

# Large Scale WAN Emulation

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# Outline

- Overview of WAN Simulation & Emulation
- Introduction to IP-TNE
- Discussion of Related Projects
- Validation of IP-TNE
- Current Projects Involving IP-TNE
- Future Work

# Performance Evaluation Approaches

## 1. Experimental

- + offers the most realistic environment
- requires significant financial investment
- can be difficult to repeat results
- restricted to existing technologies

# Performance Evaluation Approaches

## 2. Simulation

- + low-cost, flexible, controllable, reproducible environment
- abstractions can compromise usefulness of results

## 3. Analytical

- + provides quick answers
- often requires the greatest degrees of abstraction

# Performance Evaluation Approaches

## 4. Emulation

- \* a hybrid performance evaluation methodology

- \* combines aspects of other three approaches

- + enables controlled experimentation with existing applications

- still suffers from drawbacks of other approaches

# Wide-Area Network Simulation

- provides a virtual Wide-Area Network (WAN) environment
- allows all network conditions to be controlled
  - packet loss
  - packet reordering/duplication
  - link bandwidths
  - propagation delays
  - asymmetric links
  - bounded queue sizes
  - multipath
- allows alternative networking technologies to be evaluated

# Wide-Area Network Emulation

- extends capabilities of WAN simulation
- enables controlled testing with unmodified applications
- both simulation and emulation are important tools

# Challenges

- scaling to large, non-trivial sized networks
- developing realistic models of network characteristics
- keeping pace with real world events (emulator)



# Introduction to IP-TNE

## IP-TNE: Internet Protocol Traffic and Network Emulator

- developed at the University of Calgary
- a collaborative effort between researchers in:
  - high performance parallel simulation (Rob)
  - IP networking (Carey)

# Introduction to IP-TNE (cont.)

## Design

- built around IP-TN network simulator
- uses a high performance PDES kernel
- kernel modified to provide real-time features
- can simulate end hosts as well

# Introduction to IP-TNE (cont.)

## Operation

- reads packets promiscuously
- replies to ARP requests for registered hosts
- packets timestamped when read from network
- output time calculated by network simulator
- packets released when wall-clock time = output time

# Introduction to IP-TNE (cont.)

## Current Strengths

- high performance
  - this enables detailed simulation of non-trivial networks
- flexibility

## Current Weaknesses

- simple models of network behaviour
- visualizing operation of large networks
- need for repeatable validation tests

# Related Projects

## **ns-2**

- most well known network simulator/emulator
- + feature rich (e.g., multiple flavours of TCP, etc.)
- poor performance restricts size of simulated network

## **SSFNet**

- + focused on simulating extremely large scale networks
- does not provide emulation capability

# Related Projects (cont.)

## Other Network Simulators/Emulators

- dummynet
- NistNet
- Utah Network Testbed
- Network Emulator 4.0
- The Ohio Network Emulator (ONE)
- Opnet
- Shunra Cloud

# Validation of IP-TNE

## Overview

- validation is not a one-time event, but a continuous process

## Protocol Implementation

- capture and examine network traffic

e.g., use tcpdump to capture packets between emulator and host

- examine HTTP headers and responses for correctness
- examine IP and TCP headers for correctness
- analyze TCP behaviour for correctness

# Validation of IP-TNE (cont.)

## Emulator Behaviour

- compare application behaviour in real/emulated environments

e.g., Web server benchmarking

- evaluate Web server performance with benchmarking tools
- compare to benchmarking results using IP-TNE
- account for any differences; repeat tests if necessary
- can also compare to results from other emulators



# Current Projects

## Web Server Benchmarking

- demonstrate one use of IP-TNE
- helps validate our emulator (comparing to Nahum et al.)
- show that a centralized approach to WAN emulation:
  - can scale to large network sizes
  - is more manageable than a distributed approach

# Current Projects (cont.)

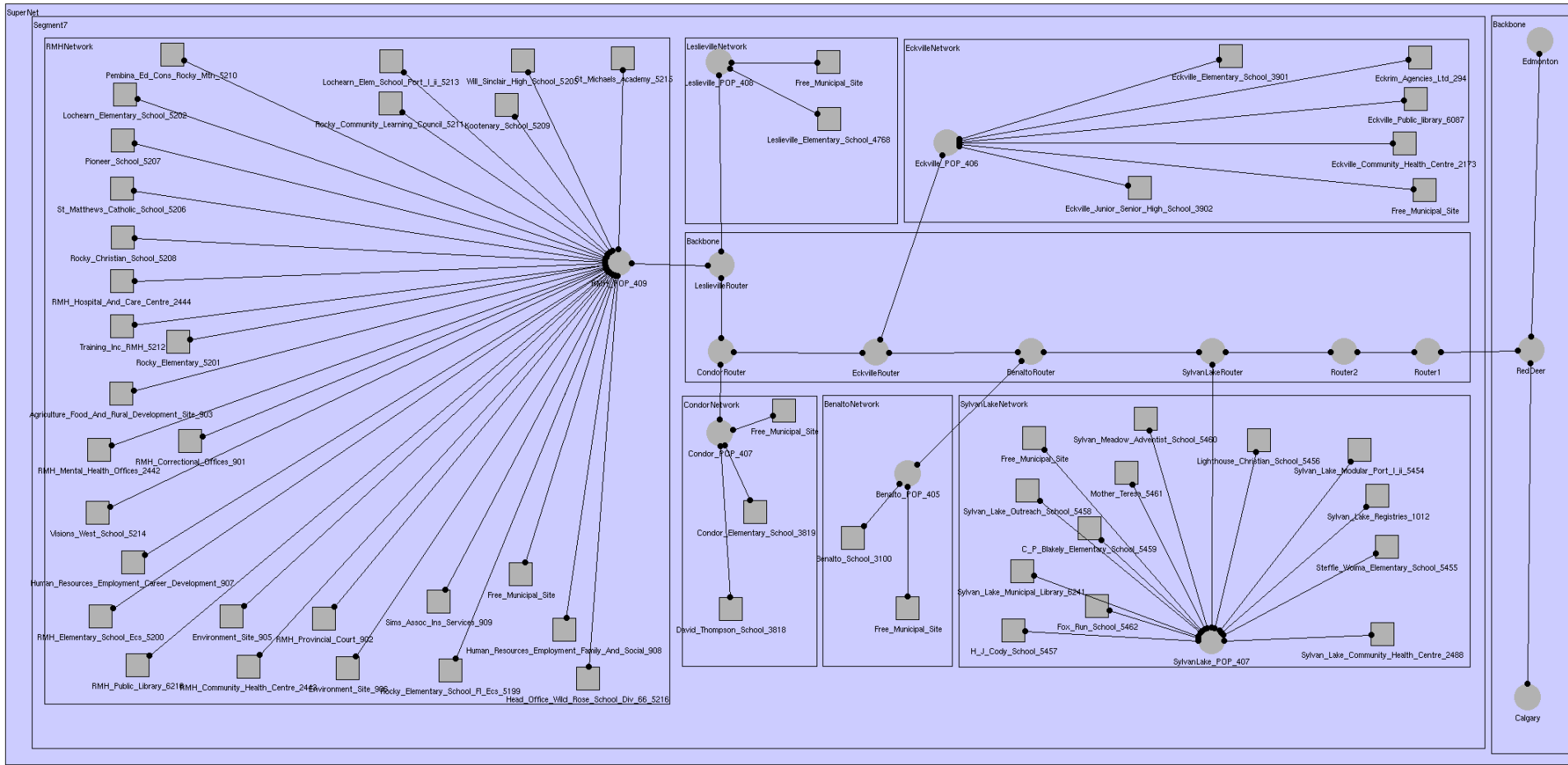
## Alberta SuperNet

- what is SuperNet?
  - ICT infrastructure throughout province of Alberta
  - will provide high-speed Internet access to:
    - \* 100% schools
    - \* 95% businesses
    - \* 80% residences
  - 422 communities to be linked
  - 5,175 miles of fiber; wireless networks in remote areas

# Current Projects (cont.)

## Alberta SuperNet

- IP-TNE will be used in development of SuperNet
- data captured from SuperNet will be used to:
  - develop more realistic models of network conditions for IP-TNE
  - validate IP-TNE
- project will test scalability of IP-TNE



# Future Work

- improve models of network conditions
- add additional features (e.g., TCP variants, routing algs)
- make protocol validation a repeatable/automated process
- improve real-time performance of PDES kernel
- participation in SuperNet
- use ELISA (an Internet testbed) to further improve IP-TNE

# Contact Information

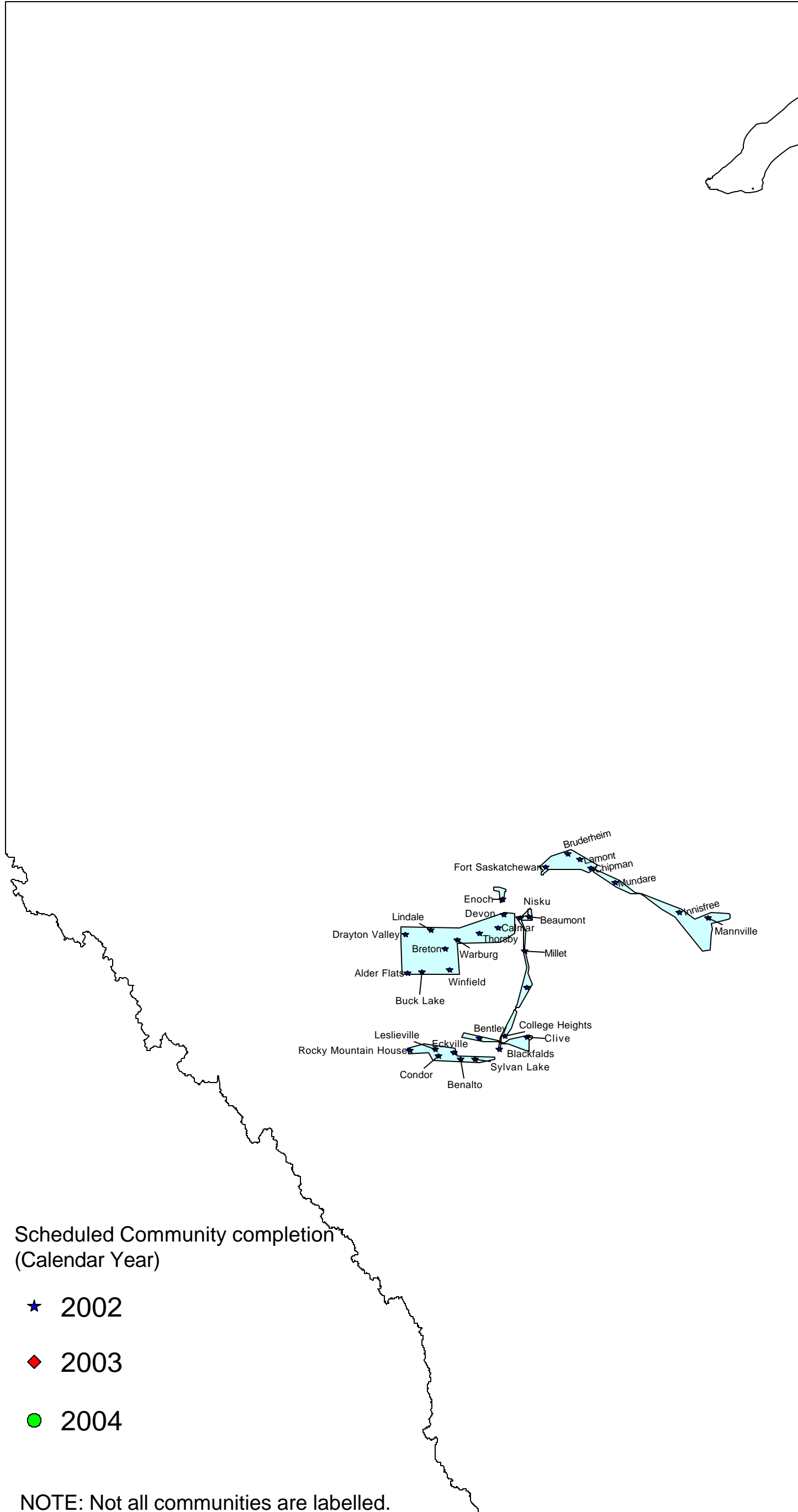
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# SuperNet Community Rollout Schedule - 2002



Scheduled Community completion  
(Calendar Year)

★ 2002

◆ 2003

● 2004

NOTE: Not all communities are labelled.

4 February, 2002.

# SuperNet Community Rollout Schedule

