Measuring the Impact of Adversarial Errors on Packet Scheduling Strategies

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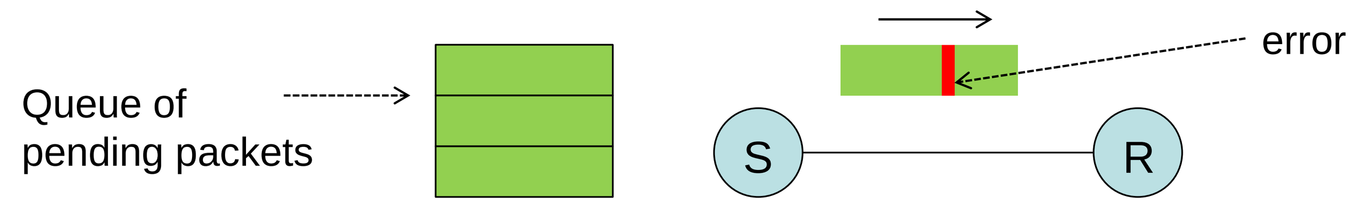
Developing the Science of Networks

Introduction

Problem definition. Packet transmission over one unreliable link with:

- worst occurrence of link errors
- adversarial or stochastic packet arrivals
- instantaneous or deferred feedback



Efficiency metric. ***Relative throughput:***

Long-term competitive ratio [1] with respect to the throughput achieved by the optimal offline algorithm.

$L_X(\mathrm{A},\mathrm{E},t)$:total length of packets transmitted successfully by an algorithm X up to time t, under packet arrival pattern A and error pattern E.

$T_{\mathrm{Alg}}(\mathrm{A},\mathrm{E},t)$:*partial* relative throughput of algorithm Alg up to time t and under A and E.

$$T_{\mathrm{Alg}}(\mathrm{A},\mathrm{E},t) = \frac{L_{\mathrm{Alg}}(\mathrm{A},\mathrm{E},t)}{L_{OPT}(\mathrm{A},\mathrm{E},t)}$$

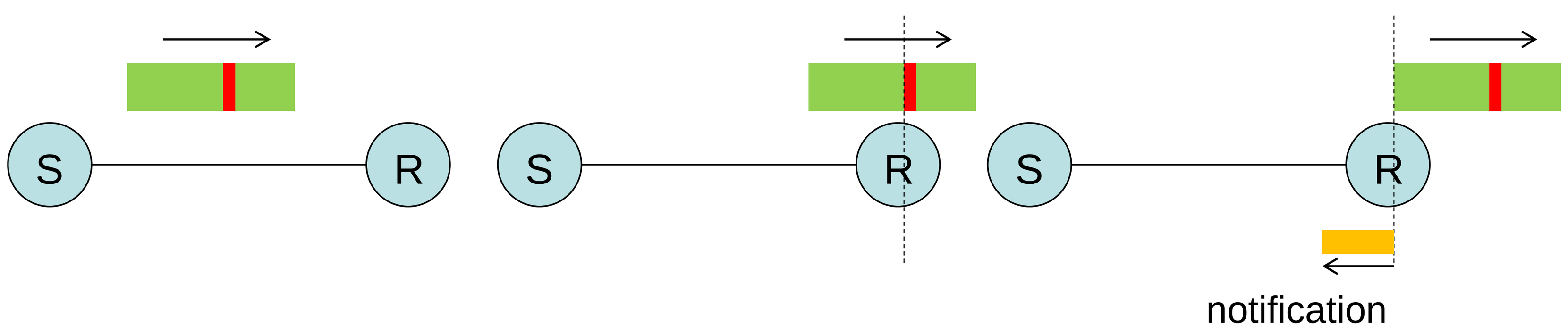
T_{Alg} :relative throughput of Alg in the long-term ($t\to\infty$), over all possible arrival and error patterns (sets A and E).

$$T_{\mathrm{Alg}} = \inf_{\mathrm{A}\in A,\mathrm{E}\in E} \lim_{t\to\infty} T_{\mathrm{Alg}}(\mathrm{A},\mathrm{E},t)$$

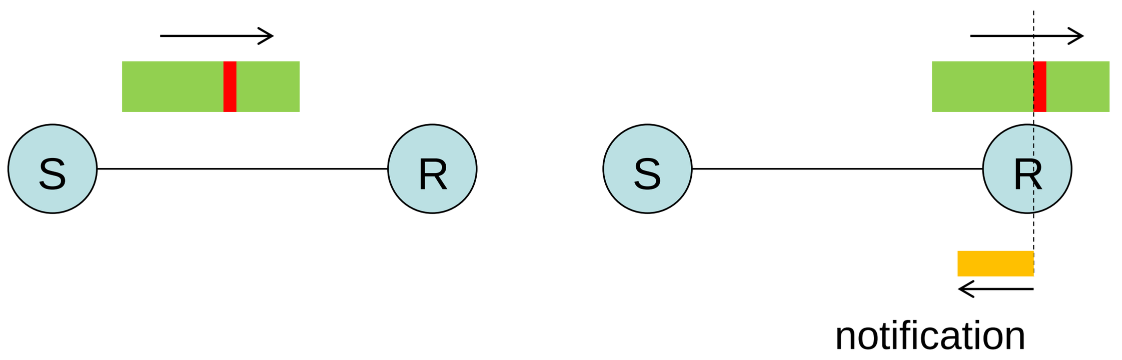
Observation: *The general offline version of our scheduling problem, where the algorithm has full knowledge of errors and arrivals, is NP-hard.*

Feedback Mechanisms

Deferred: The sender is notified of an error after the whole packet has been received by the receiver.



Instantaneous: The sender is notified that a packet has suffered an error, at the moment that the error occurs.



This mechanism is an abstraction of the Continuous Error Detection (CED) framework [2].

One Packet Length

Theorem 1 *No packet scheduling algorithm Alg can achieve a relative throughput larger than 0 in the deferred feedback model. This holds for both models of packet arrivals; adversarial and stochastic.*

Theorem 2 *Any work conserving online scheduling algorithm with instantaneous feedback, has optimal relative throughput of 1 when all packets have the same length.*

Two packet lengths / Instantaneous Feedback

Two different packet lengths, l_{min} and l_{max}, where $l_{min} < l_{max}$.

Let $\gamma = l_{\max} / l_{\min}$ and $\bar{\gamma} = \lfloor \gamma \rfloor$

Adversarial Arrivals:

Upper Bound	Lower Bound
$T_{\mathrm{Alg}} \le \bar{\gamma}/(\gamma+\bar{\gamma}) \le 1/2$	$T_{SL-\mathrm{Pr}} \ge \bar{\gamma}/(\gamma+\bar{\gamma})$

Algorithm **SL-Pr**:

At the beginning of the execution and whenever the sender is notified about a link error, it checks the queue of pending packets. If there are at least γ packets of length l_{min}, it schedules them (preamble) and then continues using the *Longest Length* (LL) policy. Otherwise, it simply schedules packets following the LL policy.

Stochastic Arrivals:

Packets arrive according to a Poisson process with parameter $\lambda>0$ and are independently assigned one of the lengths l_{min} and l_{max}, with probabilities $p>0$ and $q>0$ respectively, where $p + q = 1$.

Upper Bound	Lower Bound
$T_{\mathrm{Alg}} \le \bar{\gamma}/\gamma$	$T_{CSL-\mathrm{Pr}} \ge \bar{\gamma}/(\gamma+\bar{\gamma})$ *if* $\lambda p l_{\min} \le \bar{\gamma}/(2\gamma)$
$T_{\mathrm{Alg}} \le \max\{\lambda p l_{\min}, \bar{\gamma}/(\gamma+\bar{\gamma})\}$ *if* $p<q$	$T_{CSL-\mathrm{Pr}} \ge \min\{\lambda p l_{\min}, \bar{\gamma}/\gamma\}$ *if* $\lambda p l_{\min} > \bar{\gamma}/(2\gamma)$

Algorithm **CSL-Pr**:

If $\lambda p l_{\min} > \bar{\gamma}/(2\gamma)$, then algorithm *Shortest Length* (SL) is run, otherwise algorithm SL-Pr is executed.

References

[1] Kirk Pruhs, Jiri Sgall, and Eric Torng. *Online scheduling*. pages 115-124. CRC Press, 2003.

[2] Anand Raghavan, Kannan Ramchandran, and Igor Kozintsev. *Continuous Error Detection (CED) for reliable communication*. IEEE Transactions on Communications, 49(9):1540-1549, 2001.