ENSC 427: COMMUNICATION NETWORKS
SPRING 2017
FINAL PROJECT PRESENTATION

Netflix Over LTE Content Distribution Network Optimization

Group 2
https://www.sfu.ca/~kbohlen/
Kurtis Bohlen - 301197502 (kbohlen@sfu.ca)
Dejan Jovasevic - 301142027(djovasev@sfu.ca)
Rohan Thomas - 301195077 (rohant@sfu.ca)

Outline

- Introduction and Motivation
- Overview of Related Work
  - Long Term Evolution
  - Netflix Content Distribution Network
- Problem Description
- Riverbed Implementation
  - Scenarios
  - Configuration
  - Results and Analysis
- Future Work
- Conclusions
- References

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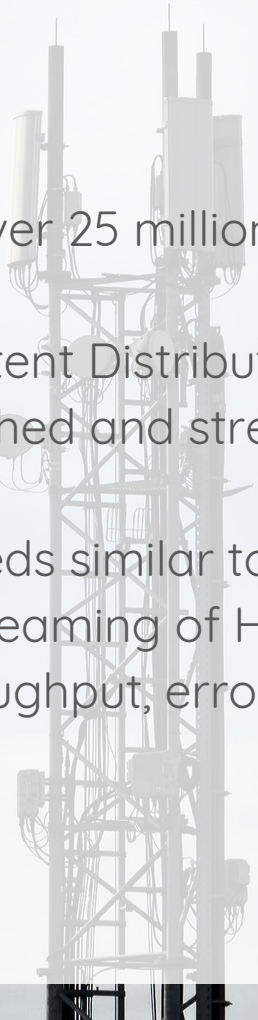
Introduction and Motivation

- In the United States and Canada alone, Netflix has over 25 million users, accounting for over 30% of all downstream traffic
- Netflix employs a system of servers that form a Content Distribution Network (CDN) from which the video chunks are cached and streamed to the users
- Long Term Evolution (LTE) provides throughput speeds similar to high speed internet access which has enabled wireless streaming of HD videos
- We analyze different CDN scenarios measuring throughput, error rate, and delay



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Long Term Evolution

- Long Term Evolution (LTE) is the latest technology deployed in cellular networks and is defined by the 3rd Generation Partnership Project (3GPP)
- Data Focused Network as opposed to prior circuit switched networks
- Created as the successor to the 3G standard to provide users faster speeds that were not achievable before
- Users can achieve speeds:
  - Peak = 335 Mbps in downlink
  - Average = 12-25 Mbps in downlink
  - Tested = [121,114,96] Mbps in downlink over 3 tests

LTE Radio Access Network

- The air interface, towers, and phones of the LTE protocol make up the Evolved Universal Terrestrial Radio Access Network (EUTRAN)
  - Air Interface = EUTRA
  - Towers = eNodeB (evolved NodeB)
  - Phones = User Equipment (UE)
- Orthogonal Frequency Division Multiplexing in Uplink and Downlink
- Multiple-input multiple-output antennas
- Beamforming

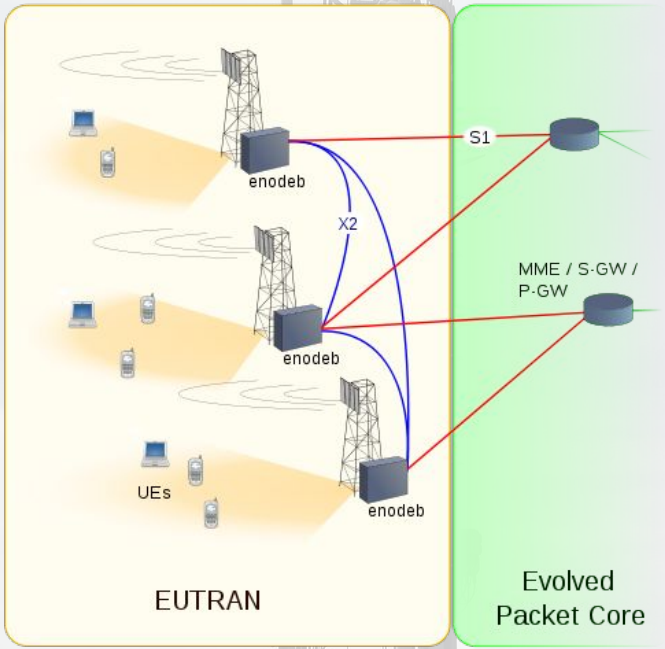


Image: https://en.wikipedia.org/wiki/E-UTRA#/media/File:EUTRAN_arch.op.svg

LTE Evolved Packet Core (EPC)

- Core network architecture standardized by 3GPP, completely IP based
- Supports high throughput, low latency EUTRAN access as well as legacy 3GPP systems and non-3GPP systems such as WiFi
- Comprised of:
  - Home Subscriber Server (HSS)
    - Database containing subscriber info used for authentication, call setup, and roaming
  - Mobility Management Entity (MME)
    - Controls paging and tracking of UEs in control pane
  - Serving Gateway (SGW)
    - Interfacing the radio network and the EPC in user pane
  - Packet Data Network Gateway (PDN Gateway) (PGW)
    - Interfacing the EPC and the external packet networks

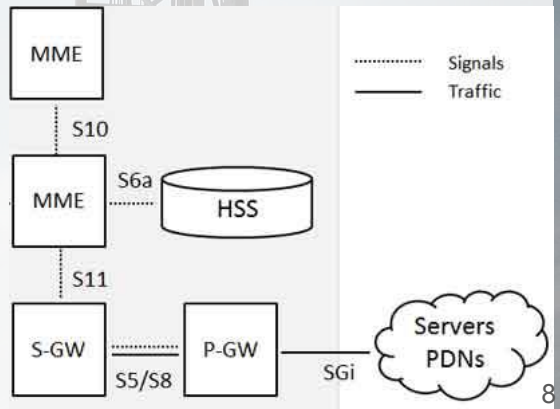


Image: https://www.tutorialspoint.com/lte/images/lte_epc.jpg

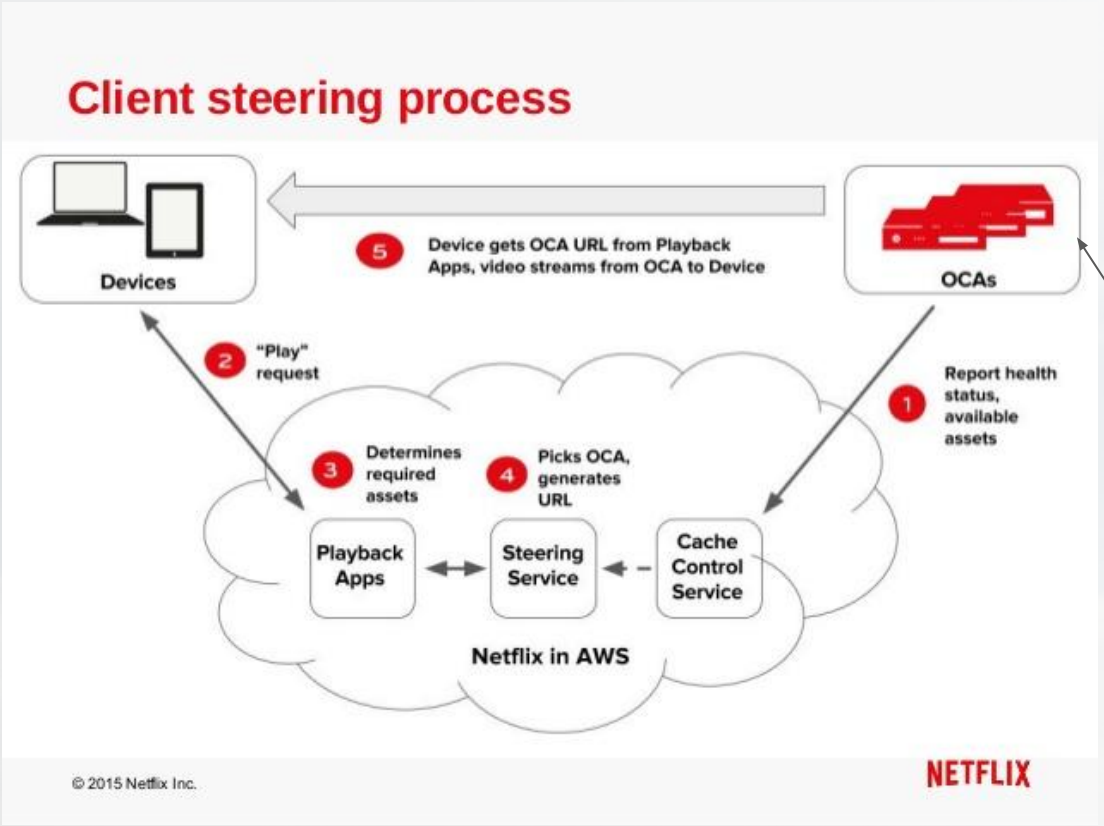
Netflix Content Distribution Network

- A Content Distribution Network consists of distributed proxy servers at various data centers to provide end users with high quality low latency service
- Originally Netflix used Third party CDN providers. The three that were used were: Akamai, Lime Light and Level 3. It would update these CDNs in off peak times with content
- In 2012 Netflix began to build its own CDN: *Netflix Open Connect*
- In the following years Netflix built its own hardware storage to provide to ISP's, they called Open Connect Appliance

Netflix Content Distribution Network

- An image of the Open Connect Appliance (OCA)
- These are embedded within the ISP's network so 100% of content streaming is done within the ISP network
- The OCA's are updated in off-peak hours

Netflix Content Distribution Network



OCA's uploaded during off-peak hours

Netflix Main Server

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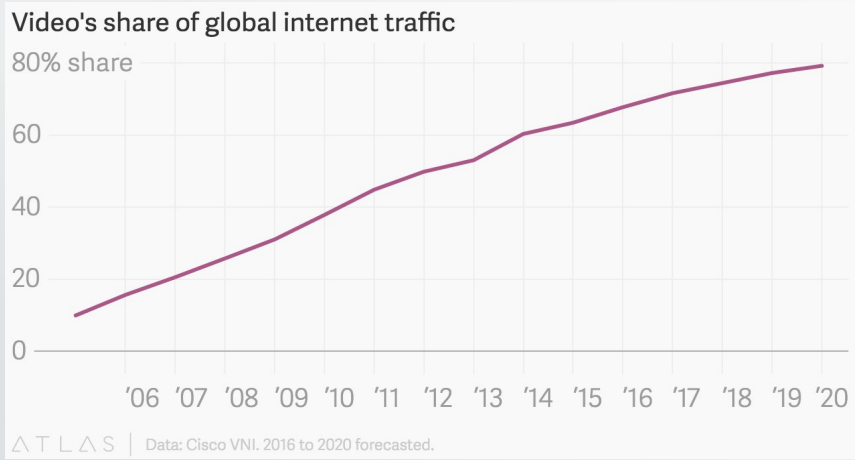
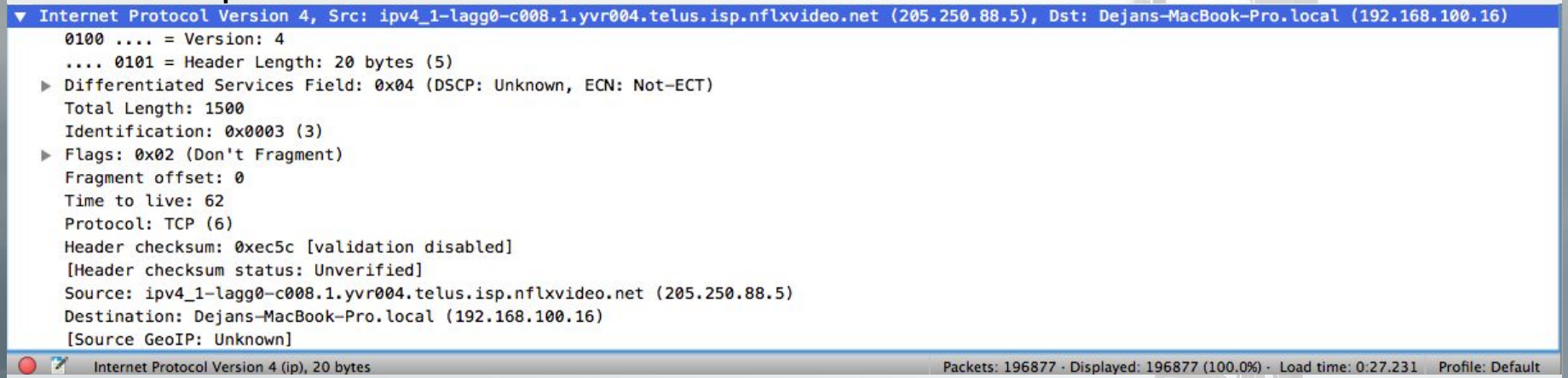
Description of the Problem



- Over the past decade, video streaming has become the main content on the internet (Content Providers: Facebook, Google, Netflix)
- Video streaming contributes about 70% of all traffic today (12% in 2006), and Cisco estimates it will reach approximately 90% by 2020

Description of the Problem

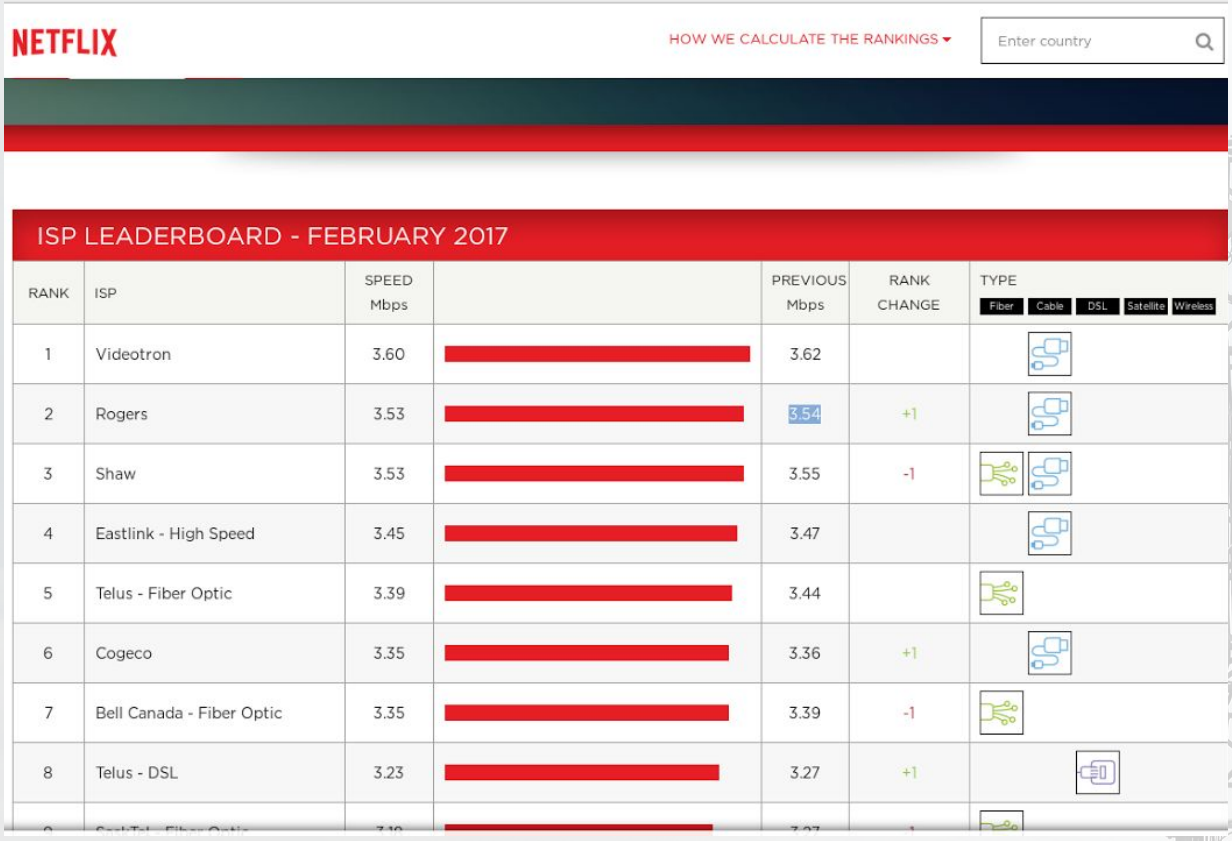


- To supply this demand and satisfy users, content providers are bringing the content close to the end user (*"pushing to the end of the network"*)
- This reduces the total number of hops
- We used Wireshark to analyze Netflix streaming over the Telus network. It goes to a local Telus CDN server in Vancouver. (Round trip time of ~6ms)

History of Problem

- After initially using third party CDNs - Netflix moves away and creates their own (OpenConnect 2012 onwards)
- Clash between Internet Service Providers (ISPs) and Content Providers
- Since the big ISPs refused to incorporate CDNs, smaller ISPs took advantage and installed OpenConnect hardware
- Since the demand was so high, the large ISPs were forced into using OpenConnect to offer the same quality of service as the smaller ISPs
- Netflix has been deploying CDN Servers around the world to provide faster and better quality video service to their user’s
- The expansion of these CDNs is what is causing a phenomenon called “Flattening of the Internet”

NETFLIX ISP INDEX



NETFLIX

HOW WE CALCULATE THE RANKINGS

Enter country

ISP LEADERBOARD - FEBRUARY 2017

RANK	ISP	SPEED Mbps		PREVIOUS Mbps	RANK CHANGE	TYPE (Fiber, Cable, DSL, Satellite, Wireless)
1	Videotron	3.60		3.62		Cable
2	Rogers	3.53		3.54	+1	Cable
3	Shaw	3.53		3.55	-1	Fiber, Cable
4	Eastlink - High Speed	3.45		3.47		Cable
5	Telus - Fiber Optic	3.39		3.44		Fiber
6	Cogeco	3.35		3.36	+1	Cable
7	Bell Canada - Fiber Optic	3.35		3.39	-1	Fiber
8	Telus - DSL	3.23		3.27	+1	DSL

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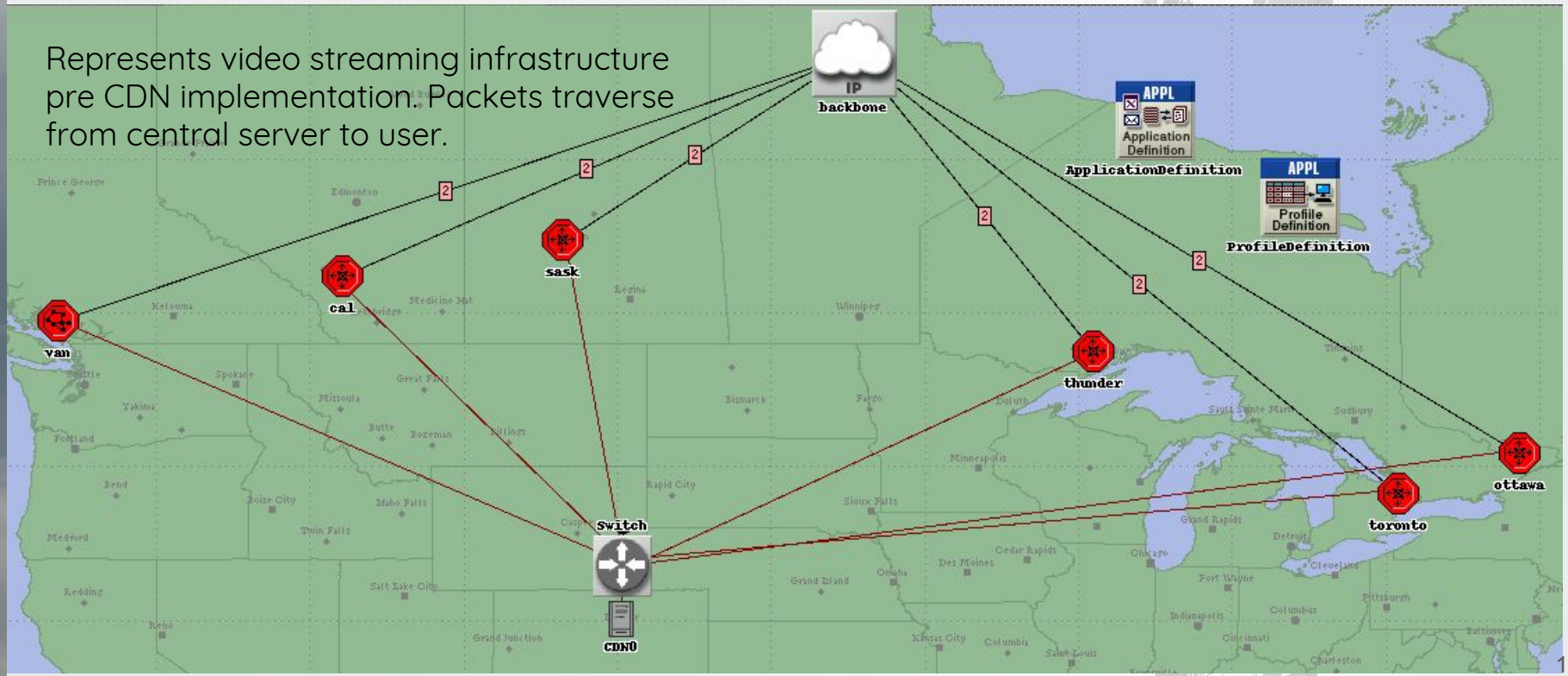
Riverbed Implementation - Scenarios

- To model in Riverbed we created 6 Mobile Subnets throughout Canada
- Each subnet consisted of an LTE Network containing, 1 eNodeB tower, 1 EPC, 1 Mobile Phone
- We created 3 scenarios to showcase the effect of CDNs on performance
- Scenario 1 involved one central server spanning to all the LTE subnets
- Scenario 2 involved two CDN servers spread out in East/West Canada, connecting to the respective closest subnets
- Scenario 3 involved a CDN server dedicated to each EPC located within the actual subnet

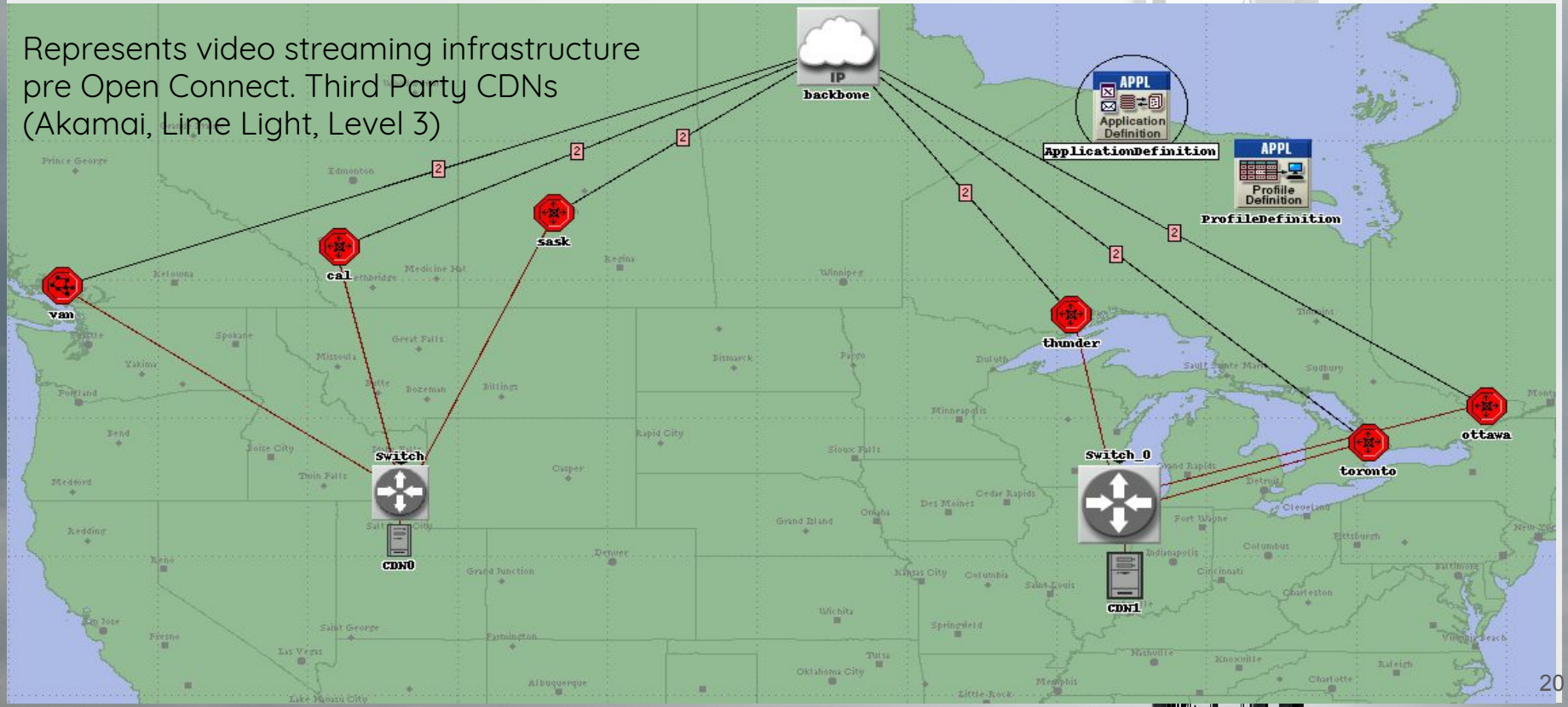
One Central Server

Represents video streaming infrastructure pre CDN implementation. Packets traverse from central server to user.



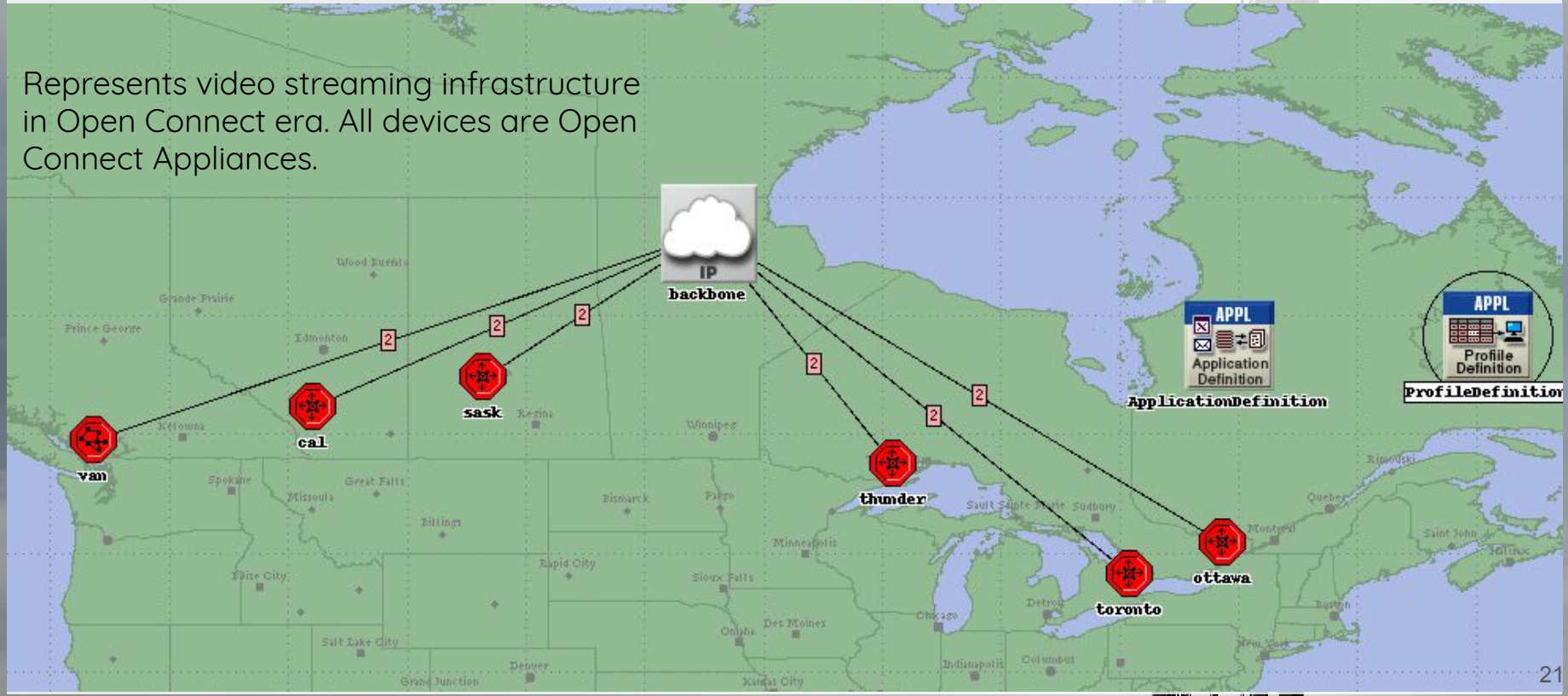
Small CDN with East/West Servers

Represents video streaming infrastructure pre Open Connect. Third Party CDNs (Akamai, Lime Light, Level 3)

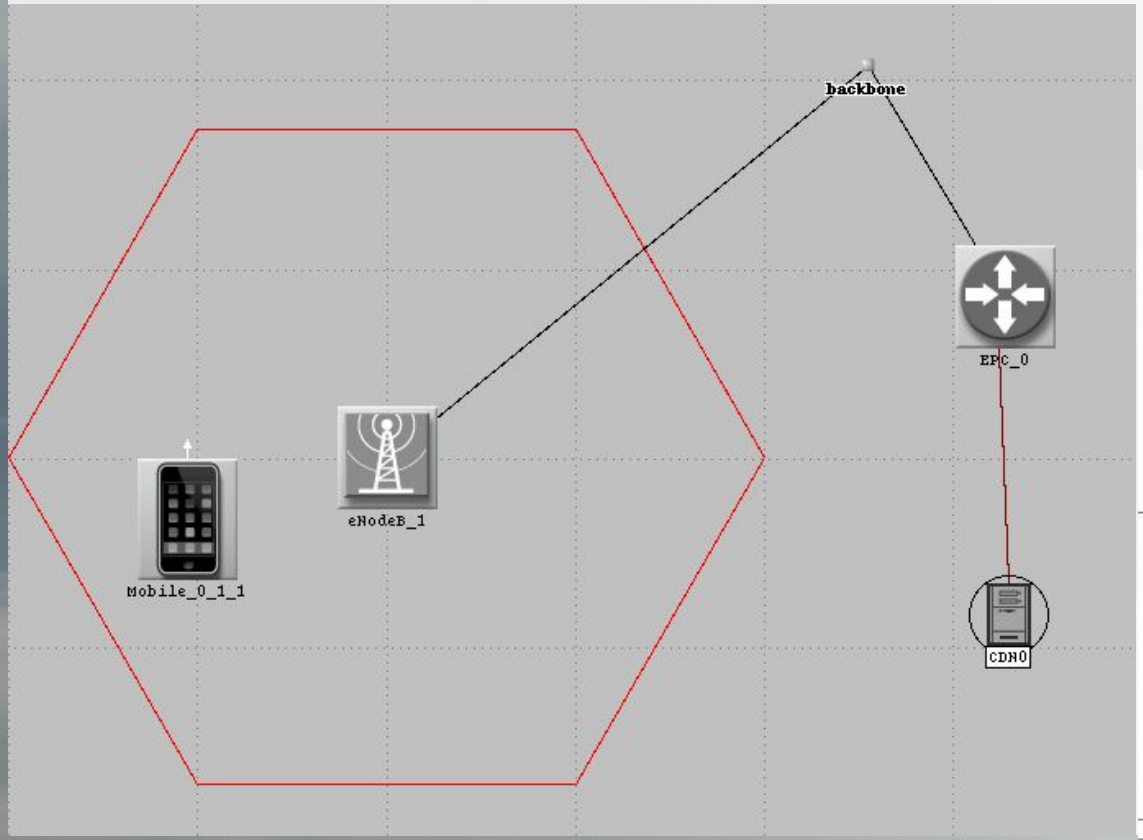


Well Distributed CDN (Each City has Server)

Represents video streaming infrastructure in Open Connect era. All devices are Open Connect Appliances.



Inside Look at LTE Network



- CDN connects to EPC specific to Network
- eNodeB tower transmits to phone

Configuration Summary

Technology	LTE
Overlay	Cell (Hexagon)
Node Placement	Random
Number of eNodeBs	1
Number of UE	1
Nodes with Mobility Con...	1

Technology Specifications

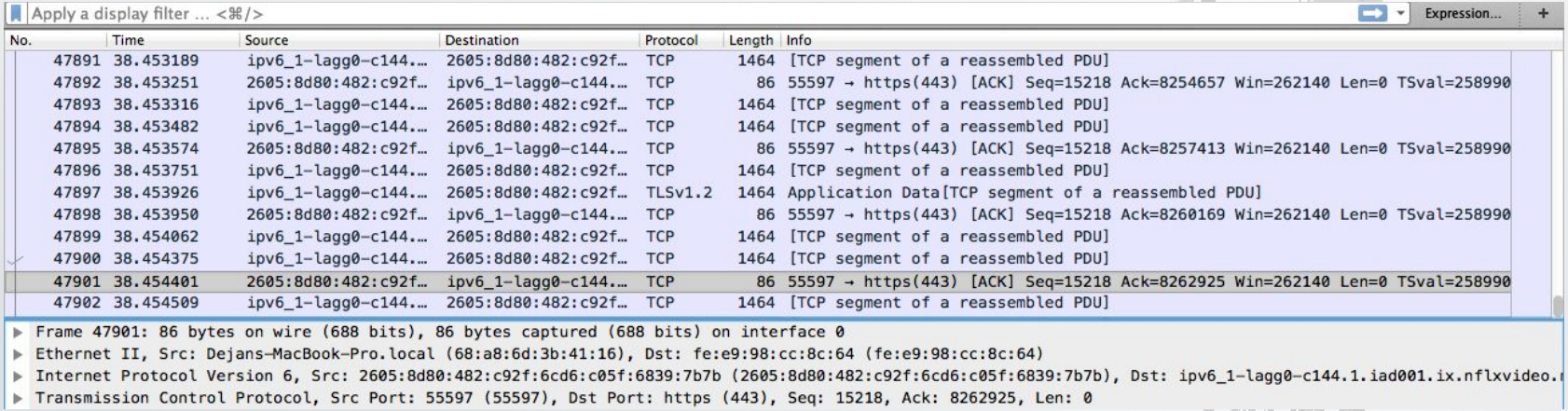
Choose technology: LTE

UE Transmission Power (W)	Cell Size Based
eNodeB Transmission Power (W)	Cell Size Based
PHY Profile	LTE 20 MHz FDD
Pathloss Model	Free Space

Riverbed Configuration

- Netflix uses a special version of Hyper Text Transfer Protocol for its application layer protocol
- It is called Dynamic Adaptive Streaming over HTTP (DASH)
- Movie content is divided into smaller segments and is encoded at variable quality and bit rates
- While client is doing playback, they are automatically selecting the next segment to download depending on the strength of the network connection
- DASH runs on top of Transmission Control Protocol (TCP)
- This meant that we could configure our application to use HTTP and then set the proper frame interarrival times and sizes

Riverbed Configuration



- Creating LTE hotspot using an Iphone 6s, we streamed netflix on laptop using this connection. Collected Wireshark data
- Found the following properties
  - Frame Interarrival Time: 0.000558 seconds
  - Frame Size: 1464 Bytes
  - Average Download Rate: 2.62 MBps

Riverbed Configuration

(ApplicationDefinition) Attributes

Type: utility

Attribute	Value
⊞ Mobile User Gaming	...
⊞ Mobile User Interactive Content ...	...
⊟ Netflix	
Name	Netflix
⊟ Description	(...)
Custom	Off
Database	Off
Email	Off
Ftp	Off
Http	(...)
Print	Off
Peer-to-peer File Sharing	Off
Remote Login	Off
Video Conferencing	Off
Video Streaming	Off
Voice	Off

(Streamed Video Properties) Table

Attribute	Value
Video Existence Probability	All Pages Include a Video
Play Start Time Offset (seconds)	None
Video Length (seconds)	constant (3600)
Video Type	On Demand
Frame Inter-arrival Time (seconds)	normal (0.000558, 0.0000000009876)
Frame Size (bytes)	constant (1464)
Location	HTTP Server
Back-End Custom Application	Not Used
Object Group Name	HTTP Video Object

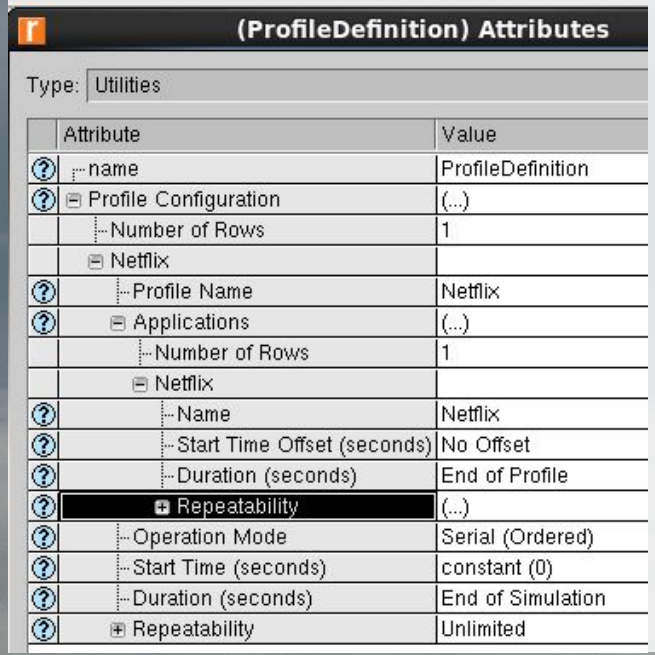
(CDN2) Attributes

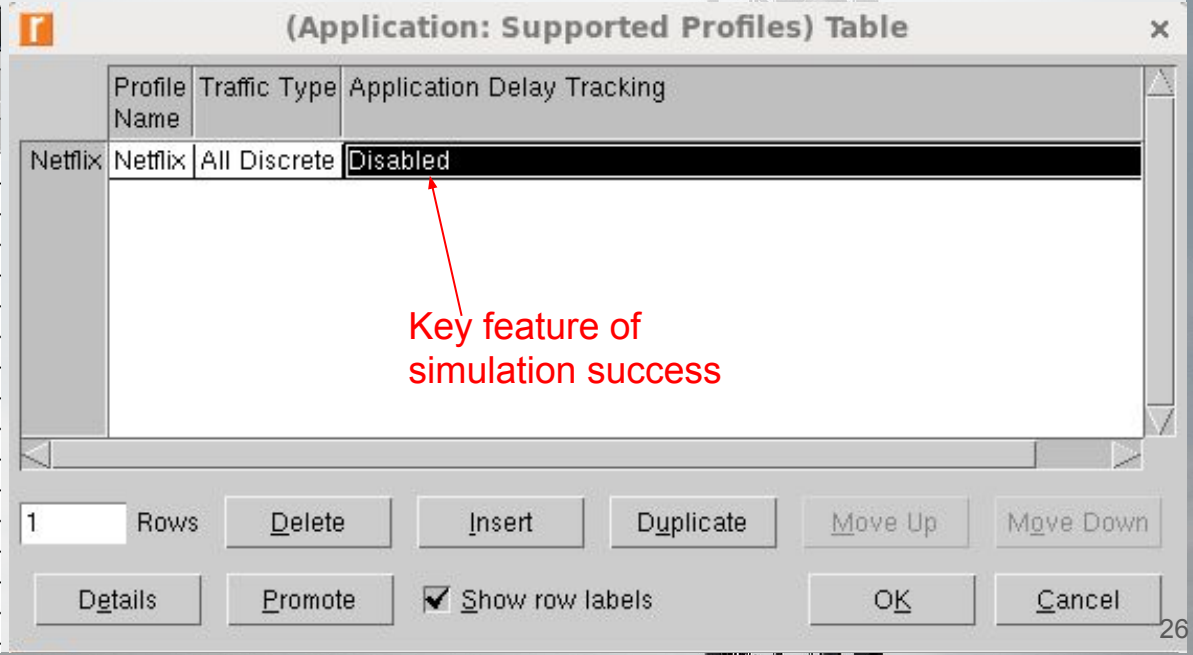
Type: server

Attribute	Value
name	CDN2
⊞ IP	
⊞ IP Multicasting	
⊟ Applications	
⊞ Application: Destination Prefere...	None
⊞ Application: Supported Profiles	None
Application: Supported Services	All
⊞ Application: Transaction Model ...	Unspecified

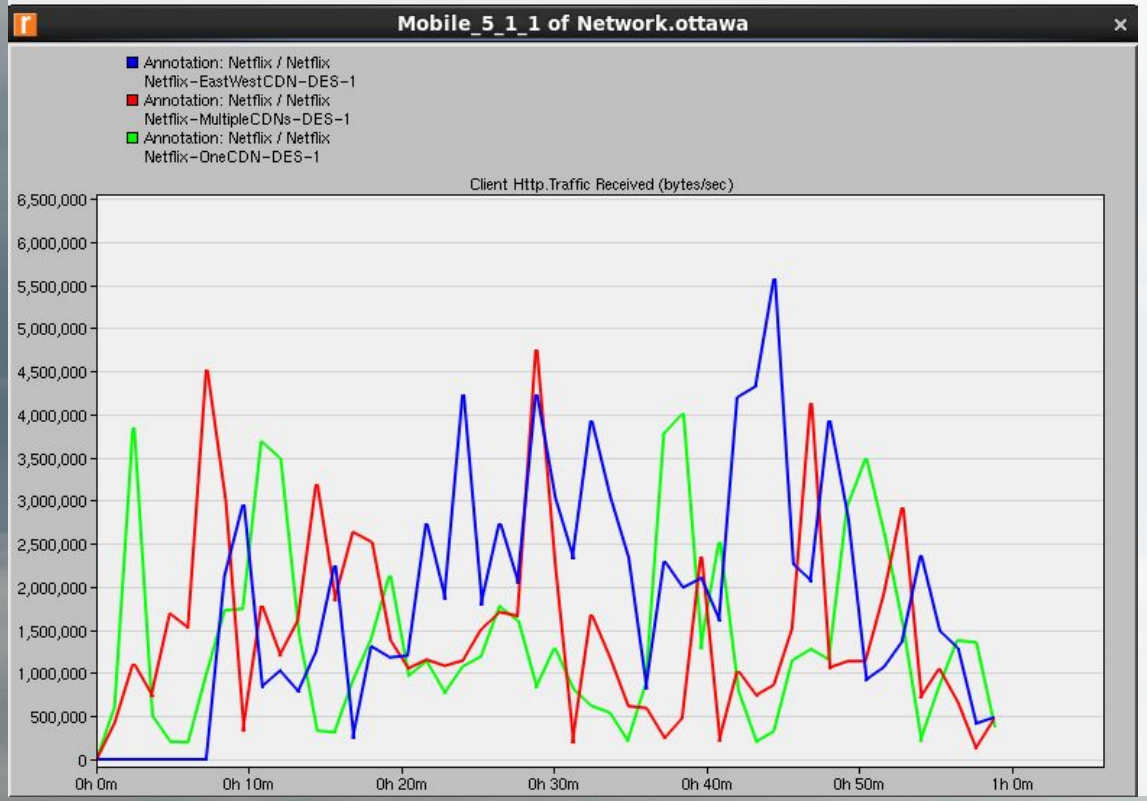
Riverbed Configuration

- We configured one profile as one user using the aforementioned Netflix application for the entire duration of the simulation, set phones to use it



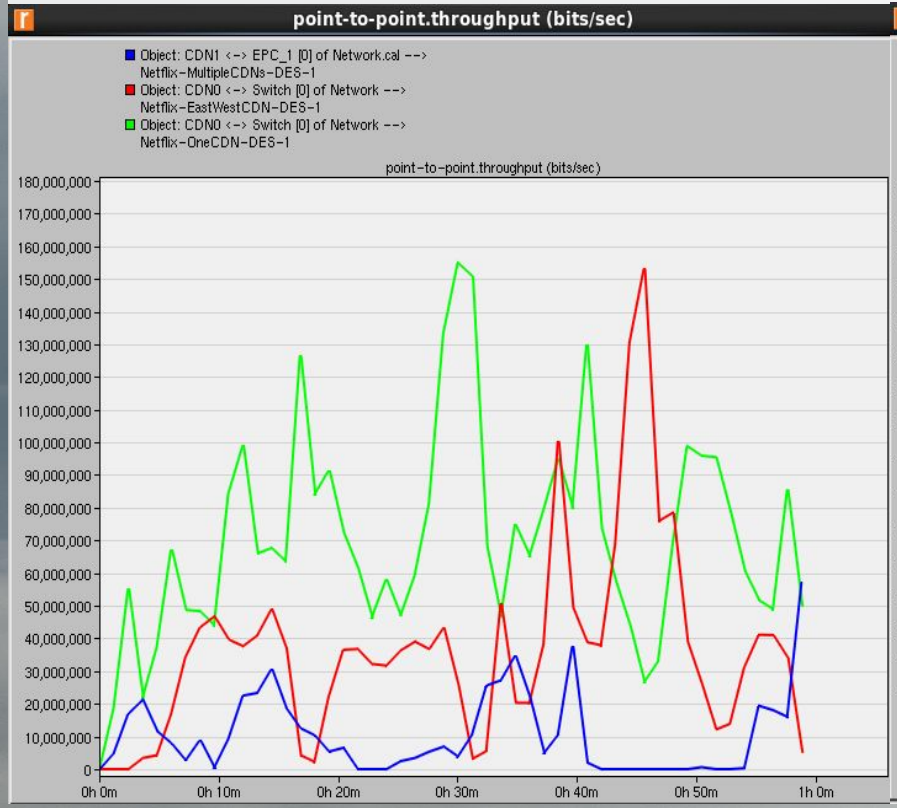


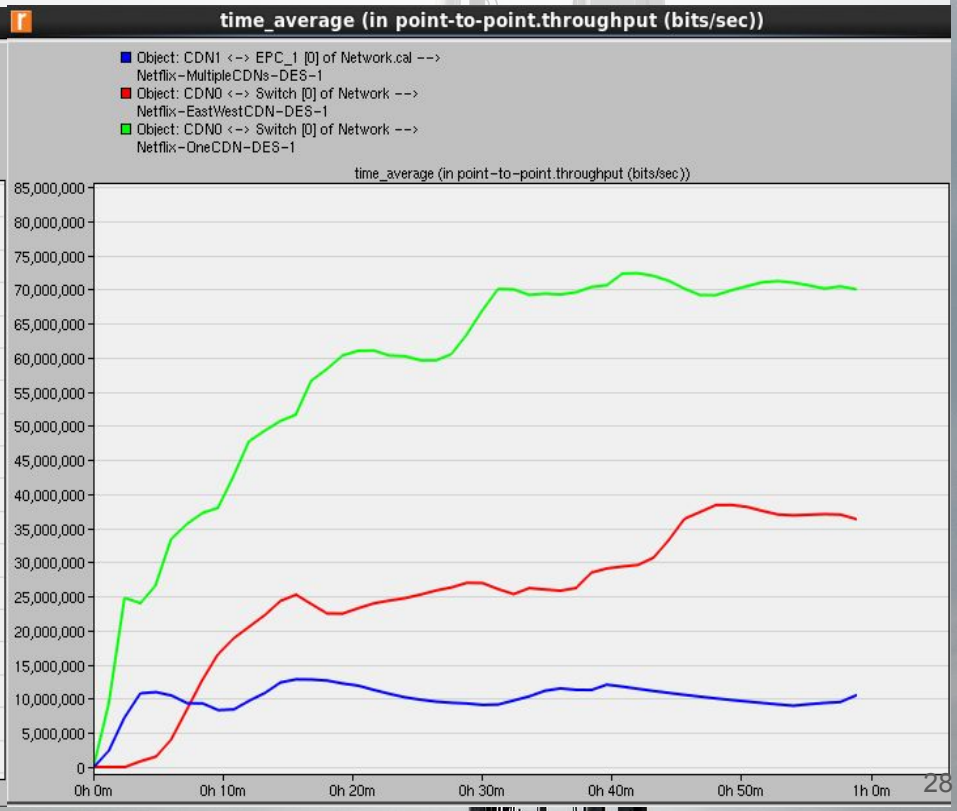
Riverbed Results - Bytes Received



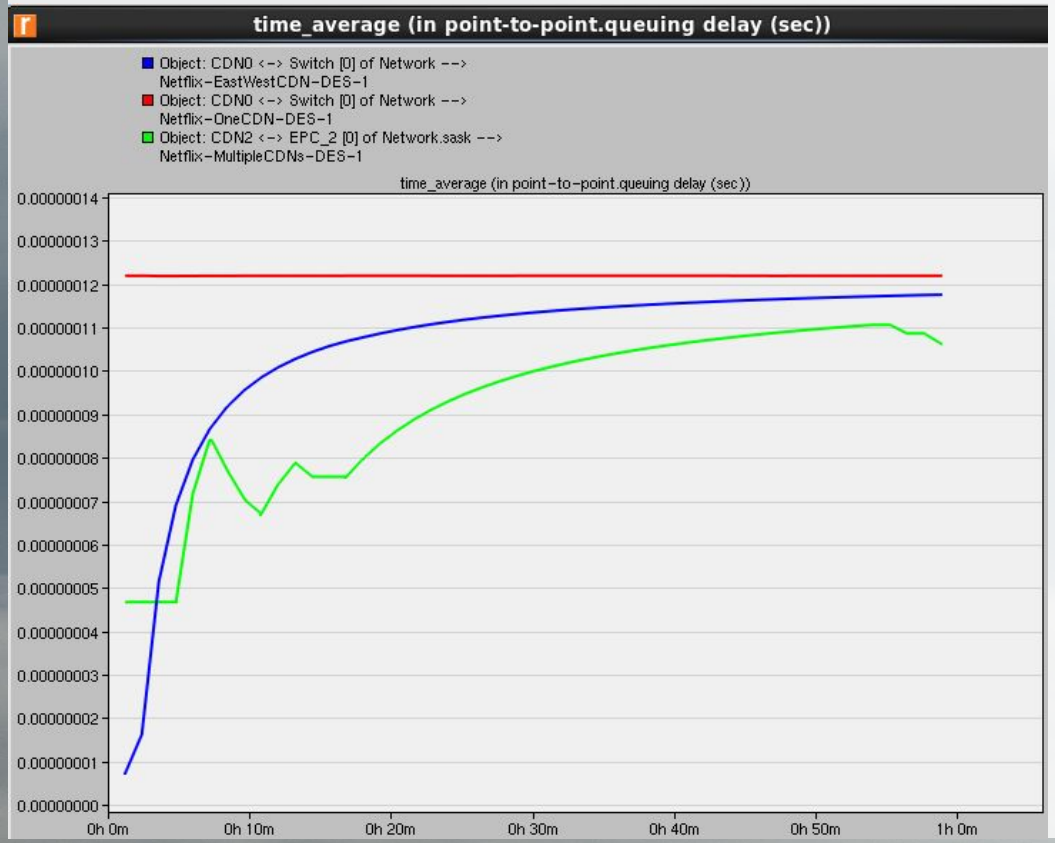
- Bytes per second for mobile phone in Ottawa network
- All scenarios have average receive rate of 2.6 MBps as configured in Netflix Application Definition

Riverbed Results - Throughput



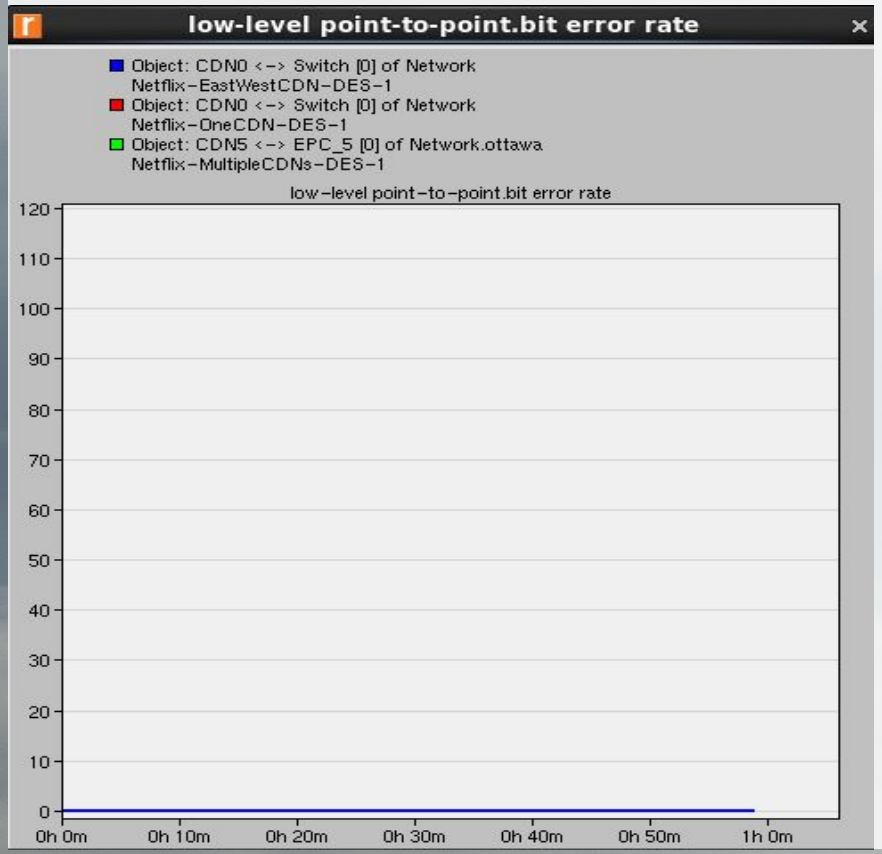


Riverbed Results - Delay



- Delay in links from EPC to the CDN servers for each scenario
- As you add more CDN servers the delay decreases

Riverbed Results - Bit Error Rate



- Bit Error Rate in links to the CDN servers for each scenario
- Bit Error Rate can not be realistically modeled due to how scaled back our LTE network had to become for simulations to run
- We are not coming anywhere close to the full utilization of the links that we are using
- Thus an extremely low bit error rate is expected

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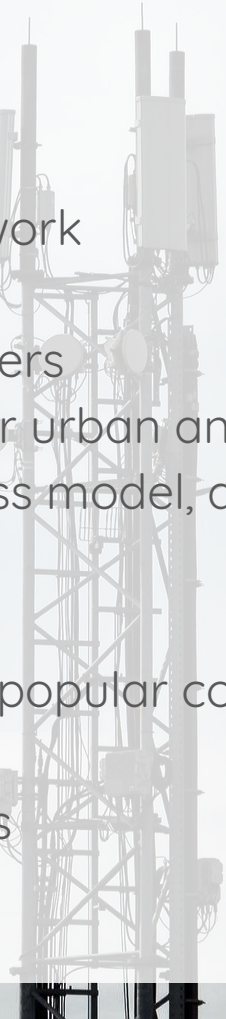
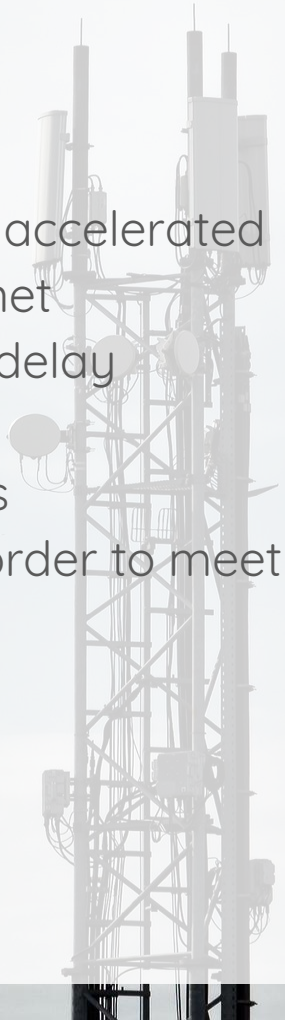
Future Work

- Background traffic and calls on LTE radio access network
- Background internet traffic on EPC
- Larger LTE networks with more phones and more towers
- Have different radio access network configurations for urban and rural areas by varying: intersite distance, cell radius, pathloss model, and number of users
- Different stream speeds HD vs non-HD vs UHD
- Distinguish between popular cached content and less popular content that takes longer to buffer and stream
- More accurate models of links and Netflix CDN servers



Conclusions

- Increasing demand for video content is causing the accelerated deployment of CDNs and the flattening of the internet
- Deploying a CDN is critical to lower bandwidth and delay
- Doing this improves the user's experience
- The more distributed a CDN is the better it performs
- Wireless providers will have to embed the OCAs in order to meet the demand for streaming Netflix over mobile devices



References

- V. K. Adhikari, Y. Guo, F. Hao, M. Varvello, V. Hilt, M. Steiner, and Z. Zhang, "Unreeling netflix: Understanding and improving multi-CDN movie delivery," in *Proc. IEEE INFOCOM*, Orlando, FL, 2012, pp. 1620-1628.
- V. K. Adhikari, Y. Guo, F. Hao, V. Hilt, Z. Zhang, M. Varvello, and M. Steiner, "Measurement Study of Netflix, Hulu, and a Tale of Three CDNs," *IEEE/ACM Transactions on Networking*, vol. 23, no. 6, pp. 1984-1997, Dec. 2015.
- J. Summers, T. Brecht, D. Eager, and A. Gutarin, "Characterizing the workload of a netflix streaming video server," in *Proc. IEEE International Symposium on Workload Characterization (IISWC)*, Providence, RI, 2016, pp. 1-12.
- C.D. Cranor, M. Green, C. Kalmanek, D. Shur, S. Sibal, J.E. Van der Merwe, and C.J. Sreenan, "Enhanced streaming services in a content distribution network," *IEEE Internet Computing*, vol. 5, no. 4, pp. 66-75, Jul/Aug 2001.
- T.Böttger, F. Cuadrado, G. Tyson, I. Castro, and S. Uhlig, *Open Connect Everywhere: A Glimpse at the Internet Ecosystem through the Lens of the Netflix CDN*, eprint arXiv:1606.05519 [cs.NI], 2016, pp. 1-14.
- K. Florance, "How Netflix Works With ISPs Around the Globe to Deliver a Great Viewing Experience," *Netflix Media Center Company Blog*, Mar. 2016.
- N. Bargisen. (2016, Aug 30). *Netflix Open Connect: Delivering Internet TV to the world* [Online]. Available: https://www.slideshare.net/InternetSociety/netflix-open-connect-delivering-internet-tv-to-the-world

Questions?