A note about evaluations

As a starting point, considering

- greedy and non-greedy flows
  - Evaluation with realistic RMCAT traffic planned as next step
Why do we need coupled cc?

- Each individual data stream (flow) has its own congestion control mechanism
- Hence, M flows, with their own congestion control modules, trying to reach a certain fairness lead to:
  - More queue growth
  - More delay
  - More packet drops
  - Fairness problems in case of heterogeneous RTTs
How to solve this

- This can be solved by using a single Congestion Control (CC) instance for the flows
  - To begin with, only for flows initiated from the same sender sharing the same bottleneck

- Congestion Manager, RFC 3124, had some unresolved issues, and was complicated to implement
  - We suggest something more in the style of RFC 2140 (but rate based, and with more features)
Flow State Exchange (FSE)

- A passive entity which stores information from the flows, calculates rate and provides this calculated rate back.

- Minimal change to existing CC: each time it updates its sending rate (New_CR), the flow calls update (New_CR, New_DR), and gets the new rate.
FSE maintains S_CR (which is meant to be the sum of the calculated rates) and TLO (Total Leftover Rate) per FG.
FSE – how it works

- Flow 1 experienced congestion, causing S_CR to drop from 11 to 9.

- Let assume that flow 2 has sent an update to the FSE.

- For all the flows in its FG (including itself), it calculates the sum of all the calculated rates, new_S_CR. Then it calculates the difference between CR(f) and new_CR, DELTA.

  for all flows i in FG do
  new_S_CR = new_S_CR + CR(i)
  end for
  DELTA = new_CR - CR(f)

<table>
<thead>
<tr>
<th>#</th>
<th>FGI</th>
<th>P</th>
<th>CR</th>
<th>DR</th>
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<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>8</td>
<td>6</td>
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<tr>
<td>2</td>
<td>1</td>
<td>0.5</td>
<td>1</td>
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</table>

S_CR = 9, and TLO = 0

New_CR = 2, new_DR = inf

New_S_CR = 7
DELTA = 2 - 1 = 1
FSE – how it works

- It updates $S_{CR}$, $CR(f)$ and $DR(f)$.

CR($f$) = new$\_CR$
if $DELTA > 0$ then
  $S_{CR} = S_{CR} + DELTA$
else if $DELTA < 0$ then
  $S_{CR} = new\_S\_CR + DELTA$
end if
$DR(f) = \min(new\_DR,CR(f))$

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$S_{CR} = 9$, and $TLO = 0$

$S_{CR} = 10$, and $TLO = 0$

$CR(f) = 2$

Delta positive, $S_{CR} = 9 + 1 = 10$

$DR(f) = 2$
FSE – how it works

It calculates the leftover rate TLO, removes the terminated flows from the FSE and calculates the sum of all the priorities, S_P.

for all flows i in FG do
  if P(i) < 0 then
    delete flow
  else
    S_P = S_P + P(i)
  end if
end for

if DR(f) < CR(f) then
  TLO = TLO + (P(f)/S_P) * S_CR - DR(f))
end if

S_CR = 10, and TLO = 0

\[ S_P = 1.5 \]
FSE – how it works

- It calculates the sending rate.

\[
\text{Rate} = \min(\text{new}_\text{DR}, \frac{\text{P}(f) \times \text{S}_\text{CR}}{\text{S}_\text{P}} + \text{TLO})
\]

if Rate \(!=\) new\_DR and TLO > 0 then

\[
\text{TLO} = 0 \quad \text{// f has ‘taken’ TLO}
\]

end if

- It updates DR(f) and CR(f) with Rate.

\[
\text{if Rate} > \text{DR(f) then} \\
\text{DR(f)} = \text{Rate}
\]

\[
\text{if Rate} > \text{CR(f) then} \\
\text{CR(f)} = \text{Rate}
\]

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<td>0.5</td>
<td>3.33</td>
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\[\text{S}_\text{CR} = 10,\; \text{and}\; \text{TLO} = 0\]

\[
\text{Rate} = \min(\inf, 0.5/1.5 \times 10 + 0) = 3.33
\]

\[
\text{DR}(f) = 3.33,\; \text{CR}(f) = 3.33
\]
Simulation Results

- Good News !!
Fairness

Fairness Index - for 2 flows

Fairness Index - for 3 flows
Fairness

Fairness Index - for 4 flows

<table>
<thead>
<tr>
<th>RTT Ratio</th>
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<tbody>
<tr>
<td>1:1:1:1</td>
<td></td>
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<tr>
<td>8:4:2:1</td>
<td></td>
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<tr>
<td>16:8:4:2</td>
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<tr>
<td>24:12:6:3</td>
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<tr>
<td>32:16:8:4</td>
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<tr>
<td>40:20:10:5</td>
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<tr>
<td>48:24:12:6</td>
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Fairness Index - for 5 flows

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</tr>
<tr>
<td>16:8:4:2:1</td>
<td></td>
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<td>32:16:8:4:2</td>
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FSE | Without FSE
Benefits From The Non-Greedy Flows

![Graph showing benefits from non-greedy flows](image-url)
Simulation Results

- Sad Part !!
Average Queue Length – 2 Flows
Packet Loss Ratio – 2 Flows

![Graph showing Packet Loss Ratio vs. RTT Ratio with and without FSE]

- Packet Loss Ratio %
- RTT Ratio

Legend:
- FSE
- Without FSE

Values:
- 0.001 to 0.008
- 5:1 to 45:1
Throughput for 2 flows

Throughput utilization %

RTT Ratio

FSE

Without FSE

5:1 10:1 15:1 20:1 25:1 30:1 35:1 40:1 45:1
Future plans

- We want to keep the FSE as simple as possible
  - Trying passive for now – see if the problems are due to TFRC, or require other changes to the algorithm

- Else, we go for (slightly) active
  - When congestion is noticed by a flow, FSE immediately informs all other flows in the same FSE
Backup Slides
Fairness Index – 2 flows

Fairness Index

RTT Ratio

FSE
Without FSE
Fairness Index – 3 Flows

The graph illustrates the Fairness Index against the RTT Ratio for 3 flows with and without FSE. The green line represents 'FSE' while the red dashed line represents 'Without FSE'. The Fairness Index values range from 0.65 to 1.0, and the RTT Ratio values range from 0 to 200.
Fairness Index – 4 flows
Fairness Index – 5 Flows

![Graph showing Fairness Index vs. RTT Ratio with two lines representing FSE and Without FSE]
Throughput – 2 Flows

Link Utilization of FSE Over Link Utilization Without FSE

- RTT Ratio vs Link Utilization %
- FSE vs Without FSE
Throughput – 3 Flows

Link Utilization of FSE Over Link Utilization Without FSE

- FSE
- Without FSE

RTT Ratio

Link Utilization %
Throughput – 4 Flows

Link Utilization of FSE Over Link Utilization Without FSE
Throughput – 5 Flows

![Graph showing Link Utilization of FSE Over Link Utilization Without FSE vs RTT Ratio. The graph compares the link utilization percentage between FSE and Without FSE conditions, with a range of RTT ratios from 0 to 500.](image)
Exceeding Bottleneck – 2 Flows

![Graph showing the number of times exceeding the bottleneck with and without FSE]

- **Without FSE**
- **FSE**

RTT Ratio vs. # of times exceeding bottleneck diagram with data points for various RTT ratios.
Exceeding Bottleneck – 3 Flows

# of times exceeding bottleneck

RTT Ratio

Without FSE
FSE
Exceeding Bottleneck – 4 Flows

# of times exceeding bottleneck

- Without FSE
- FSE

- RTT Ratio
- # of times exceeding bottleneck
Exceeding Bottleneck – 5 Flows

# of times exceeding bottleneck

- **Without FSE**
- **FSE**

![Graph showing the comparison of # of times exceeding bottleneck with and without FSE. The x-axis represents RTT Ratio ranging from 0 to 500, and the y-axis represents # of times ranging from 0 to 25000. The graph shows a clear increase in the number of times exceeding the bottleneck with higher RTT Ratios for both FSE and Without FSE.](image-url)
Benefits from the non-greedy flows