Congestion Exposure in Mobility Scenarios

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Outline

- Motivation
- Resource Management for Best Effort Data Traffic
- Congestion Exposure (overview) and previous work
- Mobility Aware Packet Marking Controller/Function
- Evaluation Setup
- Conclusions
Resource Management for Best-Effort Traffic

### Operator-perspective

- Wants to be attractive to customers: high-speed access, ubiquitous coverage, open to all applications, cost-competitive
- Has to match network infrastructure investments to achievable income
- Has to manage network resources to keep network usable for all users

![Graph showing data growth and revenue gap](chart.png)

*Source: Cisco VNI Mobile, 2010*
Existing approaches can be classified (loosely) as: Static and Dynamic

Static approaches have problems:

- Volume Cap
- Deep Packet Inspection & Filtering
- Traffic filter templates in 3GPP PCC
  - Static configuration of QCI classes

Limitation: Network congestion and Resource availability is not taken into account
Possible approaches for Best Effort Traffic (2/2)

- **Dynamic approaches**
  - Takes into account resource usage and capacity into account
  - The scheme kicks in dynamically based on parameters of interest

- **Comcast Congestion Management**
  - Protocol and Application agnostic
  - Possibly applicable to any network: wired or wireless
  - Based on periodically monitoring resource usage of individual users

- **Congestion Exposure**
  - Users are made accountable to congestion they cause on other users while sharing the network resources not based on resource usage alone: *Cost Fairness*
General Approach: Congestion Exposure

- Make congestion in the network visible
  - Leveraging existing congestion notification mechanisms (ECN)
  - Simple functions on routers, gateways and base stations

- Senders act on congestion information
  - Can declare current congestion contribution
  - Can adapt sending behavior

- Network functions proposed by congestion exposure:
  - Rate-limit traffic based on declared congestion: **Policer**
  - Enforce correct operation: **Audit Function**
Previous Work

- **Congestion Exposure benefits for mobile communication networks**

- **Wireless resource-usage-aware ECN marking for Congestion Exposure**

- **Efficient audit function implementation for Congestion Exposure**

- **Investigating effects of dynamic path characteristics changes on Congestion Exposure**
Lag between the forward and feedback path
Congestion is not stationary and changes with offered load
Sender responsibility to match congestion with response
  - Pre-Credits + Post-Credits $\geq$ Deficit
Congestion Declaration (2/2)

- Congestion Exposure context at the sending host
  - Path Adaptability i.e. cwnd = 1
  - Estimate of congestion from received acknowledgements
- The context applies to one half of TCP connection
- No activity on connection invalidate the context
Mobility aspects for Congestion Exposure

Path adaptability vs. path changes

Issues with path changes
- New path state is unknown
- In-flight packets
- How much the actual path has been changed e.g., horizontal vs. vertical handover
- How to estimate congestion on the new path?
Mobility Aware Congestion Declaration

- With path changes, congestion estimate may no longer be valid
- Invalidate the context for the sender to “adapt” to the new path
- User may move between different congestion regions with path changes
- Use Path Predictability Factor for estimating congestion
Exploiting Network Topology

- Congestion may occur in any part of a network, access or core
- Exploit exposed congestion information on the path
  - Network may estimate congestion for traffic passing going to a particular gateway node
- Pass this information to UE’s for adapting to expected congestion levels
Hints pushed from base stations to the UE
Base stations exchange congestion information e.g. X2 interface in LTE
The goal is to measure deficit close to the receiving host on path changes
- NEC IP-8800 OpenFlow switch for dynamic load shifting
- NOX controller for switching path between hosts
- RED Queues in Linux Routers for congestion markings
Impact of TCP Slow Start

- TCP exponential increase during Slow Start causes lots of congestion.
- During congestion avoidance deficit remains low.
- Characteristic of the transport on how bandwidth is probed.
Loss of Marked Packets

- Response packet loss causes deficit not recoverable
- Audit Function would classify such traffic as non-conformant
Path Changes with different capacity Regions

- Load shift on 3 second interval
- Capacity is varied by 50% for a single TCP flow
- Deficit is recorded for scenario when load is shifted from lower to higher congestion regions
Conclusions

- Congestion exposure can be done on different time scales and with different granularity levels
  - For effective capacity sharing and sender adaptivity, accurate and timely congestion exposure is required

- Sender should take mobility into consideration
  - Need some flexibility for dynamic changing of path characteristics
  - Congestion estimate may not be valid after changes

- A slightly more tolerant policer configuration
  - Avoid policing/accounting for probing traffic

- Relaxed Audit Function configuration for short time scales
  - Tradeoff between accurate enforcement and accommodating mobility
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