# A Performance Evaluation Architecture for Hierarchical PNNI and Performance Evaluation of Different Aggregation Algorithms in Large ATM Networks

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# Organization

- PNNI Basics
- Motivation
- Implementation
- Performance Metrics
- Experiments and Results
- Conclusions and Future Work

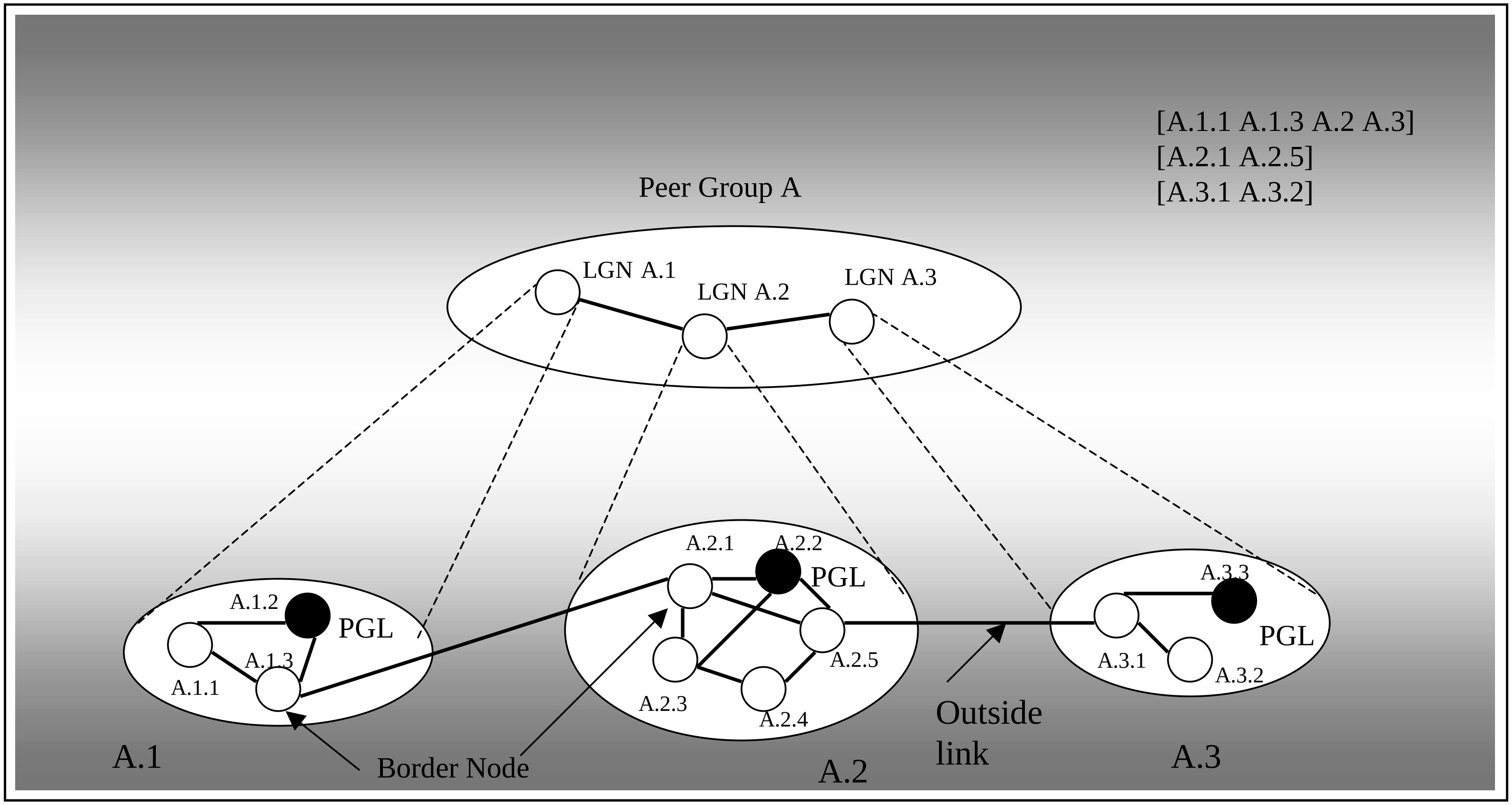
# PNNI Basics

- PNNI (Private Network to Network Interface) is a comprehensive routing and signaling protocol in ATM Networks
  - Link State Routing Protocol
  - Source Routing Protocol
  - Hierarchical Routing Protocol
- Reattempts failed calls using Crankback and Alternate Routing
- As size of the peer group increases, the topology database size and PNNI Data overhead increases. For scalability, peer groups of reasonable size are formed
- Each peer group has complete state information about its own peer group and aggregated information about foreign peer groups

# Motivation

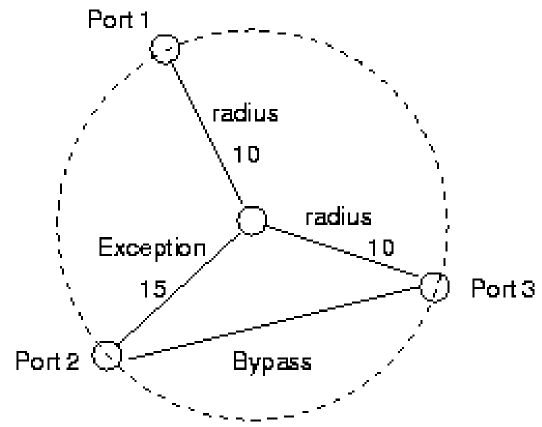
- Design and implement Multiple Peer Group functionality in the KUPNNI simulator to study the performance of the PNNI protocol in Hierarchical ATM Networks
- Propose, implement and evaluate different topology aggregation schemes
- Develop a comprehensive simulation tool that can help network engineers evaluate the performance of hierarchical ATM networks before actually deploying them

# PNNI Hierarchy



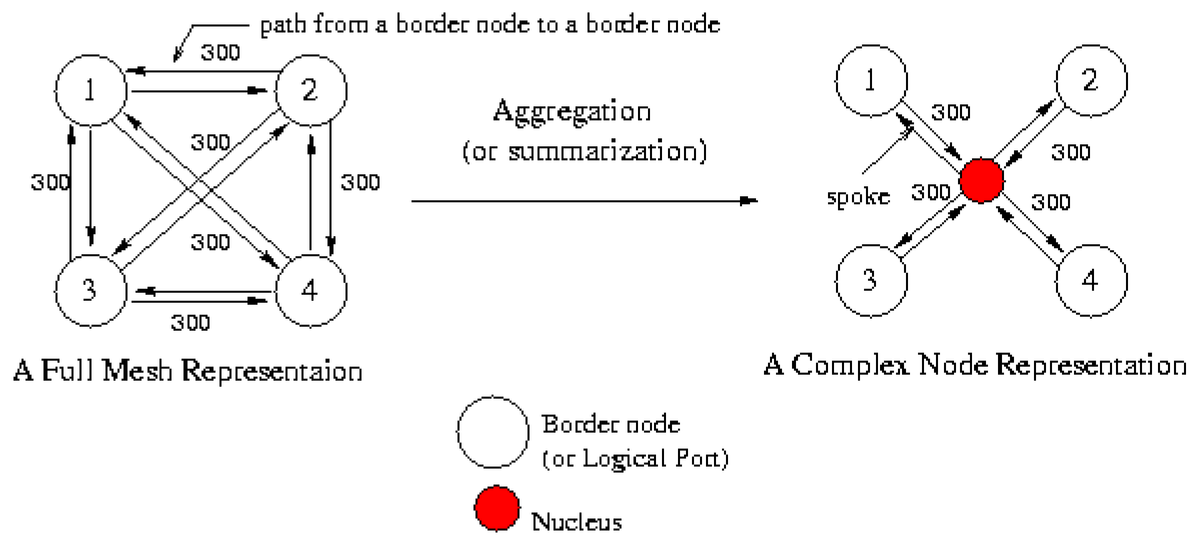
# Implementation

- Creation of Uplinks
- PGL Nomination and Aggregation Trigger
- Aggregation consists of *Nodal and Link Aggregation*
- Our simulator supports both
  - Simple node representation
  - Complex node representation



# Aggregation

- Nodal Aggregation consists of the following steps:
  - group the network into domains
  - derive the port-to-port distances as a *full mesh*
  - represent the port-to-port distances in a compact way
  - exchange the aggregated information among domains
- Conversion from *full mesh* to *star*



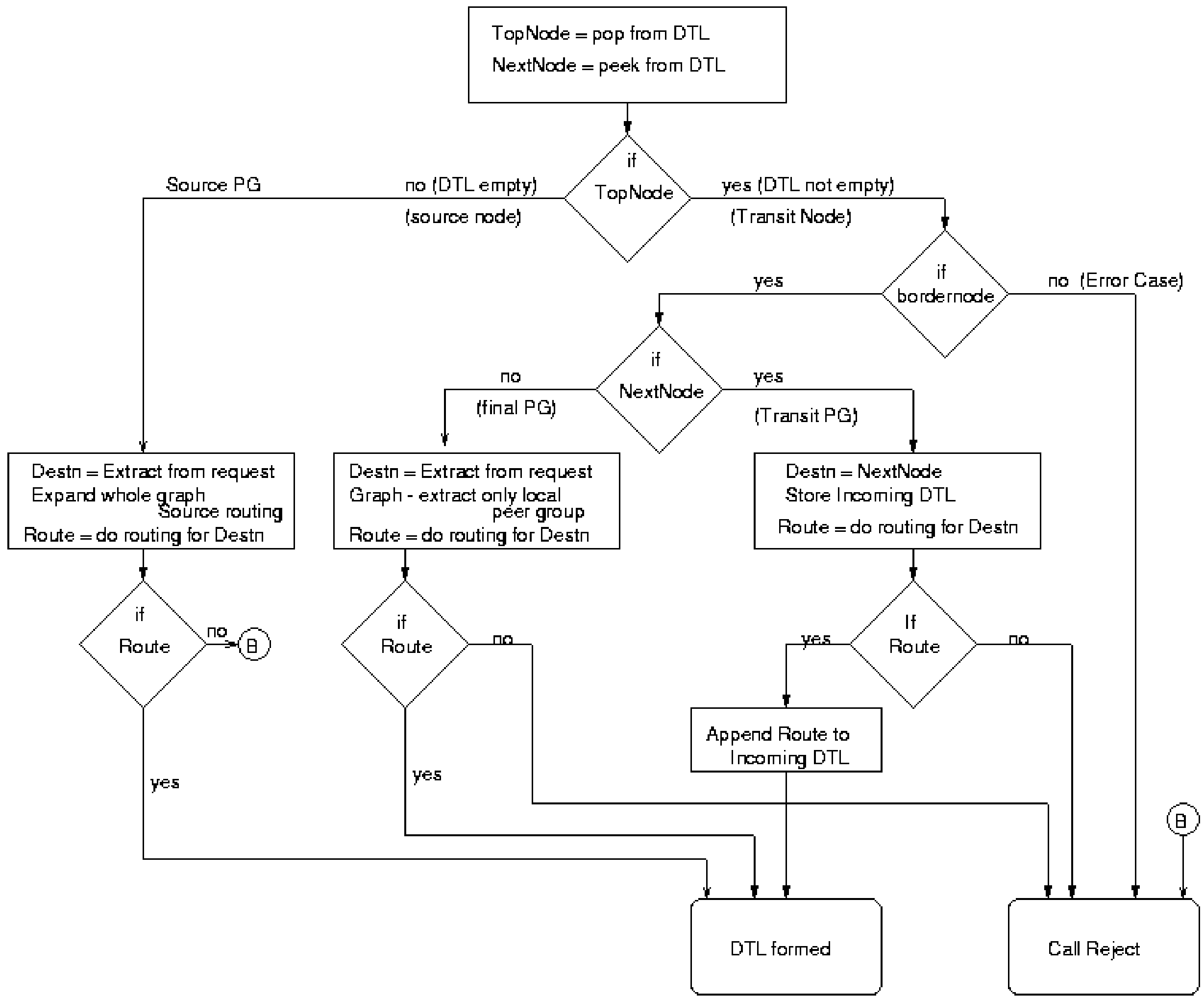
# Aggregation (continued)

- The different nodal aggregation schemes implemented are:
  - Full Mesh
  - Symmetric Star
  - Asymmetric Star (Pessimistic, Optimistic, Average)
  - Simple Node Representation
- Link Aggregation is part of constructing the PNNI hierarchy
- Link aggregation summarizes the outside links between peer groups and represents them as logical links in the next higher level in the hierarchy
- The state parameters of the logical link are derived from the underlying physical link - Optimistic, Pessimistic or Average values chosen

# Routing in Hierarchical PNNI

- When a new call request comes, the complex node needs to be expanded in the graph representation of the network for routing
- Source Routing - entire graph needs to be constructed
- Transit Routing - a subset of PNNI Topology State Element (PTSEs) are extracted from the database and expanded
- The source node gives a hierarchically complete DTL
- Expansion of DTL at the ingress border node of every intermediate and destination peer group
- Reaggregation at periodic intervals

# Route Computation Flowchart



# Performance Metrics

- $\text{Average Call Failure Rate} = \dfrac{\text{Total Number of Rejected Calls}}{\text{Total Number of Requested Calls}}$

- $\text{Average Call Setup Time} = \dfrac{\text{Total Call Setup Time}}{\text{Total Number of Successful Calls}}$

- $\text{Link Utilization} = \dfrac{\text{Used Link Bandwidth}}{\text{Total Link Bandwidth}}$

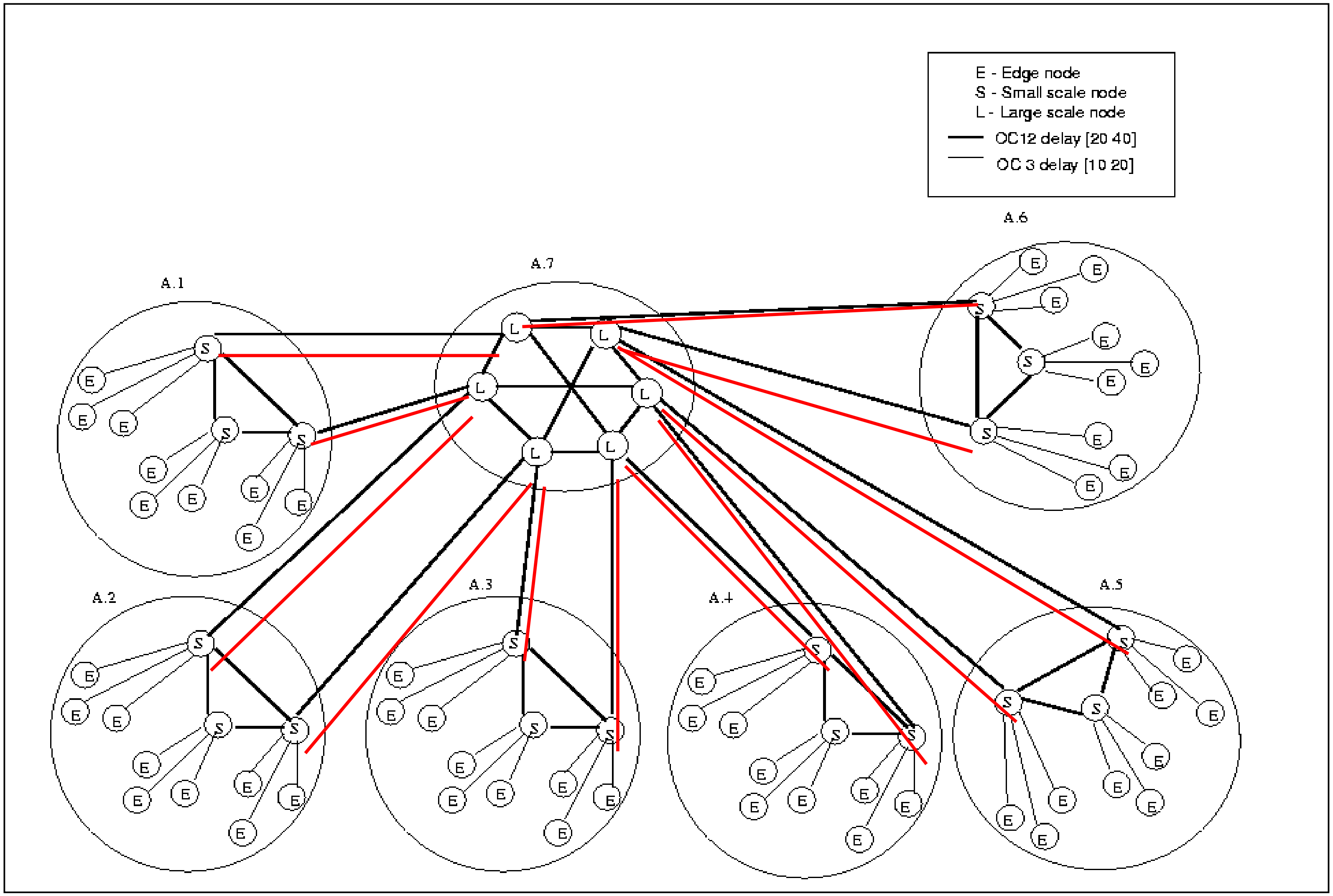
- Topology Database Size
- Convergence Time
- Aggregation Time
- Volume of PNNI Data

# Experiments and Results

# Test Scenarios

- Varying outside connectivity in Edge-Core Topology
- Peer Group Size Studies
- Aggregation Policy Evaluation
- Reaggregation Studies
- Source Routing vs Transit Routing
- Scalability Test

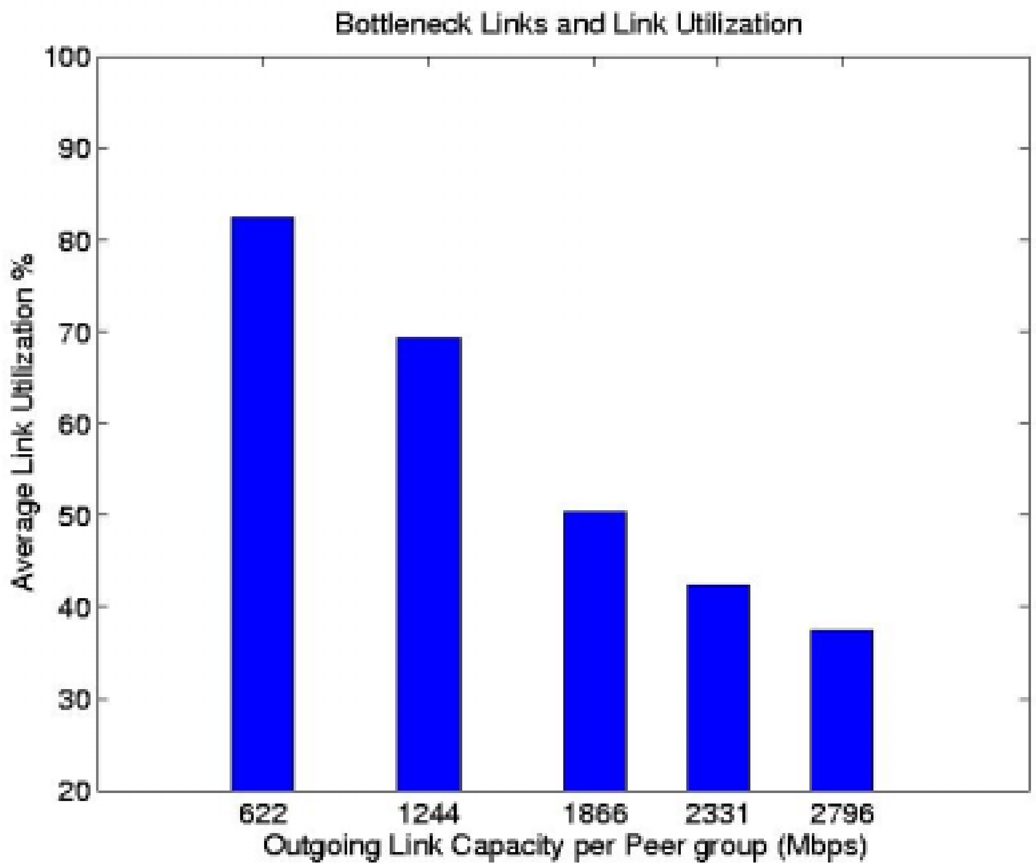
# Edge-Core Topology



# Experiment Space for Edge Core Topology

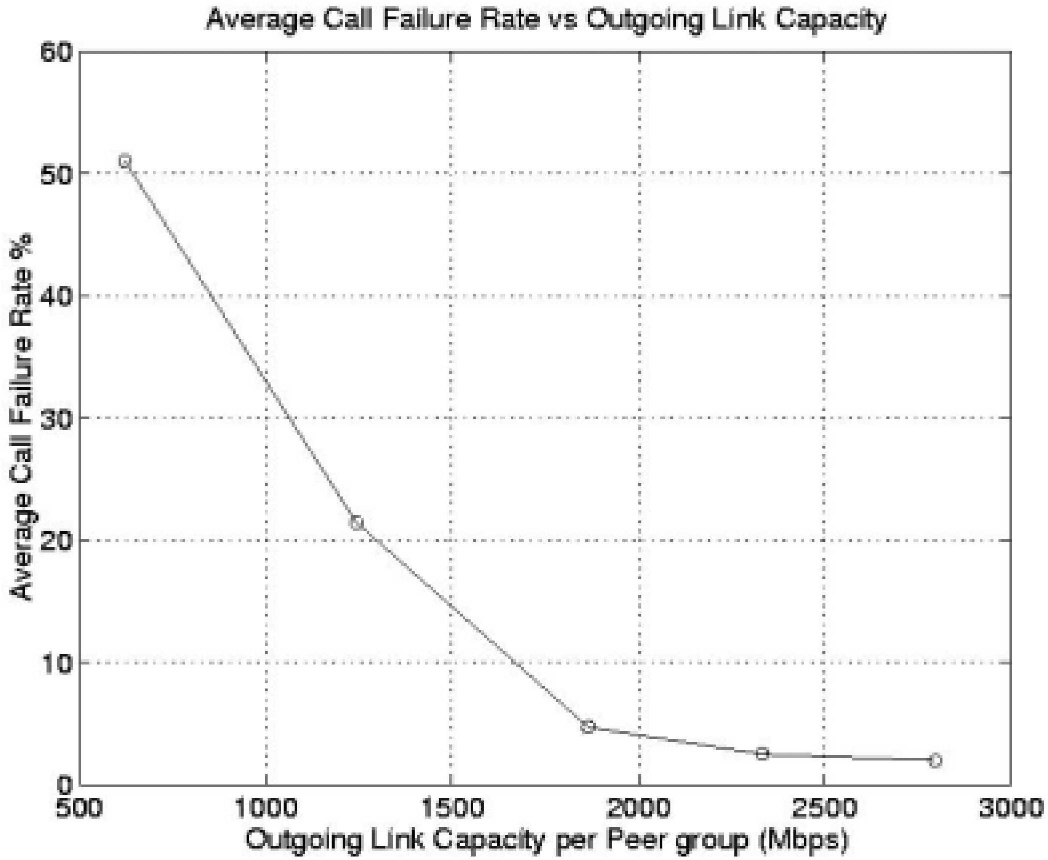
| | |
|---|---|
| Number of calls per host | 100 |
| Total Number of calls | 5400 |
| Destinations | Uniformly chosen from all hosts |
| Call bandwidth | CBR traffic, Uniform, 8-10 Mbps |
| Call duration | Poisson with mean 60 sec |
| Call arrival | Poisson with mean 5 sec |
| Node Representation | Complex with Asymmetric Average |
| Routing policy | Widest minhop |

# Link Utilization Test



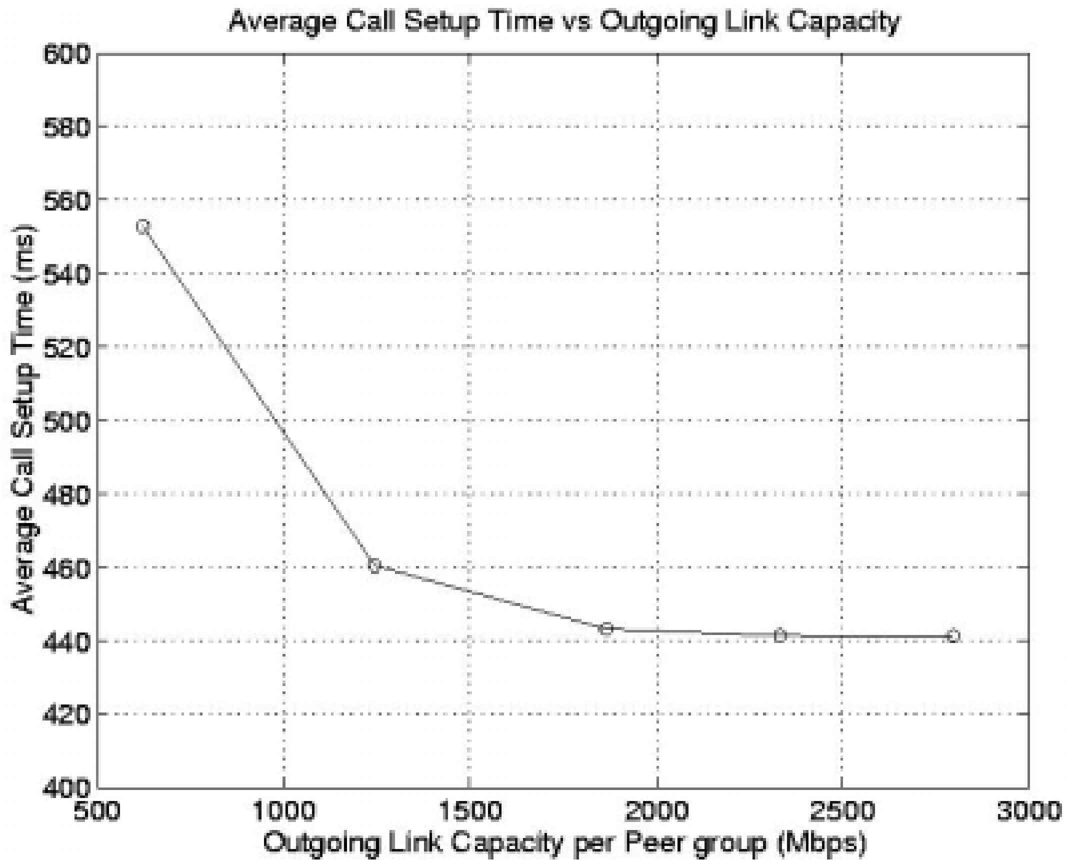

The lesser the outgoing link capacity, the greater the congestion and these links become bottle necks

# Call Failure Rate vs Outside Connectivity



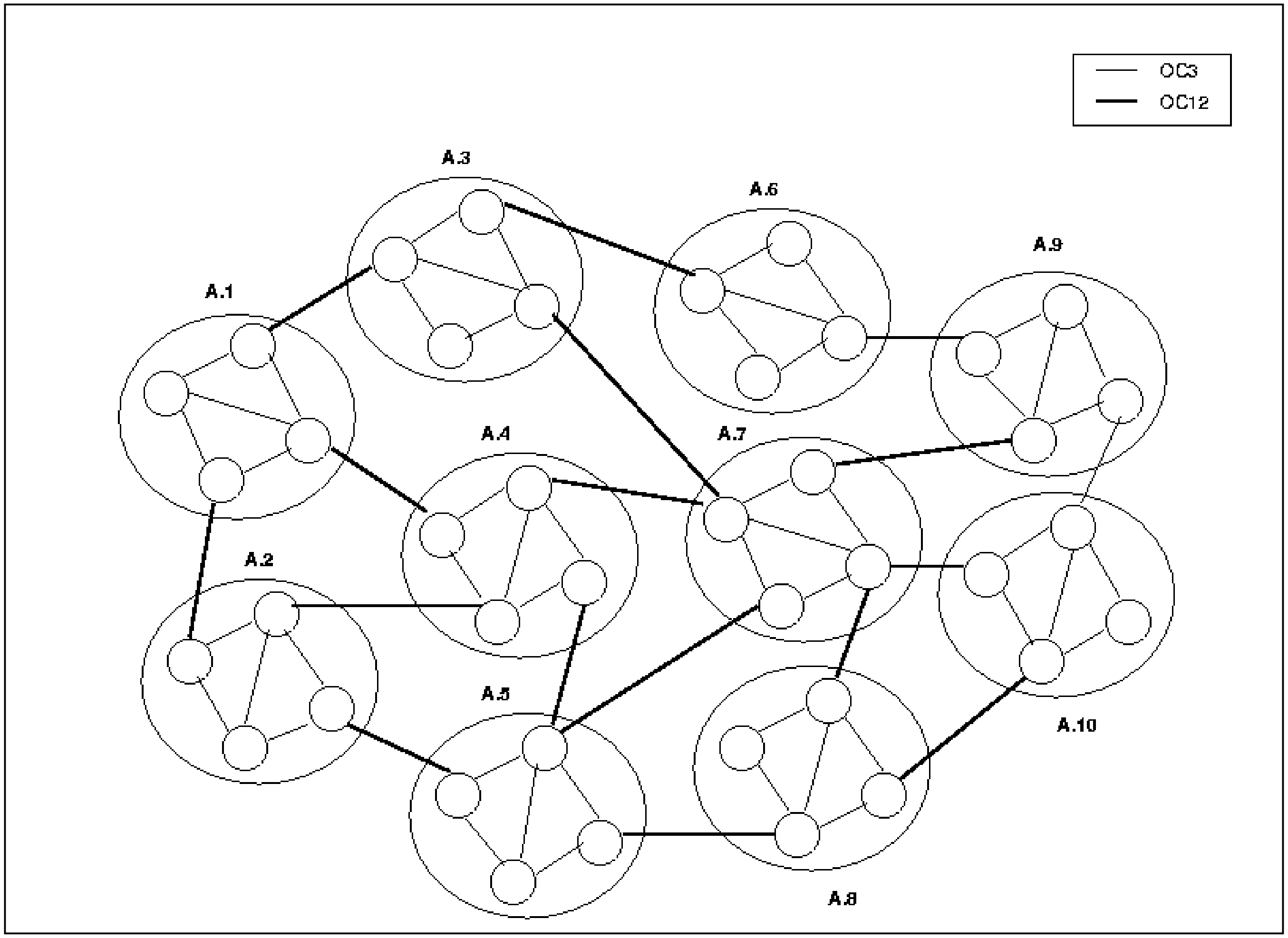

Call Failure Rate reduces with increase in outgoing link capacity

# Average Call Setup Time vs Outside Connectivity




Average Call Setup Time reduces with increase in Outside Connectivity

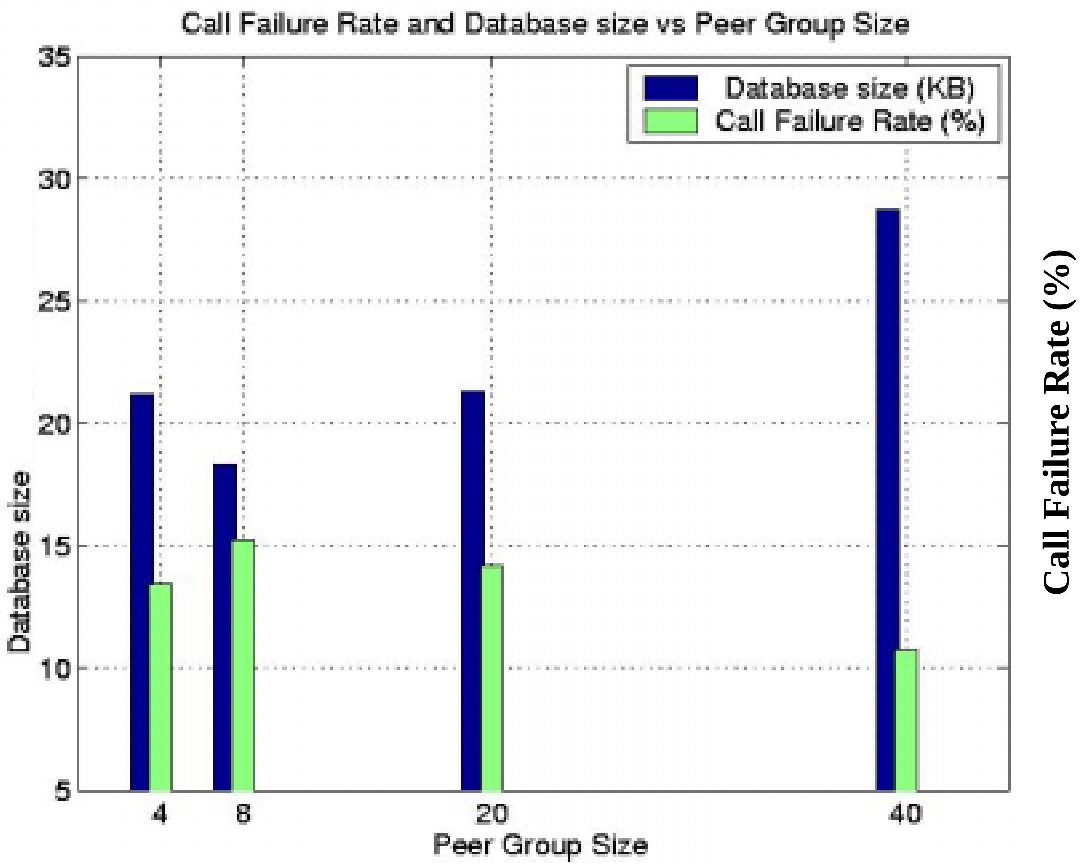
# Peer Group Size Studies with Multi Cluster Topology



# Experiment Space For Peer Group Size Studies

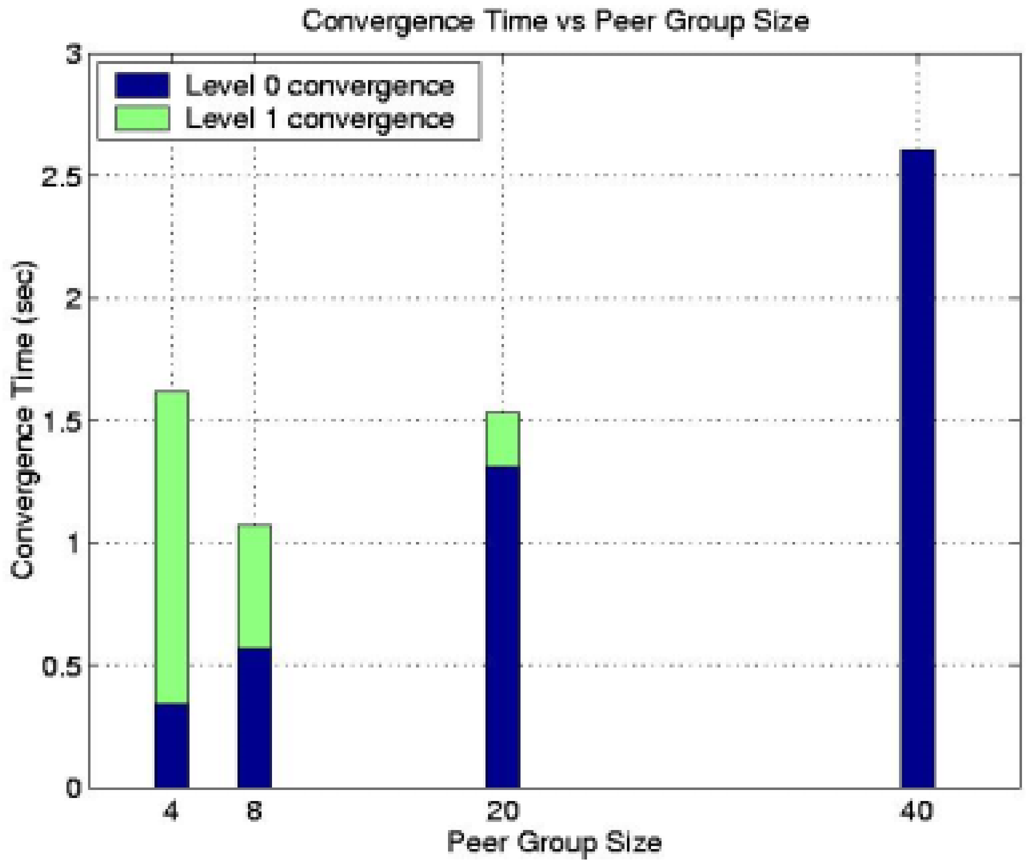
| Parameter | Value |
|---|---|
| Number of calls per host | 100 |
| Total number of calls | 4000 |
| Destinations | Uniformly selected from all hosts |
| Call bandwidth | CBR traffic, Uniform 1-8 Mbps |
| Call duration | Poisson with mean 60 seconds |
| Call arrival | Poisson with mean 5 seconds |
| Node Representation | Complex node with Asymmetric Average |
| Routing policy | Widest minhop |

# Database Size and Call Failure Rate vs Peer Group Size



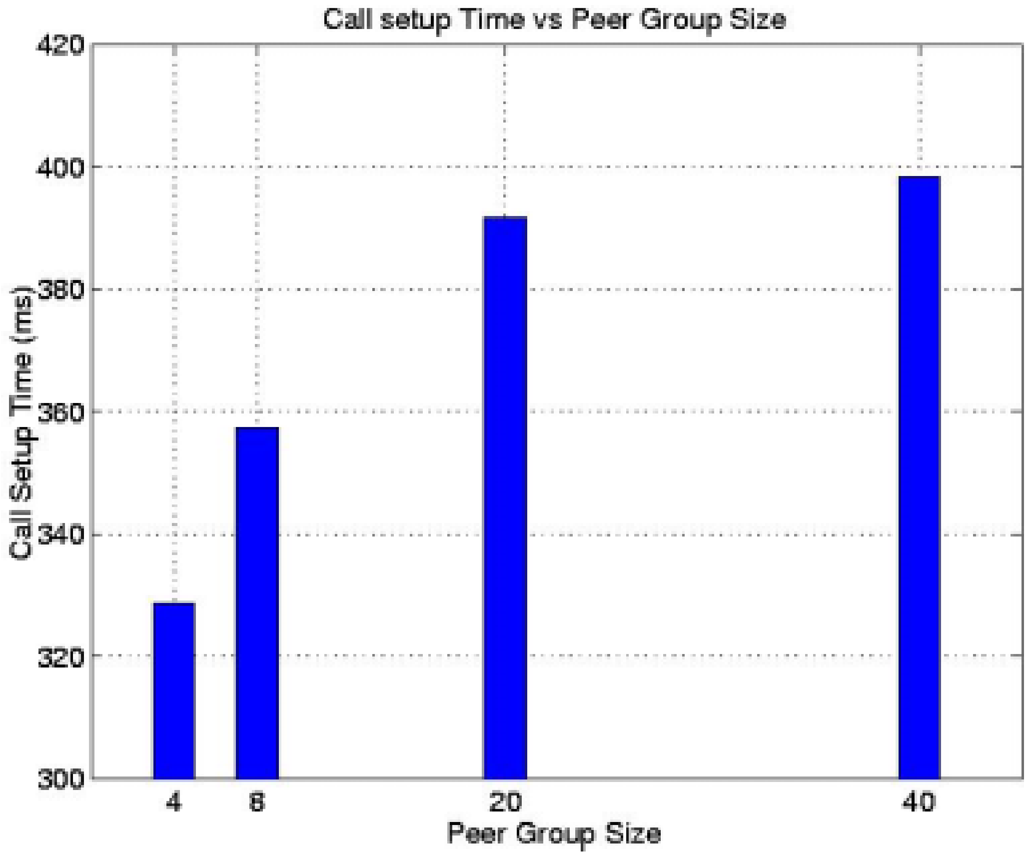

The greater the topology database size, the richer the state information and lower the call failure rate

# Convergence Time vs Peer Group Size




Convergence Time is highest for a single peer group and is the lowest for a peer group size of 8

# Call Setup Time vs Peer Group Size

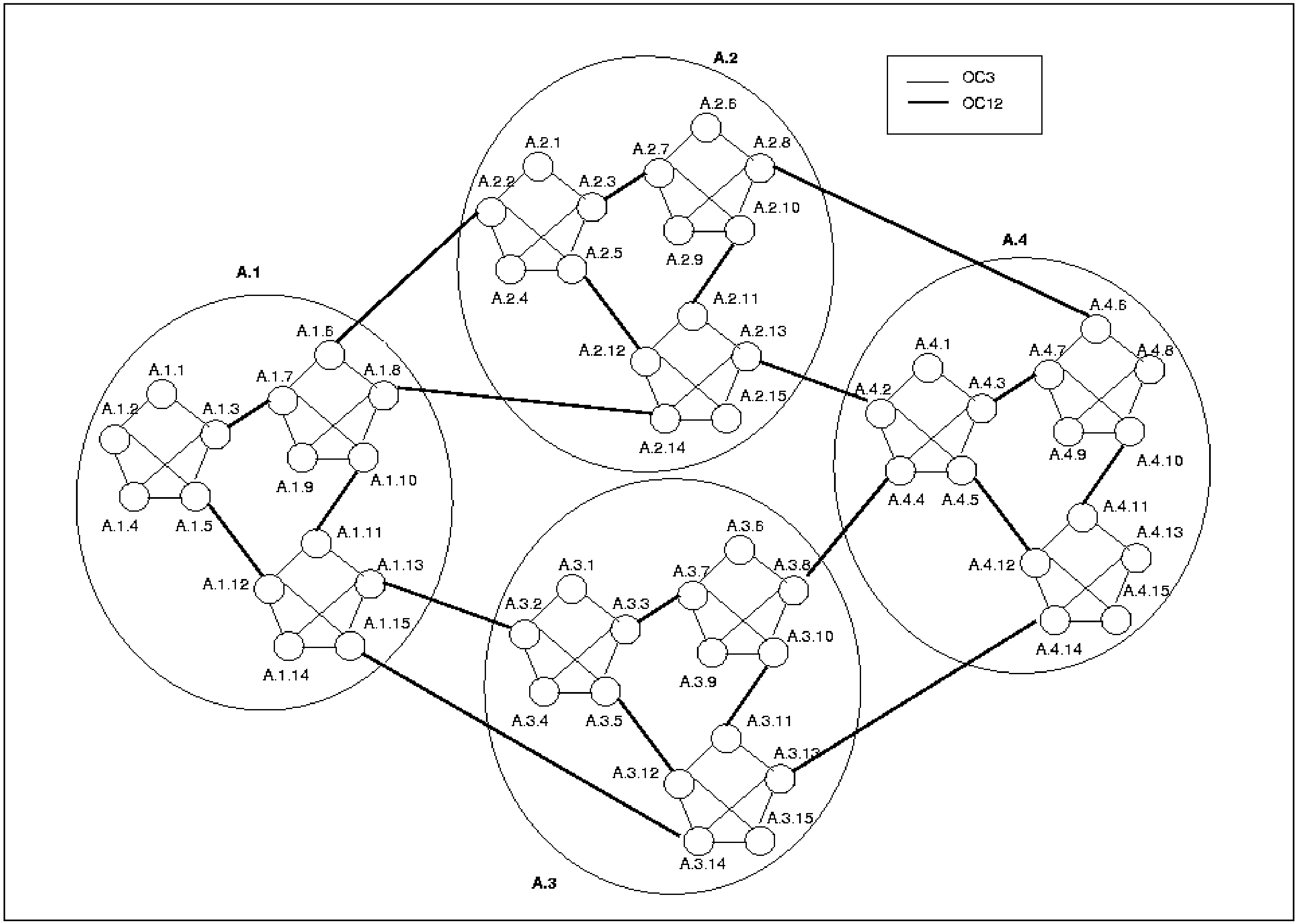



Call Setup Time reduces as peer group size reduces because the time taken for routing decreases with decrease in peer group size

# Results from Peer Group Size Studies

- Topology database size reduces with decrease in peer group size up to a point, after that the database size increases
- Call setup times reduce with decrease in peer group size
- Volume of PNNI topology update messages reduces considerably with decrease in peer group size
- Time taken for aggregation reduces with decrease in peer group size
- Call failure rate is directly dependant on the topology database size, the richer the state information, the lower the call failure rate

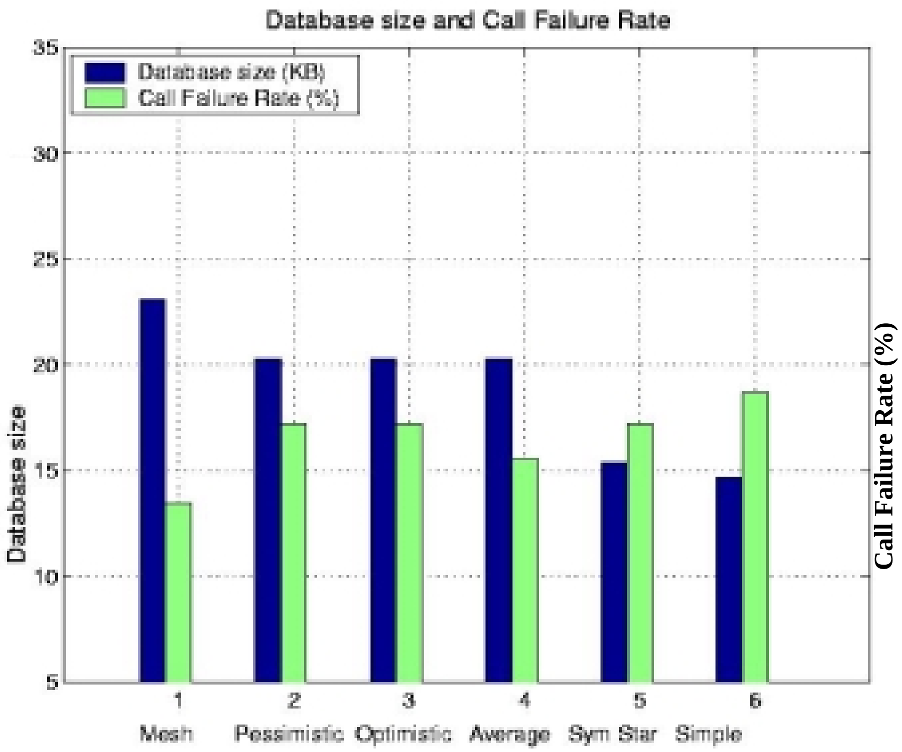
# 4-Cluster Topology

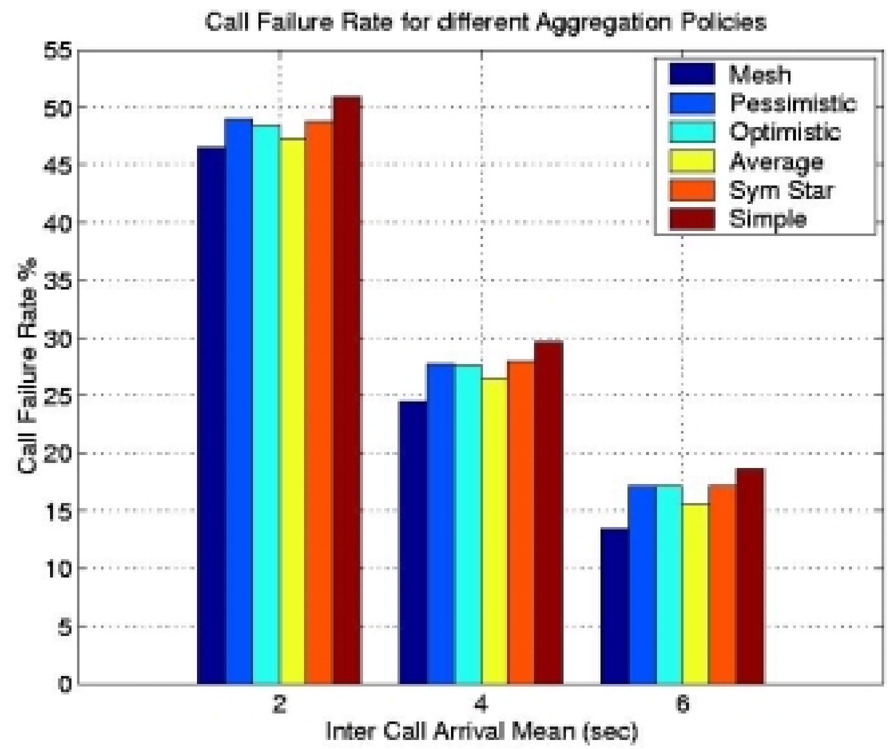


# Experiment Space For 4-Cluster Topology

| Parameter | Value |
|---|---|
| Number of calls per host | 100 |
| Total number of calls | 4500 |
| Destinations | Uniformly chosen from all hosts |
| Call bandwidth | CBR traffic, Uniform 1-10 Mbps |
| Call duration | Poisson with mean 60 seconds |
| Call arrival | Poisson with mean 5 seconds |
| Routing policy | Widest minhop |

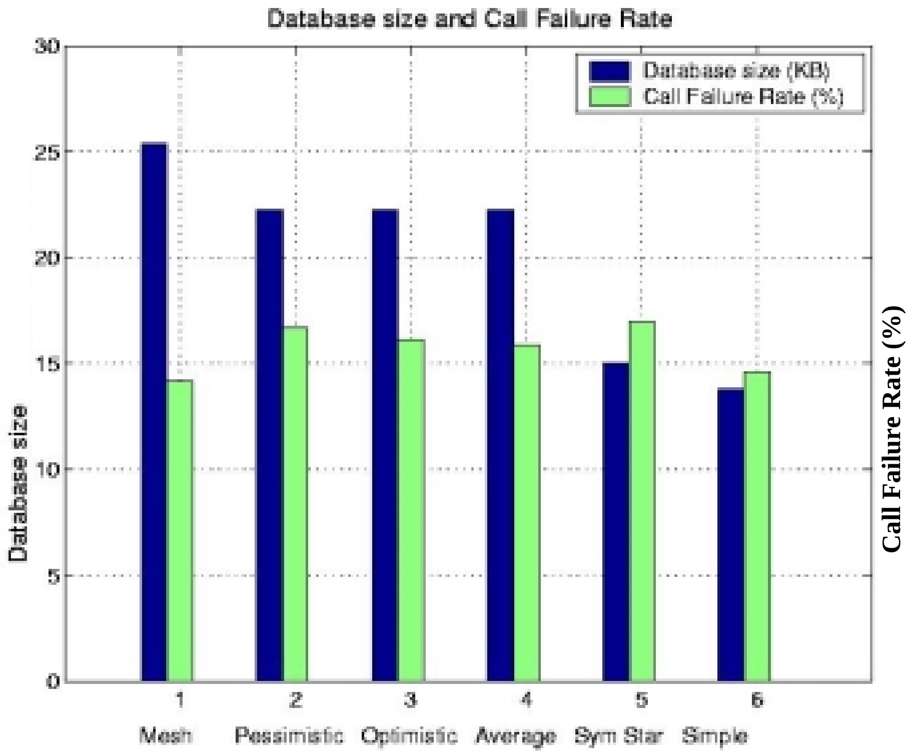
# Topology Database Size and Call Failure Rate for Different Aggregation Policies in 4-Cluster Topology

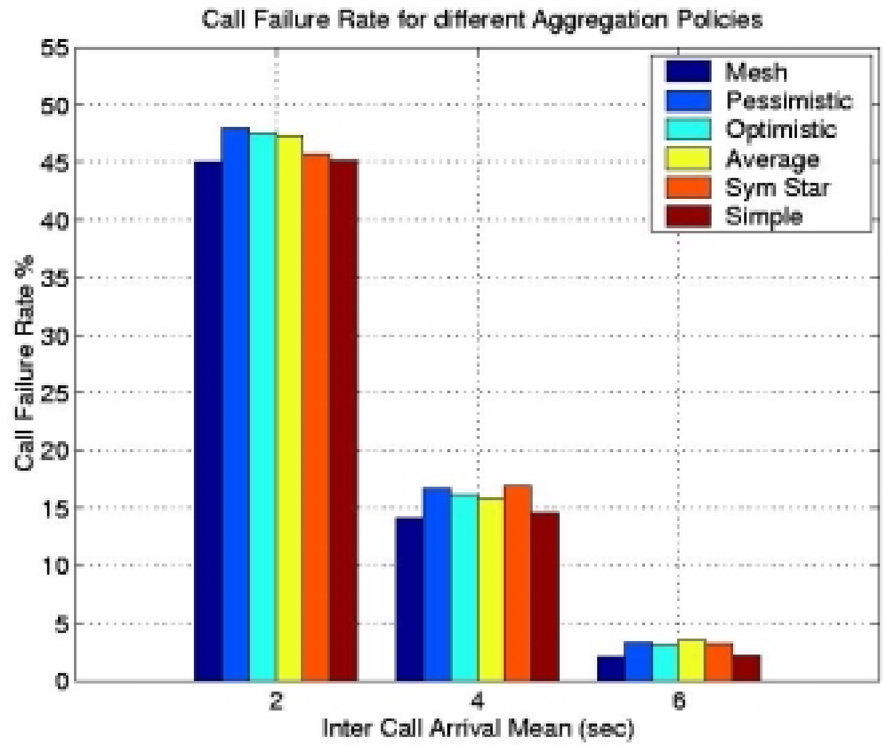



Mesh Representation has the lowest call failure rate and simple representation has the highest call failure rate

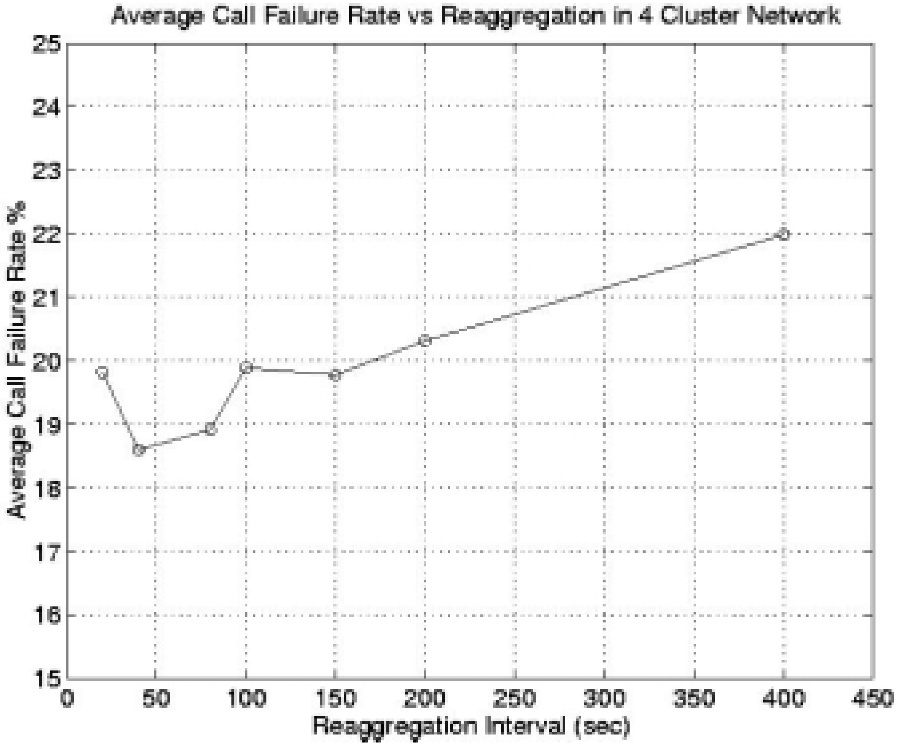
# Topology Database Size and Call Failure Rate for Different Aggregation Policies in Edge-Core Topology

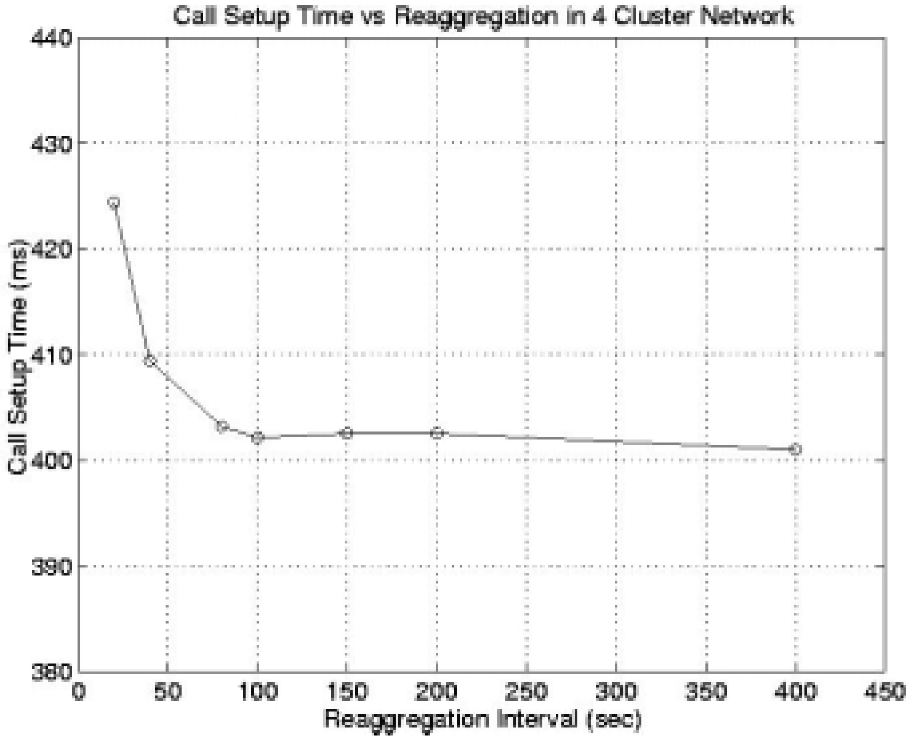



Mesh Representation and Simple Representation have almost the same call failure rate.

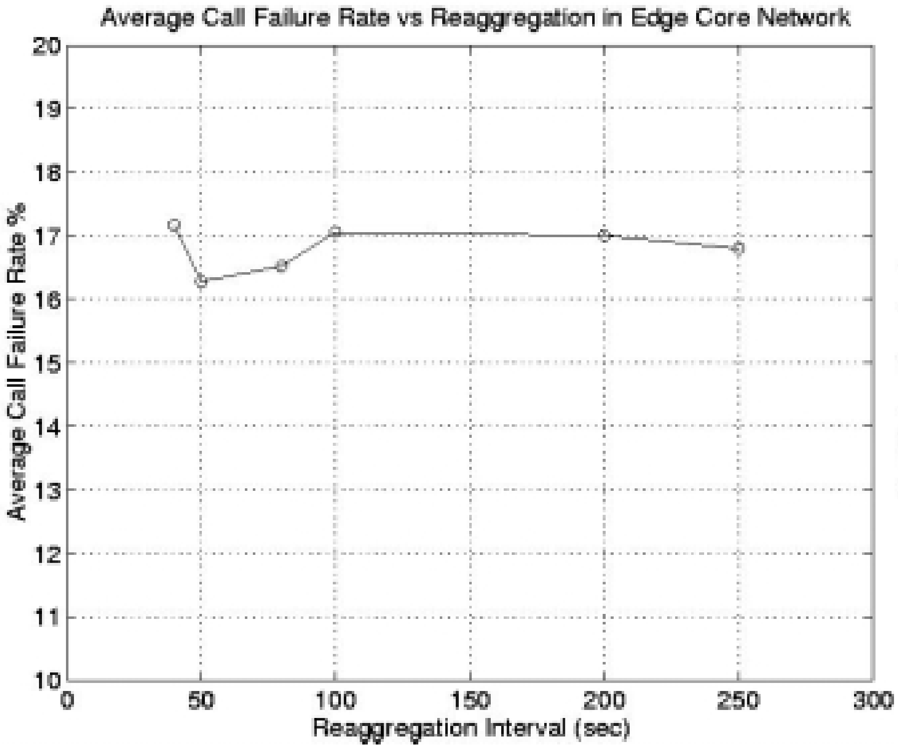
# Reaggregation Studies in 4-Cluster Topology

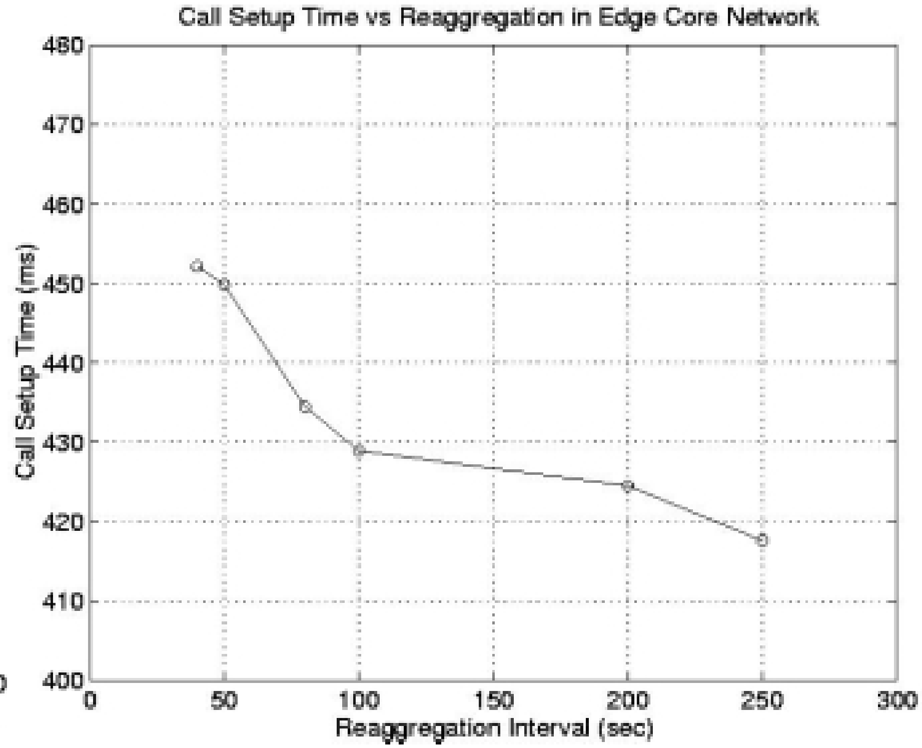



At too small and too large values of the reaggregation timer, call failure rate increases. Call Setup Time and Volume of PNNI data decrease as reaggregation timer increases

# Reaggregation Studies with Edge-Core Topology

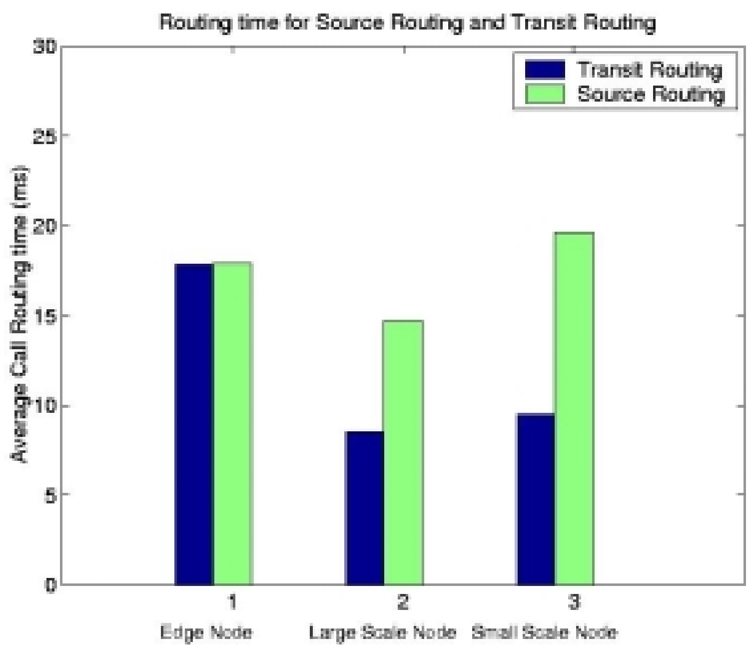



The call failure rate does not vary much with reaggregation intervals, however the call setup time and volume of PNNI data decreases with increase in the reaggregation timer value

# Source Routing vs Transit Routing

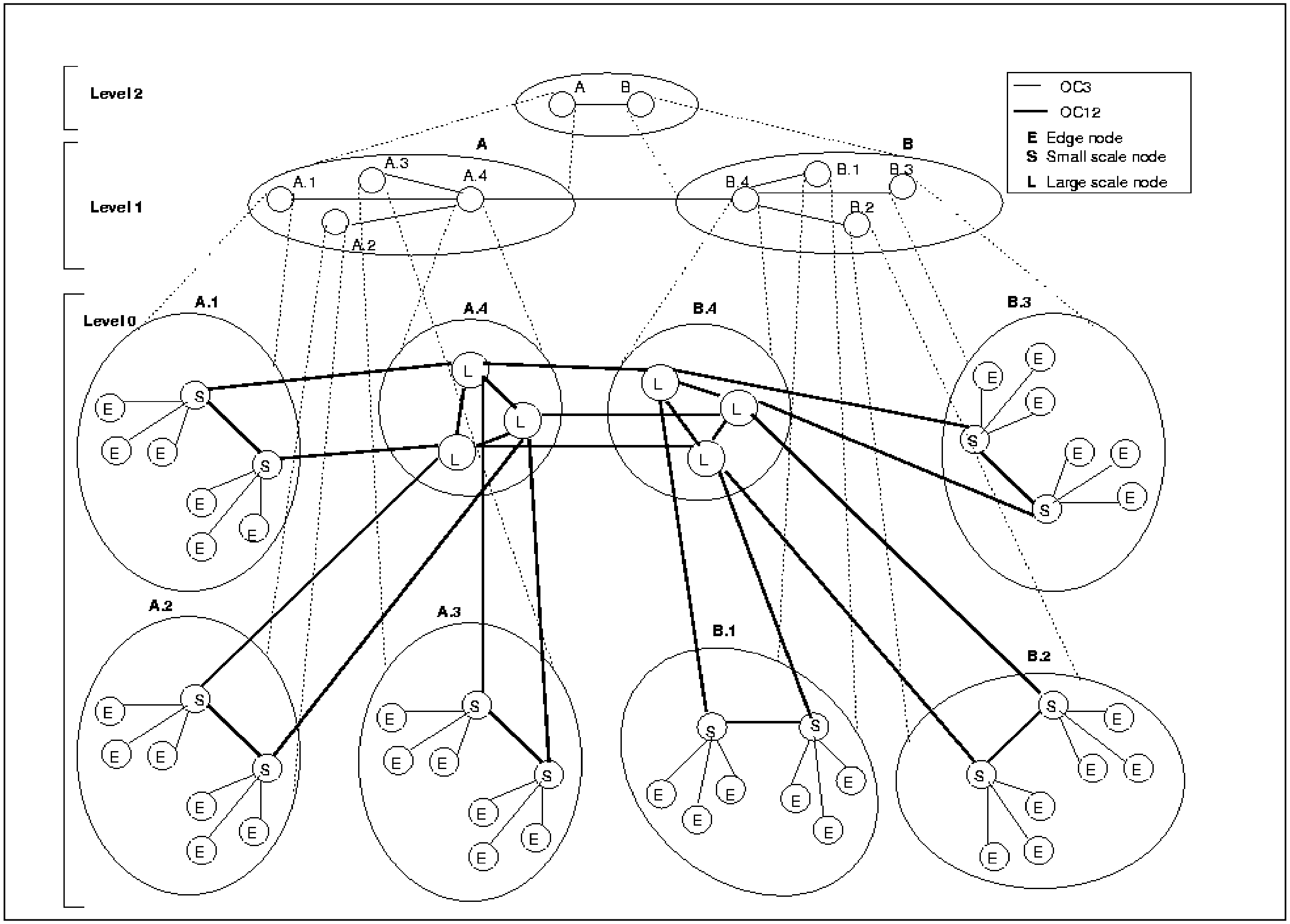
- Source Routing - Entire graph constructed from the database
- Transit Routing - The graph constructed from a subset of PTSEs extracted from the database




Routing Times and Call Setup Times reduce in Transit Routing

Call Failure Rate decreases slightly for Transit Routing

# Scalability Test



# Results for Scalability Test

| Performance Metric | 1 Level | 3 Level |
|---|---|---|
| Database Size (KB) | 27.792 | 9.28 |
| PNNI Data (KB) | 86497.8 | 9727.52 |
| Call Success Rate (%) | 98.58 | 88.41 |
| Call Setup Time (ms) | 438.071 | 425.607 |
| Convergence Time (ms) | 3500 | 662 |

# Conclusions

- Varying Outside Connectivity

  - Outside links should have sufficient capacity to carry inter peer group traffic and avoid bottle necks
  - As the average outgoing link capacity increases, the average call failure rate and the average call setup time reduces

- Peer Group Size Studies

  As peer group size reduces

  - Topology database size reduces up to a certain point
  - Volume of PNNI data decreases
  - Aggregation time reduces
  - Call setup time reduces
  - Call failure rate directly depends on the database size

# Conclusions (continued)

- Aggregation Policy Evaluation

  Edge Core Topology

  - Mesh and Simple Representation have almost same call failure rate
  - Routing computation complexity and state information maintained by full mesh representation is highest

  4-Cluster Topology

  - Mesh is the most accurate and has the least call failure rate but database size is large
  - Because of insufficient information, simple representation has high call failure rate and high call setup time
  - Asymmetric Average seems to be a good balance between database size and call failure rate

# Conclusions (continued)

- Reaggregation has to be done at periodic intervals, but having too small or too large values for the reaggregation timer is not advisable
- Transit Routing at the intermediate and destination peer groups reduces routing time and call setup time
- Single peer group has its advantages in terms of better call failure rate, but is not scalable. Hierarchy gives scalability to the PNNI protocol

# Future Work

- Crankback and Alternate Routing
- Advanced Aggregation Algorithms
  - Hybrid Aggregation Algorithm
- Performance of Multiple Criteria Routing Algorithms in Multiple Peer Groups
- Reaggregation based on significant change within the peer group is a good research topic

# Thank You

Questions ?