Quality of Protection: A Quantitative Unifying Paradigm to Protection Service Grades

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Source: paper written by Ornan Gerstel, Galen Sasaki
MOTIVATION

• Protection classes considered for the optical layer:
  – Guaranteed protection (99.999%)
  – Best effort protection
  – Unprotected traffic
  – Preemptable traffic
Problem: not all of them are completely specified and quantified
  -Priority class only provides relative protection
MOTIVATION

• This approach provides:
  – Absolute guarantee for protection (very useful for service level agreement)
  – Reduce the bandwidth requirements for protection bandwidth
  – Reduce the cost for the customer by gauging the level of protection he wants
HOW DOES IT WORK?

• First consider a case without the preemptive class of protection

• For a given link L with connections $C_1, C_2, \ldots, C_n$:
  – Assign:
    
    $Q(C_i) =$ the probability that $C_i$ on L will be protected if L fails.
    
    $B(C_i) =$ bandwidth required by $C_i$
    
    in our case $B(C_i) = 1$ for all $i$
HOW DOES IT WORK?

• For a Link L, with $C_1, C_2, \ldots, C_n$ connections, each with $Q(C_i)$ assigned, define:

$$ESB(C_i) = Q(C_i) * B(C_i) \Rightarrow \text{Equivalent Survivable Bandwidth}$$

The protection bandwidth we need to reserve to guarantee the $Q(C_i)$ probability protection is:

$$ESL(L) = \left[ \sum_{i} ESB(C_i) \right]$$
HOW DOES IT WORK?

- Let’s say L1 is the working link with 4 links on it. Each link has assigned Q(C) as follows:
- \(Q(C_1)=0.7\)  \(Q(C_2)=0.15\)  \(Q(C_3)=0.5\)  \(Q(C_4)=0.35\)
HOW DOES IT WORK?

• Problem:
  1. How many connections do we need to reserve for protection on L2 incase L1 fails in order to meet the requirements?

\[
ESL (L1) = \left[ \sum_{i=1}^{4} Q(C_i)B(C_i) \right] = \left[ 0.7 + 0.15 + 0.5 + 0.35 \right] = 2
\]
HOW DOES IT WORK?

• Problem
  – Since we are only going to be allocating two connections for protection, how do we determine which two of \{C_1, C_2, C_3, C_4\} will be picked to be protected

\[
\begin{align*}
Q(C_1) &= 0.7 \\
Q(C_3) &= 0.20 \\
Q(C_2) &= 0.15 \\
Q(C_3) &= 0.15
\end{align*}
\]

Generate Random Uniformed variable \(V\) (between 0 and 1)

– Answer: for the shown \(V\), \(C_1\) and \(C_4\) will be switched to the L2
EXTENDING THE IDEA TO PREEMPTIVE TRAFFIC

- Each connection C has a parameter $-1 \leq Q(C) \leq 1$

<table>
<thead>
<tr>
<th>Guaranteed</th>
<th>$Q(C) = 1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best Effort</td>
<td>$0 = Q(C) &lt; 1$</td>
</tr>
<tr>
<td>Unprotected</td>
<td>$Q(C) = 0$</td>
</tr>
<tr>
<td>Preemptable</td>
<td>$-1 &lt; Q(C) &lt; 0$</td>
</tr>
<tr>
<td>Free link</td>
<td>$Q(C) = -1$</td>
</tr>
</tbody>
</table>

- If $Q(C) > 0$ then C survives with probability $Q(C)$
- If $Q(C) < 0$ then C is interrupted with probability $\text{abs}(Q(C))$
EXTENDING THE IDEA TO PREEMPTIVE TRAFFIC

• Define:
  – $SP(C) = \max\{Q(C), 0\}$ survivability probability
    • If $SP(C) > 0$ then $C$ is survivable connection
  – $PP(C) = \max\{-Q(C), 0\}$ preemptable probability
    • If $PP(C) > 0$ then $C$ is preemptable connection
  – $EPB(C) = PP(C) * B(C)$ equivalent preemptable bw
    • $B(C) = 1$
EXTENDING THE IDEA TO PREEMPTIVE TRAFFIC

- EPL equivalent preemtable load

\[
EPL(L) = \left[ \sum_i EPB(C_i) \right]
\]

- Theorem: A sufficient condition to insure that the QoS grades for each connection is valid for the failure is:

\[
ESL(L1) \leq EPL(2)
\]
Algorithm

• Upon a failure of L2 the following algorithm is used:
  1. The connections on L2 are preempted according to the EPL(L2) requirements
  2. This will free up at least ESL(L1) ≤ EPL(L2) bandwidth.
     Chose the survivable connection from L1 based on ESL(L1) requirements (previous example)
COMPLETE EXAMPLE

• The following connections exist on L1:
  – C1; \( Q(C1) = 0.60 \)
  – C2; \( Q(C2) = 0.70 \)
  – C3; \( Q(C3) = 0.30 \)
• The following connections exist on L2:
  – C4; \( Q(C4) = -0.40 \)
  – C5; \( Q(C5) = 0.20 \)
  – C6; \( Q(C6) = -0.80 \)
  – C7; \( Q(C7) = -1 \) (unused link)
• Problem: Determine if there is enough bandwidth allocated for protection and determine how will be connection will be switched in case of failure on L1 in order to insure the assigned QoS grades.
LIMITATIONS

- The proposed algorithm is only for two-node networks and ring networks.
- The analysis for ring networks is more complicated and it is only presented for \( Q(C) = 1 \) or \( Q(C) = 0 \). Also, it only provides the size of the reserve protected bandwidth, not how to go about establishing the connections upon failure.
- The calculation for the required restoration bandwidth is not valid for mash networks.
GOOD CHARACTERISTICS

• A unified definition for all Quality of Services categories for the first time
• A significant savings in reserved bandwidth allocation
• A good marketing/legal tool for Service Level Agreement
HOMEWORK

• For a two node network the probability of protection on the connections on L1 specified in the service level agreement are as follows:
  – \( Q(C1)=0.7; Q(C2)=1; Q(C3)=0.2; Q(C4)=-0.5 \)

  Question: How much bandwidth does the service provider needs to reserve on L2 in order to fulfill the SLA requirements for protection. What are the all possible combination of connections that will be switched to L2 in case of a failure on L1. What is the probability for each combination.
HOMEWORK

• In a two node network the provider has a SLA that specifies the following protection grades for links L1 and L2:
  – L1: Q(C1)=0.7; Q(C2)=0.4; Q(C3)=−0.2; Q(C4)=0.8; Q(C5)=0.2
  – L2: Q(C6)=−0.7; Q(C7)=−0.3; Q(C8)=−1
Will the provider be able to support the specified protection grade in case of L1 failure. Why yes or Why no?
Questions