Relaxing Delayed Reservations: An approach for Quality of Service differentiation in Optical Burst Switching networks

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Optical Burst Switching

- Packets destined to the same egress node and with similar QoS requirements (same FEC) are aggregated into a burst at the edge.
- Control and data travel separately on different channels.
- The control packet is sent first to reserve resources at intermediate nodes.
- The burst remains in the optical domain.
OBS signaling schemes

- One-way (Tell-and-Go)
  - The control packet precedes the burst by a Time Offset (TO)
  - The control packet setups the path for the following burst
  - Minimizes pre-transmission delay
  - Requires small buffers
  - High burst dropping probability (congestion avoidance techniques)

RGVC, Horizon, JET, JIT
OBS signaling schemes (cont.)

- Two way (Tell-and-Wait)
  - Establish end-to-end connections before transmitting the bursts
  - Enables setup retrials
  - In large networks: high delay (RTT for reservations)
  - Requires large buffers
  - Improved dropping performance

WR-OBS and EBRP
QoS in OBS networks

Open issue in OBS networks

- offset-time-based JET
  - Maps classes to different TO

- Burst segmentation
  - Packets from lower classes are placed at the tail of the burst. The tail is discarded in a contention

- Early dropping
  - Randomly drops bursts depending on their class

- INI-hybrid signaling scheme
  - TAW until an intermediate node, followed by TAG
Efficient Burst Reservation Protocol (EBRP)

- 2-way reservation scheme
- Suitable for
  - Bufferless OBS networks
  - Non delay sensitive traffic
- Provides the ability to reserve capacity for a duration larger than the burst
  - Schedule the burst flexibly in the time domain
    -> Increase forwarding acceptance probability
  - Control the degree of flexibility
    -> Provide service differentiation
EBRP mechanisms

- **In-advance reservations**
  - If the capacity is not available when requested, the reservation is scheduled for the future.

- **Relaxed Delayed reservations**
  - **Reservation Duration (RD)** Parameter
  - Reserved Duration on a link may exceed the burst duration during SETUP phase.
  - Extra RD increases the acceptance probability at subsequent nodes.
  - Window for *in-advance* mechanism.
  - Strict time requirements are restored during the ACK phase.
Control Plane

- SETUP and ACK/REJECT packets
- Packet format

| ID | L₁ | L₂ | … | Lₙ | D | I | ST | RD | TO |

- \(L₁, L₂, \ldots, Lₙ\): link sequence (source routing)
- \(I\) specifies the amount of information
- \(D\) specifies the maximum allowable delay
- \(ST\) specifies the time after which the reservation of capacity should begin
- \(RD\) specifies the maximum time period following \(ST\), for which the specific link should be reserved
- \(TO\) time that the source has to wait after the reception of ACK to transmit the burst

Fields \(ST\), \(RD\) and \(TO\) are updated at every node
EBRP: Successful SETUP

1st Transmission Request

2nd SETUP Message

3rd Resource Negotiation

4th Forward SETUP to next hop

5th Complete Reservation

6th Send Confirmation

7th Release excess reservations

8th Wait time offset \((\delta_1 + \delta_2)\)

9th Begin Transmission

I. Examine resource availability
II. Perform the reservation
III. Update the ST and RD fields

\[ \text{Reserved} \]

\[ \text{Reserved} \]
EBRP: Blocked SETUP

1st Transmission Request

2nd SETUP Message

3rd Resource Negotiation

4th Forward SETUP to next hop

5th Send REJ packet

6th Examine resource availability

7th SETUP Retrial

8th Perform the reservation

9th Update the ST and RD fields

10th Release reserved capacity

\[
\begin{align*}
S &\quad \text{ST}_0 = T_{RTT} \\
S_1 &\quad \text{ST}_1 = T_{RTT} + \delta_1 \\
S_2 &\quad \text{ST}_2 = T_{RTT} + \delta_1 + \delta_2 \\
D &\quad \text{Reserved} \\
\end{align*}
\]

\[
\begin{align*}
\text{ST}_0 &\quad \text{RD}_0 \\
\text{ST}_1 &\quad \text{RD}_1 = \text{RD}_0 - \delta_1 \\
\text{ST}_2 &\quad \text{RD}_2 = \text{RD}_1 - \delta_2 \\
\end{align*}
\]

\[
\begin{align*}
\text{RD}_0 + \delta_1 &\quad \text{Reserved} \\
\text{RD}_1 + \delta_2 &\quad \text{Reserved} \\
\end{align*}
\]
Timing Considerations

**Blocked SETUP**

- $S_0$ at $T_{RTT}$
- $S_1$ at $T_{RTT}$
- $S_2$ at $T_{RTT}$
- $S_h$ at $T_{RTT}$

**Successful SETUP**

- $S_0$ at $T_{RTT}$
- $S_1$ at $T_{RTT}$
- $S_2$ at $T_{RTT}$
- $S_h$ at $T_{RTT}$

**Acknowledgement phase**

- $S_0$ at $T_{RTT}$
- $S_1$ at $T_{RTT}$
- $S_2$ at $T_{RTT}$
- $S_h$ at $T_{RTT}$
Reservation Duration Parameter

- During SETUP the RD is trimmed down
- RD larger than burst duration: provides higher probability of reserving at least the minimum duration at subsequent nodes
- Initialize the RD?
  - Dynamic, not static
  - Function of the size and number of hops
  - Map different functions to different classes of service
Reservation Duration Functions

1. \( RD(T_{data}) = k \cdot T_{data}, \ k \geq 1 \)

2. \( RD(T_{data}, h) = T_{data} \cdot h^n, \ n \geq 0 \)

3. \( RD(T_{data}, h) = T_{data} \cdot (1 + \theta)^h, \ \theta \geq 0 \)

- Large RD values increase the forwarding acceptance probability but might hinder other SETUP requests
Performance Evaluation

- Ns-2 platform
- EBRP, JET and TAW
- NSFnet
  - Single wavelength, $C=40Gb/s$
  - Edge node buffer = 256MB
- Traffic
  - Poisson process rate ($\lambda$)
  - Burst size exponential ($B$)
  - Uniform destinations
  - Deadline=0.3 sec
- Performance metrics:
  - Data loss ratio (take into account burst size)
  - Average end-to-end delay
Effect of RD function

1) \( RD(T_{data}) = k \cdot T_{data}, k \geq 1 \)

- **Tradeoff**: reserving excess resources on a link give a higher acceptance probability at subsequent nodes but might hinder the acceptance of other requests on that link
- Optimum \( k \) depends on network topology and traffic
- When \( k=1 \), EBRP resembles TAW with delayed reservations
- Compare \( k=1 \) and \( k=2 \) → Positive effects of *in-advance* and *relaxed delayed* mechanisms
Effect of RD functions (cont.)

2) \(RD(T_{data}, h) = T_{data} \cdot h^n, \ n \geq 0\)

3) \(RD(T_{data}, h) = T_{data} \cdot (1 + \theta)^h, \ \theta \geq 0\)

- Bursts traveling many hops have a smaller success probability
- Include \(n\) to treat fairly bursts that travel different # of hops
Comparison with JET and TAW

- JET and JET with retrials
- TAW with immediate reservations
- EBRP with $RD(T_{data}) = k \cdot T_{data}$ ($k=1$ and $k=2$)

✔ EBRP can accomplish high to medium data loss ratio gain with a small delay penalty
Service Differentiation

- Map different classes of service to different RD functions
- 3 Classes of Service
- \[ RD_i(T_{\text{data}}) = k_i \cdot T_{\text{data}} \]
  \[ k_1 = 2, \ k_2 = 1.5 \text{ and } k_3 = 1.25 \]
- CoS-1 exhibits the lowest data loss ratio and the lowest delay
Service Differentiation (cont.)

- Increase $k_1$ ($k_1=3.0$)
- CoS-1 performance improves
- CoS-2 and CoS-3 deteriorate
- If we increased further $k_1$ the performance of CoS-1 would also deteriorate

<table>
<thead>
<tr>
<th>Arrival Rate ($\lambda$)</th>
<th>Data Loss Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CoS 1 ($k=2.0$)</td>
</tr>
<tr>
<td></td>
<td>CoS 2 ($k=1.5$)</td>
</tr>
<tr>
<td></td>
<td>CoS 3 ($k=1.25$)</td>
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<tr>
<td></td>
<td>non QoS EBRP</td>
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<td>10MB</td>
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<tr>
<td>130</td>
<td>10MB</td>
</tr>
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Summary

- Efficient Burst Reservation Protocol
- *In advance and Relaxed Delayed reservations* mechanisms
- Reservation Duration (RD) Parameter
- Evaluated 3 different functions to initialize RD
- Compared EBRP performance with other typical protocols
- Presented an example of service differentiation