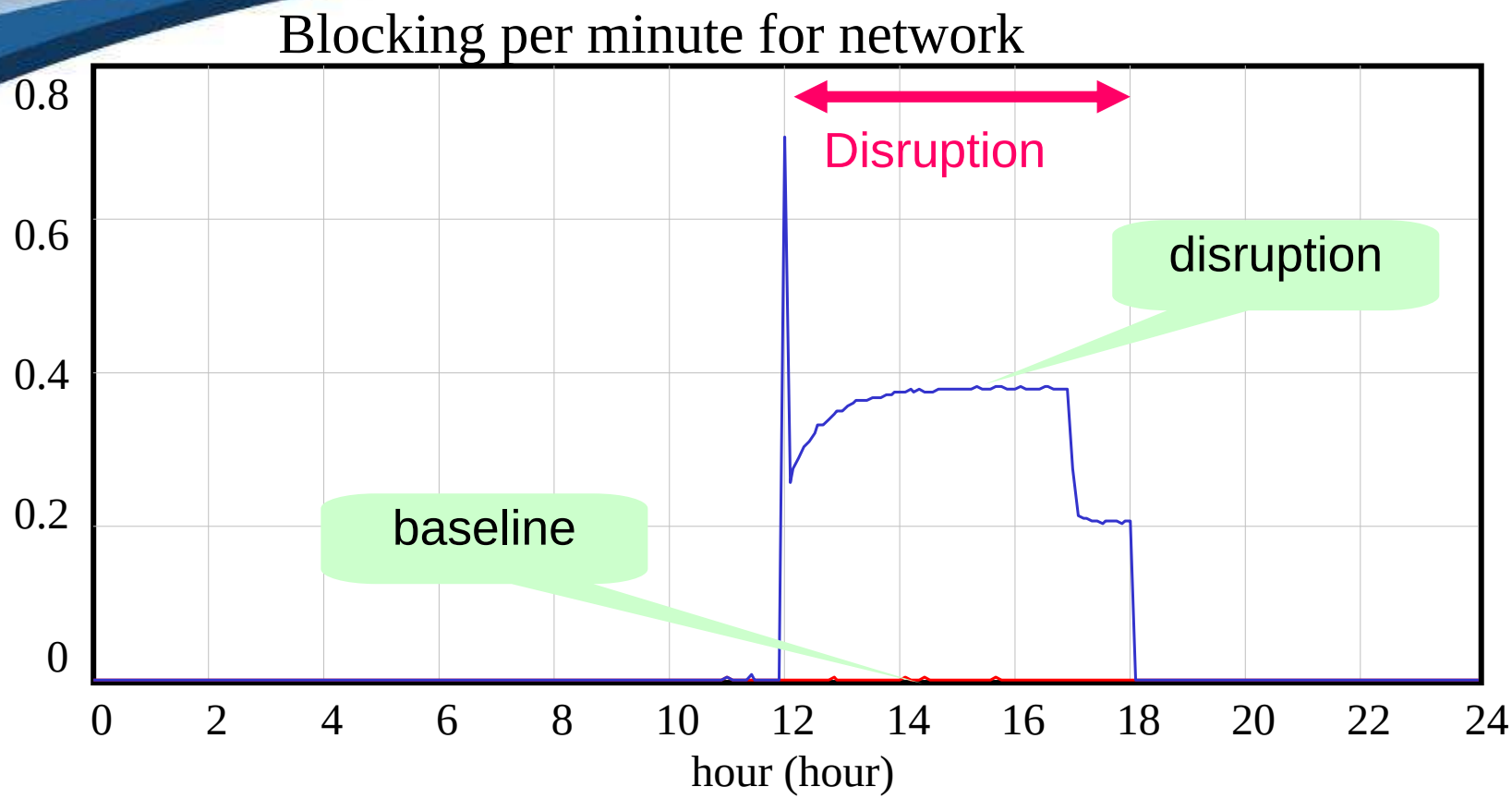
Example Disruption Scenario: 6 hour outage:
Discrete Event Simulation vs. Dynamic Simulation



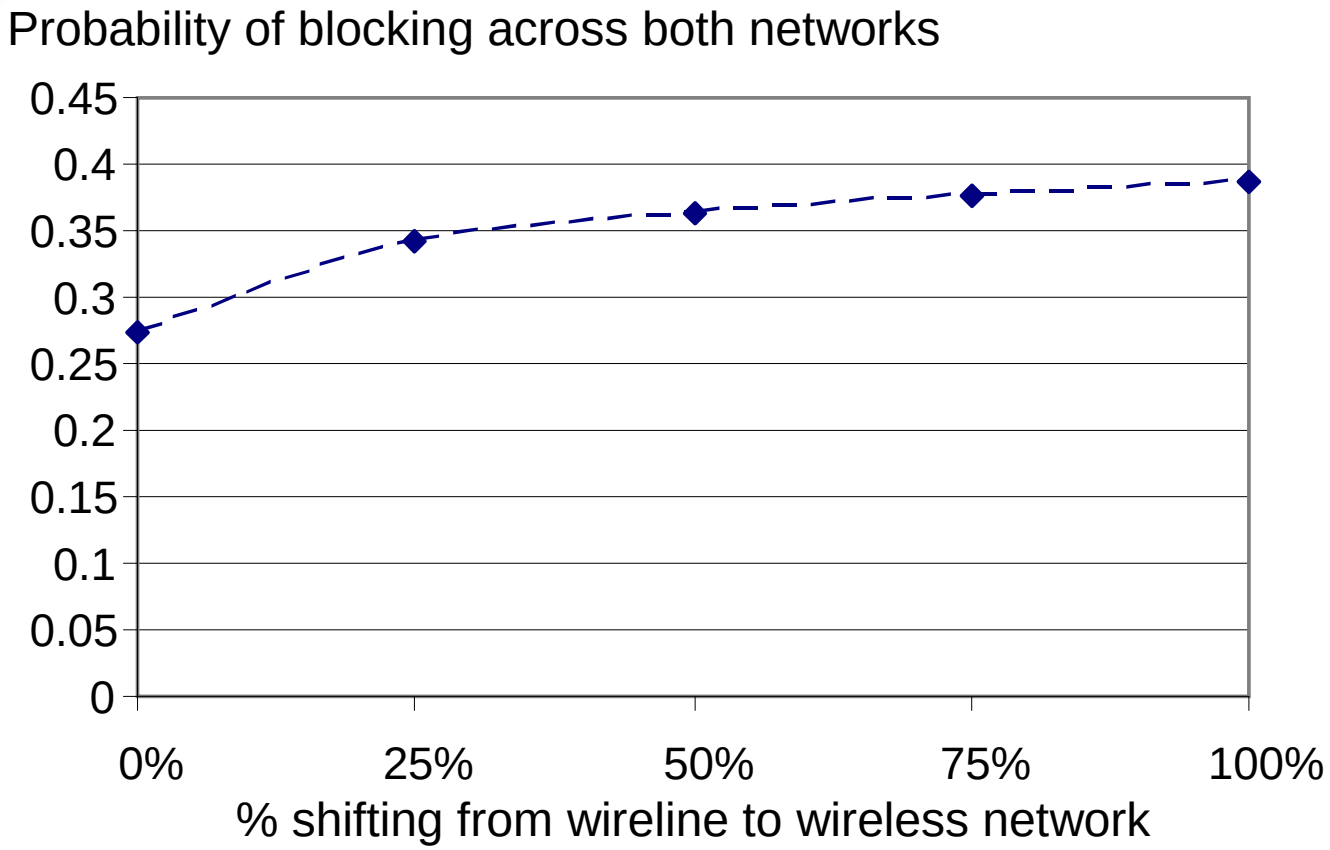
Generated calls (first attempts + reattempts)



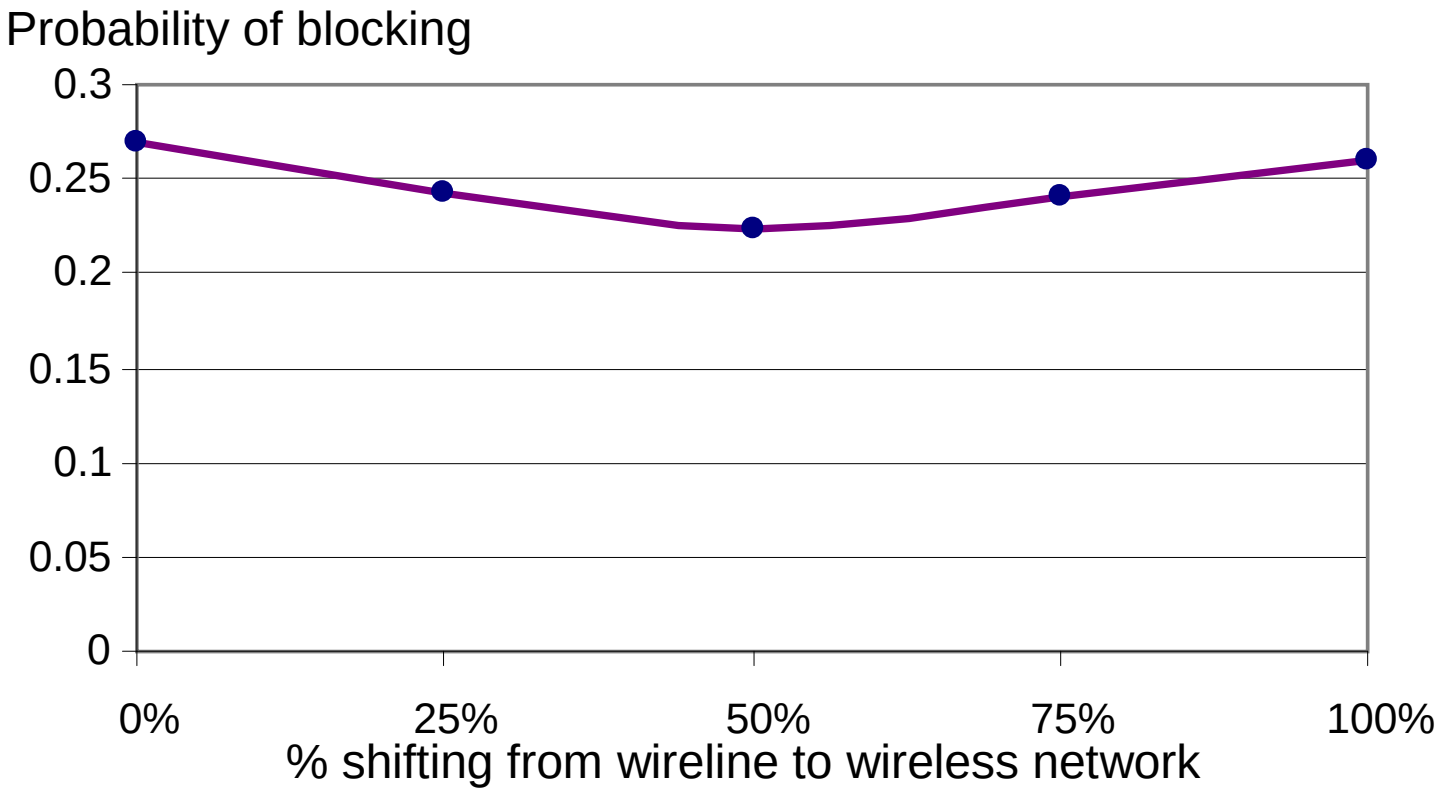
Blocking level for baseline and disrupt



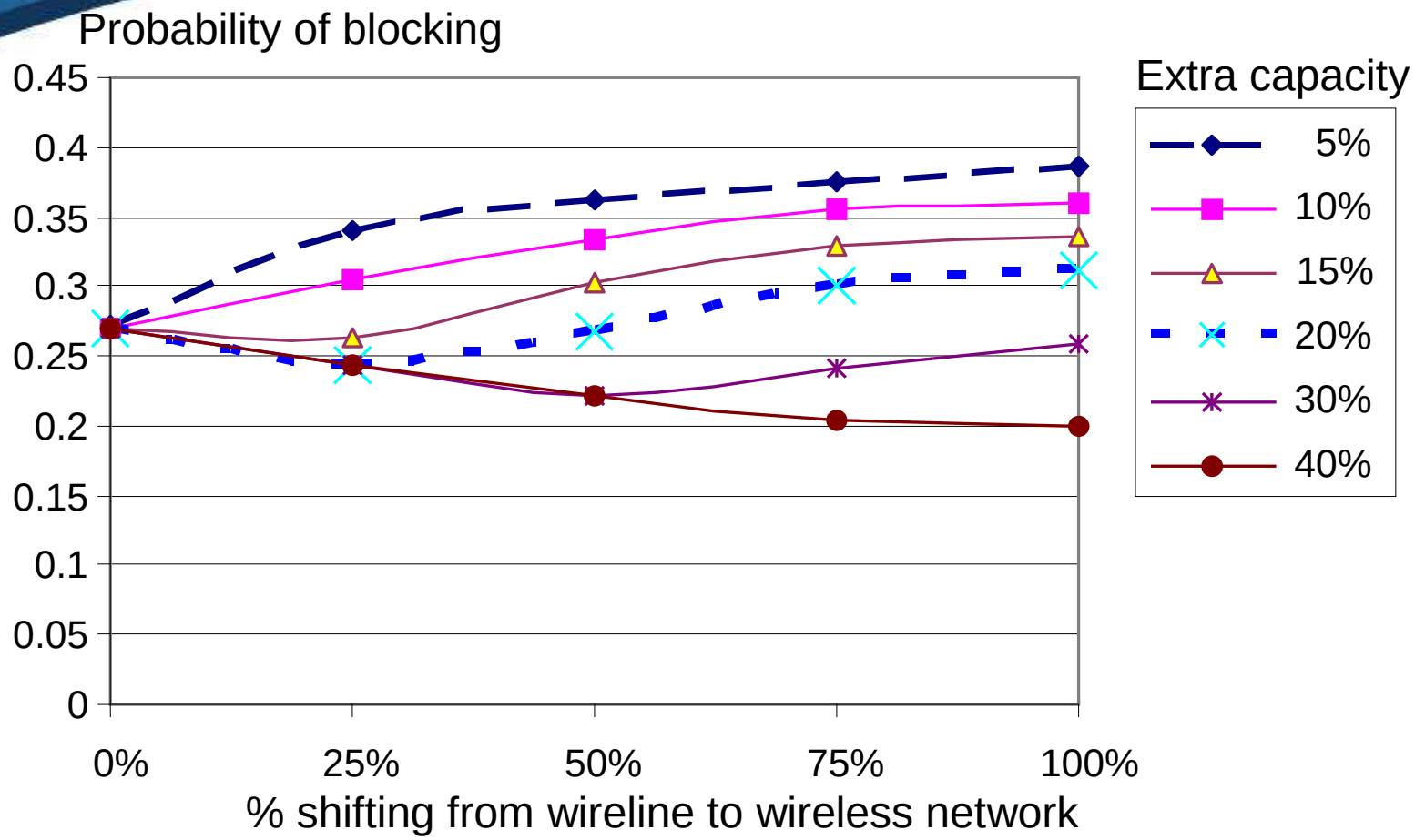
Blocking with 5% EXTRA wireless capacity



Blocking with 30% EXTRA wireless capacity



Blocking with 5%-40% EXTRA wireless capacity



What does all of this mean?

- Careful network planning of extra capacity to account for disruptions is required.
- Obviously, the more extra capacity in networks the better, but it comes with extra costs.
  - So, these extra costs must be traded off against the benefits they achieve and there will be a point of diminishing returns where the lower blocking levels and the extra calls completed are not worth the extra costs of that capacity.
  - Cost benefit trade-off is a simple extension of these models. There are optimal points of extra capacity to produce the minimum blocking levels (and therefore maximum network throughput) for a given shift in traffic from the distressed network to the non-distressed network.

Potential Uses of this System Dynamics Approach

- **Convergence: Conference Theme…..**Network Operators are now moving towards combining wireline and wireless functionalities and operations for greater efficiencies in network capital costs and operations costs.
  - Develop how best this might be done in protecting a working network from another network in distress using network management controls for maximizing throughput during disruptions.

- Many different outage scenarios can be modeled quickly from single disruptions to multiple disruptions of varying lengths of time.
  - An example future scenario where networks become largely VoIP (Voice over Internet Protocol) involves rolling blackouts from thunder storms which would knock out those VoIP services in households without back-up power.

Conclusions

- Dynamic simulation models can be a good choice in doing network capacity analysis for networks undergoing stress from man-made or natural disasters. They can model complex situations in a fast and efficient manner for a number of different problem sets.

- Run Time Differences (secondary factor)
  - Dynamic simulations are very fast on the order of just 1 second on a laptop to run the model for 24 hours.
  - Discrete event simulations run much slower, since its time clock and events are real time, based on call arrivals (can be milliseconds apart or less), across hundreds of switches and millions of lines. Typical discrete-event times for a simulation run for 24 hours are approximately 20 minutes.

  ➔three orders of magnitude faster for the dynamic simulation.