The re-ECN Protocol

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Overview of the re-ECN Protocol

A TCP/IP signaling mechanism for "Congestion Exposure"

Principle Protocol Mechanism

- Receive congestion information from receiver (Explicit Congestion Notification – ECN)
- Re-insert congestion information (= estimation about expected congestion level)

Goal of Congestion Exposure

- Monitor upstream/downstream congestion in the network and at network borders
- Make end-systems accountble for the congestion they cause in the network
Outline

• Problem Statement

• The re-ECN Protocol

• The re-ECN Framework

• Simulations with Linux Kernel Code

• Conclusion and Outlook
Problem Statement

Capacity Sharing in the Internet

The end-to-end principle

• Congestion control mechanisms in the end-systems avoid a congestion collapse
• Over-provisioning of network resources encounters workload peaks

Problems

• Amount of traffic in the Internet is increasing vs. decreasing profit/bit
  – More and more data though P2P, video streaming, network data storage
  – New services with challenging demands (const. data rate, interactive, high data volumes)
  – Higher access rates, always-on contracts
• Upgrading of the physical network will not improve Quality of Experience (QoE)
  – A minority of heavy users allocate a large share of the bandwidth capacity
  – This traffic bothers time-critical transmission of other users
  – Physical expansion implies costs for all costumers, but only a minority benefits

→ ISP’s do not want to extent their networks but want to achieve a fairer share
Problem Statement

Congestion Management in the Network

Current Practise

1. Application rate limiting for high bandwidth services (Deep Packet Inspection - DPI)
2. Volume counting at network ingress to improve the Quality of Experience (QoE) for the majority of the users
3. "Comcast’s Protocol Agnostic Congestion Management System"
   → assign lower priority status to heavy users

Problems

1. IPSs do not know the end-systems intent
   → application rate limiting is not appropriate (Network neutrality, Fairness)
2. ISPs do not know the congestion situation in their network
   → policing would only be necessary if congestion occurs
   → policing would be most beneficial at network ingress

→ End-system-based congestion control with per-user fairness (Congestion Accounting)
The ECN Protocol

**ECN** (Explicit Congestion Notification)

1. Routers mark packets (instead of dropping them – Random Early Detection, IP flag)
The ECN Protocol

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2. ECN receiver feeds congestion announcement back to the sender (TCP ACK)
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**ECN (Explicit Congestion Notification)**

1. Routers mark packets (instead of dropping them – Random Early Detection, IP flag)
2. ECN receiver feeds congestion announcement back to the sender (TCP ACK)
3. ECN sender reduces congestion windows (as on loss – TCP Congestion Control)
The re-ECN Protocol

re-ECN (re-insert ECN) – expose expected whole path congestion to network elements

re-ECN sender marks a packet for every congestion announcement from the receiver
  • Fraction of red marks ("congested") gives level of congestion experienced so far
The re-ECN Protocol

**re-ECN** (re-insert ECN) – expose expected whole path congestion to network elements

- **Fraction of red marks** ("congested") gives level of congestion experienced so far
- **Fraction of black marks** ("congestion expected") give the whole path congestion

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**re-ECN sender** marks a packet for every congestion announcement from the receiver

- Fraction of red marks ("congested") gives level of congestion experienced so far
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The re-ECN Framework

Congestion Accounting – enable appropriate congestion control

- Dropper: Detection of permanent negative flows
- Policer: Limitation of congestion volume (pos. marked packets, Token-Bucket principle)
  - Inter-Domain Policer (Border-charging, flow control, routing)
The re-ECN Framework

Inter-Domain Policer – border charging and inter-domain (re-)routing

Dropper
- Detection of permanent negative flows

Policer
- Limitation of congestion volume (pos. marked packets, Token-Bucket principle)
- Inter-Domain Policer (Border-charging, flow control, routing)
Congestion Accounting with re-ECN

Exposure of downstream congestion to network components
→ can be used for inter-domain SLAs
→ may be used for traffic management in the network

Congestion Exposure at network ingress
→ establishes an information equilibrium between end-system and network
→ enables to police packets before imposing congestion
→ permits to use as much as possible of the available capacity (if no congestion occurs)

Per-costumer limitation of congestion volume
→ introduces an incentive to not cause more congestion than needed while sending data
→ provides the basis for a fair share between costumers (not flows or applications or...)

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Network Simulation with Linux kernel code

IKR SimLib and Network Simulation Cradle

Network Simulation Cradle (NSC)

http://research.wand.net.nz/software/nsc.php

"cradles real world operating systems' network stacks in a wrapper"

- Framework which allows Linux, FreeBSD, OpenBSD and lwIP code to be executed as user space program
- Provides interface to be used in a network simulation context

IKR SimLib

http://www.ikr.uni-stuttgart.de/en/Content/IKRSimLib/

- Event-based Simulation Library of the Institute of Communication Networks and Computer Engineering, University Stuttgart
- NSC TCP adapter allows to measure realistic traffic traces in complex scenarios
  - Copy function allows easy configuration of complex topologies
  - Generation of syntetic traffic or replay of Internet traffic traces
Network Simulation with Linux kernel code

Functional analysis of the re-ECN protocol

- Implementation: TCP/IP-Stack Linux Kernel 2.6.26
- Simulation: SimLib with Network Simulation Cradle (version 0.5.0)
Network Simulation with Linux kernel code

Simulation Scenario with Linux kernel code

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Congestion Exposure with the re-ECN Protocol

re-ECN balance of one TCP connection at network egress with bulk traffic

→ Number of congestion marking differs but is relevant for Congestion Accounting
Network Simulation with Linux kernel code

*Simulation runs with const. bit rate (CBR) cross traffic*

**Scenario**

- Cross traffic with constant bit rate and greedy source
- Assume positive marked packet 100ms (min. RTT) after a negative mark for CBR traffic
- Several simulation runs with cross traffic with different CBR rates (1 minute each)
Preliminary Results

Number of negative markings with const. bit rate (CBR) cross traffic (8Mbit/s capacity)

- Number of markings depends on share of channel capacity and TCP CA periods
- Less markings for TCP flows in slow start overshoot with high CBR
Conclusion and Outlook

Summary

• re-ECN: Exposure of expected congestion on a network path (to network elements)
• Policer: Limitation of congestion volume per end-system/customer
  → can enable new congestion control schemes
• Impact of path characteristics and other protocol mechanism on re-ECN
  – Different AQM/RED parameterization and congestion control/Slow-Start options influence
    the total number of markings for one flow under the same network conditions
  – Total number of markings is relevant for Congestion Accounting
    ↪ new protocol mechanisms are needed to minimize congestion markings

Open Issues

• Policer and dropper design
• Congestion management in the end-system
• Economic implications (Inter-domain charging and Inter-domain routing)