Performance analysis of optical networks: a polling model with retrial queues and glue period

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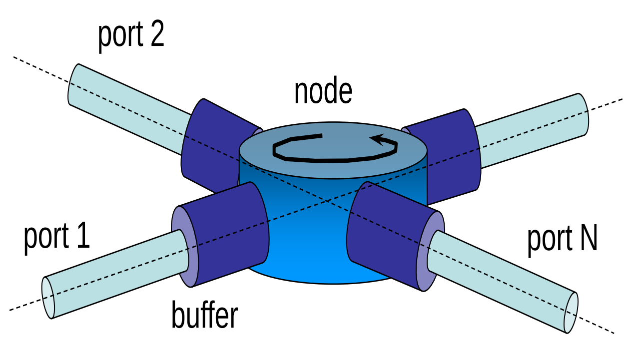
We investigate the performance of optical networks involving queuing processes in the nodes. The basic model is explained and key performance measures are discussed. Then the idea of extending this model to a multi-wavelength system is explained.

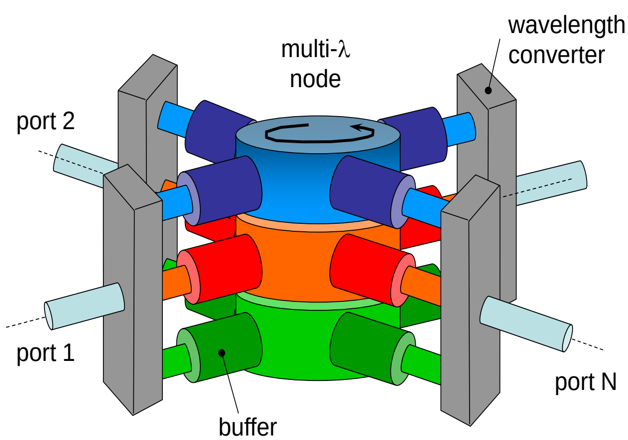
Introduction

In large scale communication networks packets are routed through a series of nodes from source to destination. In copper-based systems this is usually done by time-slot routing. These systems are modeled mathematically as single server polling models. Buffers are essential for enabling time-interleaved handling of multiple packet streams inside the nodes. In optical routing and buffering, a few salient features are fiber delay loops, slowing down the optical packets (using high refractive index materials) and multi-wavelength transmission. We include the first two features in our model and study the key performance issues, like queue length, waiting time and work (time the server should work without interruptions in order to serve all the jobs present in system).

Network Nodes



Switching in time domain



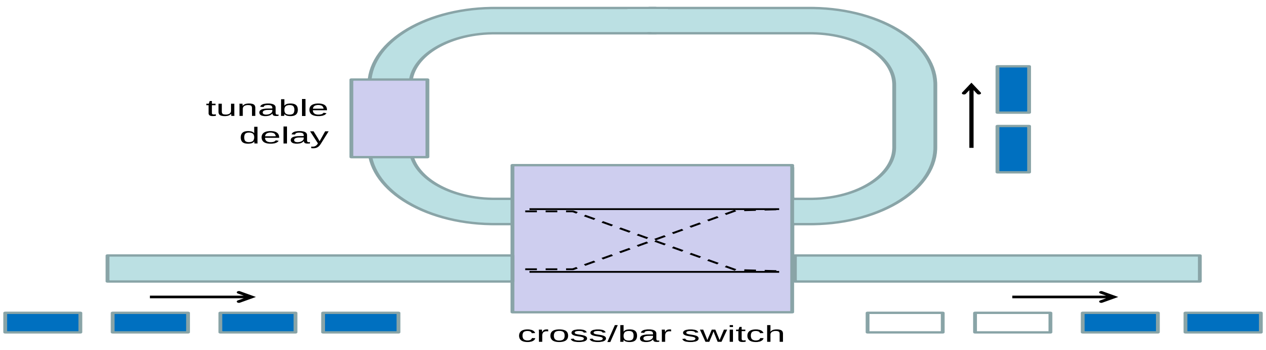
Switching in time and wavelength domain

Model

Our model is based on the idea that a single server, cyclically, visits all the ports in a node. In the queueing literature, this is called a cyclic polling system. The major difference from the usual polling systems is that, instead of normal queuing, we have retrial queues with a glue period. A glue period is the time interval between the server's arrival to the port and beginning of service. During this interval packets who arrive or retry are collected in a queue. Packets arriving or retrying in any other period go 'into the loop' and retry after being delayed for a circulation loop time. After the glue period the server starts serving (i.e. routing packets) and it serves only the packets which were collected during that glue period. The retrial queues model the fiber delay loops and the glue periods model the slowing of light.

Results

In [1], the above-sketched polling model is analyzed. The joint queue length distribution for such a system under given conditions is calculated. In the upcoming work [2] the steady state workload distribution is determined. That can be used to approximate the mean waiting time and queue length at each port.



Optical loop buffer with fine-tuning delay stage (glue period)

One of the most important reasons for studying such mathematical models is to improve the performance of the system. In this model the glue length and retrial rates are system design parameters. So we want to choose these two in such a way that the steady state mean amount of work in our system is minimized. The retrial rate depends on the size of the retrial loop and many other factors. So optimizing the system with respect to it requires consideration of factors which the current model does not study. Instead the authors choose to optimize the system w.r.t. the glue period length. For the above model, given all other terms, they show that if the glue periods of all ports have the same distribution then the work in system at steady state is convex w.r.t. the glue period length. This means, for given distribution, the system designer can choose a particular mean glue period length for the nodes to get best system response.

Extension

The current model doesn't take into consideration one of the most important advantages of optical networks, i.e., multi-wavelength operation by which multiple optical paths independently can exist within a single fiber, and cross-overs between these paths can be made by wavelength conversion. The idea of multi-wavelength can be incorporated into the polling model by allowing multiple servers, where each wavelength channel represents a server. The literature available for such models is scarce. See [3,4] for a stability analysis of multiserver polling and a mean field approximation of large optical passive networks respectively and also for further references. We are designing a model which captures the essential features of multi-wavelength optical networks. For such a system we have to decide on system parameters so as to come up with an efficient model. One of the most important aspects in that system would be the allocation of servers (wavelengths) to different nodes, e.g. we can a allocate server to a particular set of nodes or allocate them uniformly in cyclic (or some fixed) order or allocate dynamically according to the requirement.

Acknowledgment

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References

[1] M.A. Abidini, O.J. Boxma and J.A.C. Resing (2015). Analysis and optimization of vacation and polling models with retrials. Eurandom report 2015-003. arXiv:1501.05563.
[2] M.A. Abidini, O.J. Boxma, B. Kim, J. Kim and J.A.C. Resing (2015). Performance analysis of polling systems with retrials and glue periods- Tentative title, paper in preparation.
[3] N. Antunes, Chr. Fricker and J. Roberts (2011). Stability of multi-server polling system with server limits. Queueing Systems, 68, 229-235.
[4] N. Antunes, Chr. Fricker, Ph. Robert and J. Roberts (2010). Traffic capacity of large WDM Passive Optical Networks. Proceedings 22nd International Teletraffic Congress (ITC 22), Amsterdam, September 2010.