

Deadline-Driven Bandwidth Allocation with Flexible Transmission Rates in WDM Networks

Andrei, Dragos, et al. "Deadline-driven bandwidth allocation with flexible transmission rates in WDM networks." *2008 IEEE International Conference on Communications*. IEEE, 2008.

Background

- Different applications and services (e.g., stock market applications) have different bandwidth and deadline requirements.
- In traditional traffic grooming, a request is provisioned using a bandwidth pipe whose capacity is defined by the request.

Contributions

- **In general:**
 - Combination of a request's deadlines and its file size together determine a bandwidth range from which the bandwidth can be allocated.
- **In details:**
 - Route Computation
 - Bandwidth allocation with fixed policies
 - Adaptive bandwidth allocation based on network states
 - Dynamic bandwidth readjustment
 - $MinRate \leq Rate \leq MaxRate$ where $MinRate = Filesize / (Deadline - arrival)$;
 $MaxRate = \text{line rate}$

Route Computation

- First find a route with enough bandwidth (at least *MinRate*) to satisfy the request's deadline.
- Second, determine a specific rate *Rate within the range*, based on current network state, so that the network throughput is maximized.
- Rate is allowed to vary in the dynamic bandwidth readjustment scenario.

Bandwidth allocation with fixed policies

- After path computation, the maximum bandwidth to be offered to the request is B (*bottleneck residual bandwidth along the path*), while the minimum is *MinRate*.
- **Max:** provision B .
 - Disadvantage: it can create resource contention and congestion at high network loads.
- **Min:** provision *Minrate*
 - Advantage: it tends to multiplex the requests very densely on the lightpath pipes, and it does not create timing conflicts

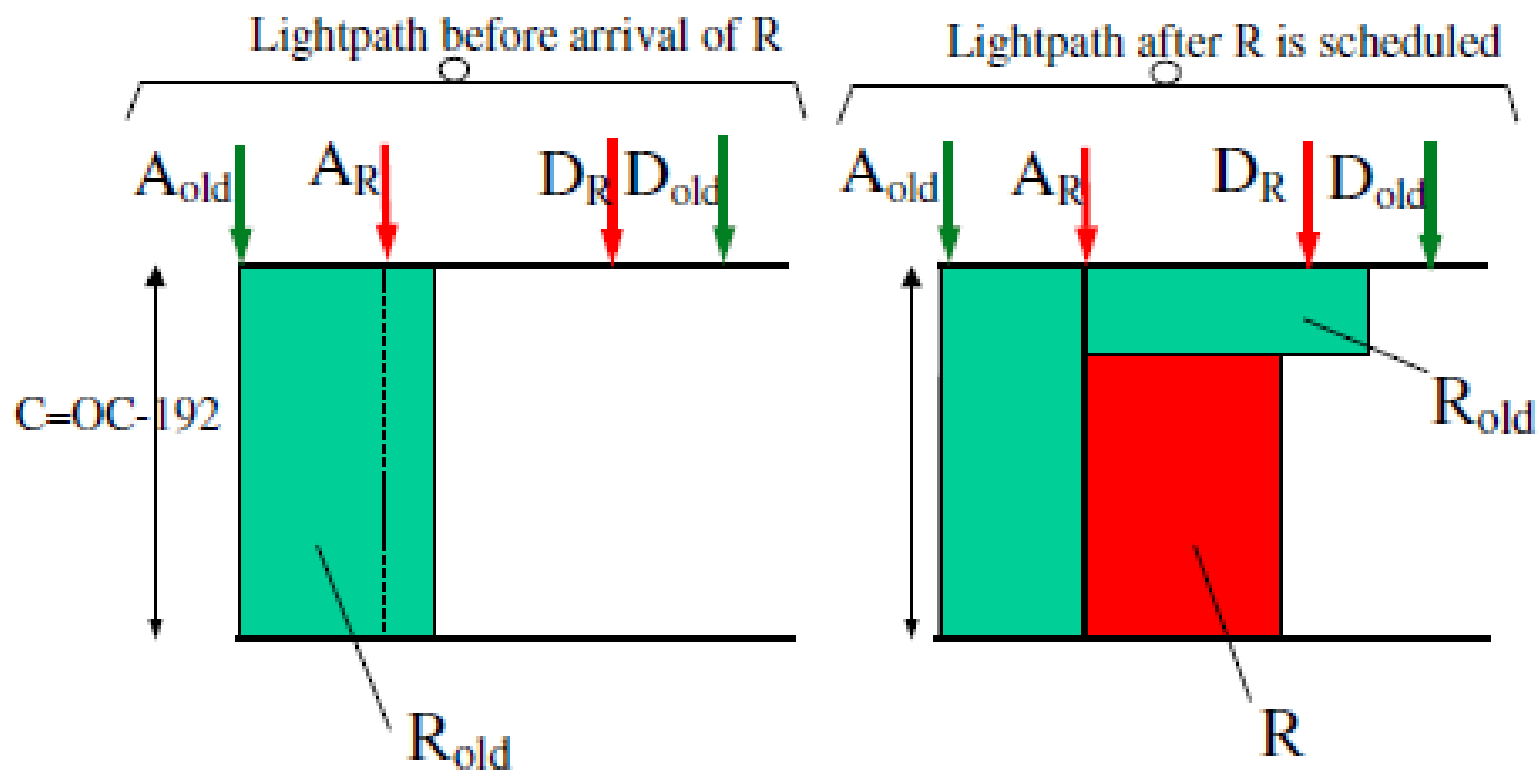
Adaptive bandwidth allocation

- First determine how congested(busy) the computed path is by choosing a threshold TH . If there is at least one link on the path with used wavelengths more than TH , the path is congested.
- If the computed path is congested, allocate ***Min*** (*Minrate*), else allocate ***Max*** (B).

Dynamic bandwidth readjustment

- **Previous two methods:**
 - In the previous two methods, the bandwidth along the path was fixed for the request.
 - If no path with at least *MinRate* bandwidth is found for the request, the request is blocked.
- **Dynamic bandwidth readjustment** frees up bandwidth for incoming requests which cannot be provisioned otherwise by readjusting bandwidth of scheduled requests.
 - Check the number of already-scheduled requests who conflict with current request and whose rates can be reduced while still satisfying their deadlines.
 - Decrease the rates of scheduled requests which conflict with current request.
 - Check if the current request will now meet its deadline by having at least *MinRate* bandwidth free on its path.

Dynamic bandwidth readjustment -- Example



Dynamic bandwidth readjustment – Variations

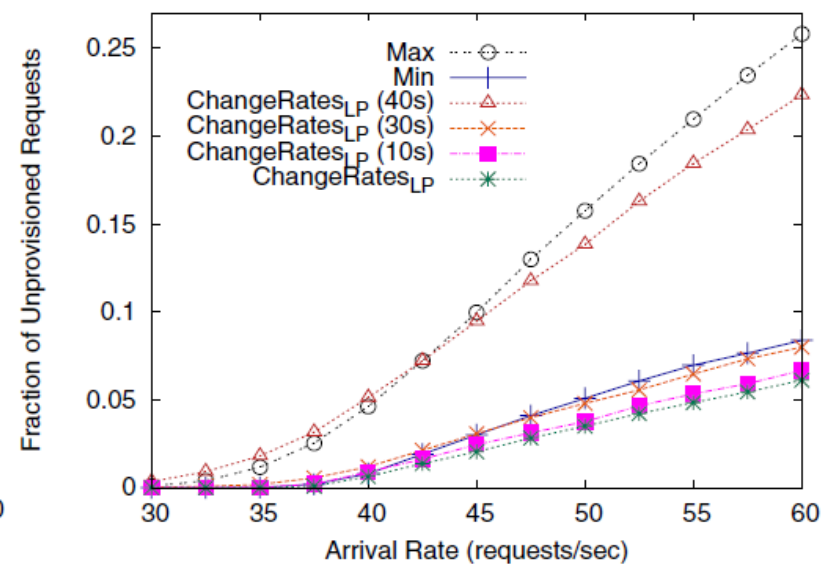
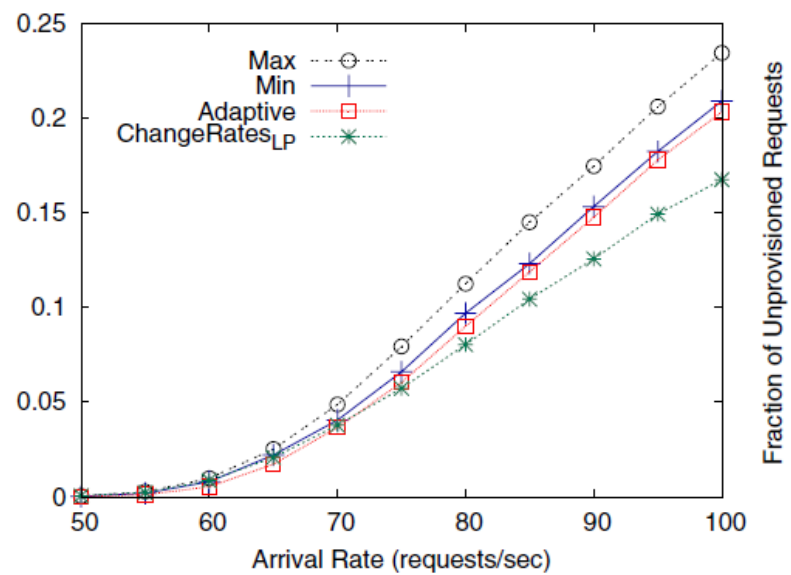
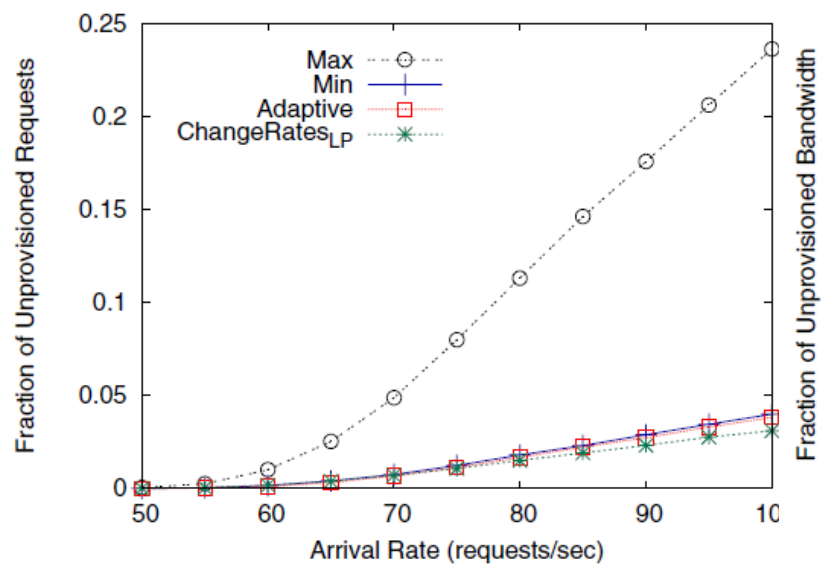
- **Changing the Rates for Long Paths**

- Because of the *Max* policy, which uses high bandwidth in bursts, the path we find for the current request may become very long.
- In this variation, rates of already-scheduled requests may be changed even if a path is found for the current request, if it is much longer than the shortest path plus a pre-defined value.

- **Changing Rates with Time Limitations**

- limit the number of rate changes for the lifetime of a request.
- Allow changing the rate of a request only if at least an amount of T data has been transmitted since the last rate change.

Results



Routing and Scheduling for Variable Bandwidth Advance Reservation

Patel, Ankitkumar N., and Jason P. Jue. "Routing and scheduling for variable bandwidth advance reservation." *Journal of Optical Communications and Networking* 3.12 (2011): 912-923.

Bandwidth Reservation Schemes

- **Immediate Reservation (IR)**

- A fixed amount of bandwidth is reserved at the immediate instance of a request arrival.

- **Disadvantages**

- The probability of instantaneous bandwidth availability for high bandwidth applications may be low, causing high request blocking probability.

Bandwidth Reservation Schemes

- **Advance Reservation (AR)**

- A fixed amount of bandwidth is reserved in advance prior to the data transfer.
- A scheduler may potentially delay the request to achieve high network resource efficiency and high probability of success.

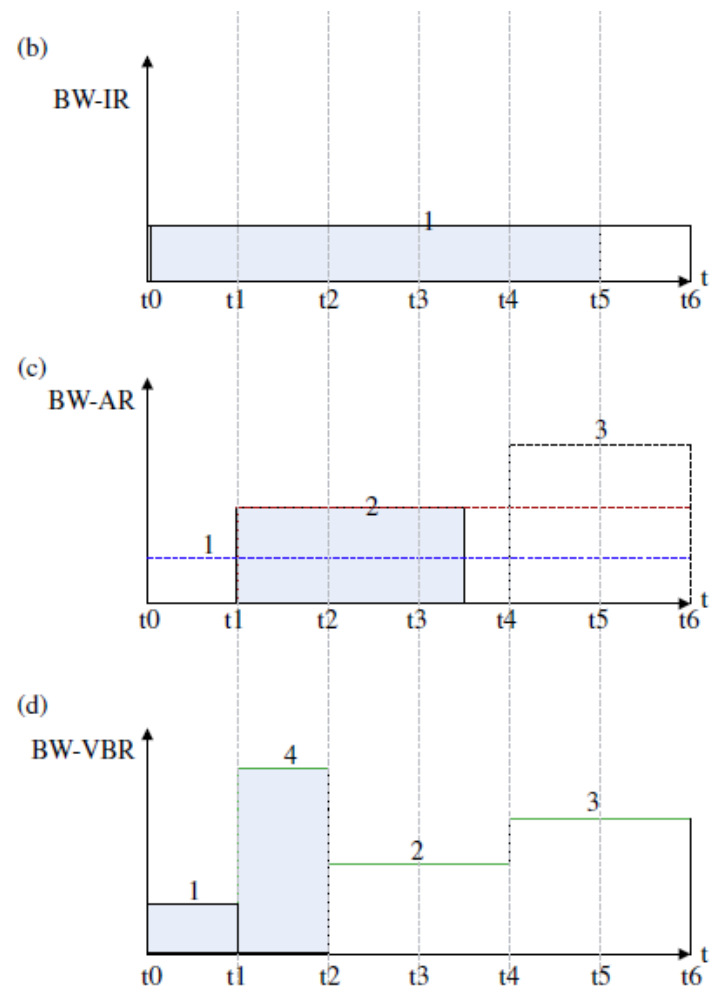
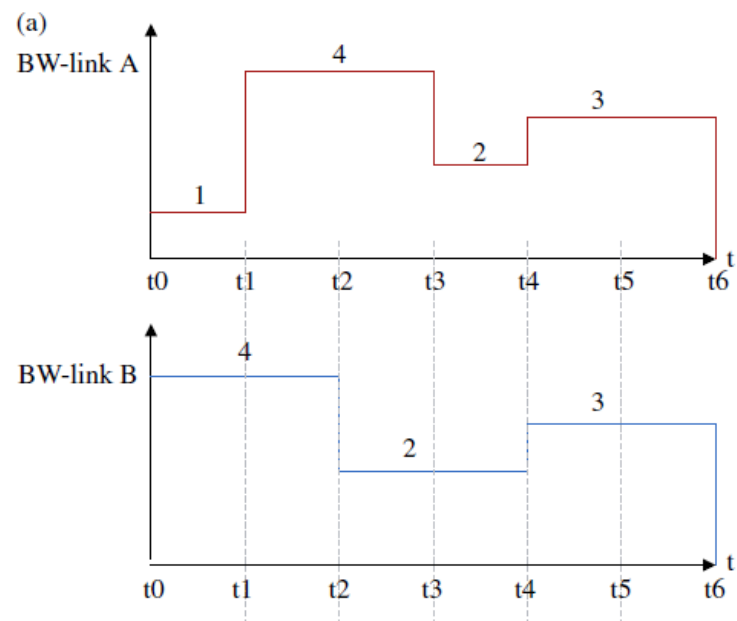
- **Disadvantages**

- Resource scheduling may cause high end-to-end delay.
- Requests are still possible to be blocked if the deadline cannot be met.

Bandwidth Reservation Schemes

- **Variable Bandwidth Advance Reservation (VBAR)**
 - A variation of AR approach without the requirement of fixed bandwidth allocation.
 - Bandwidth reserved for a path is adjustable depending on the variation of the bottleneck residual bandwidth of the path over time.
- **Disadvantages**
 - Control plane aspects, such as maintaining the network state information, and establishing and terminating the VBAR connections become complicated.

Example of three schemes



Contributions

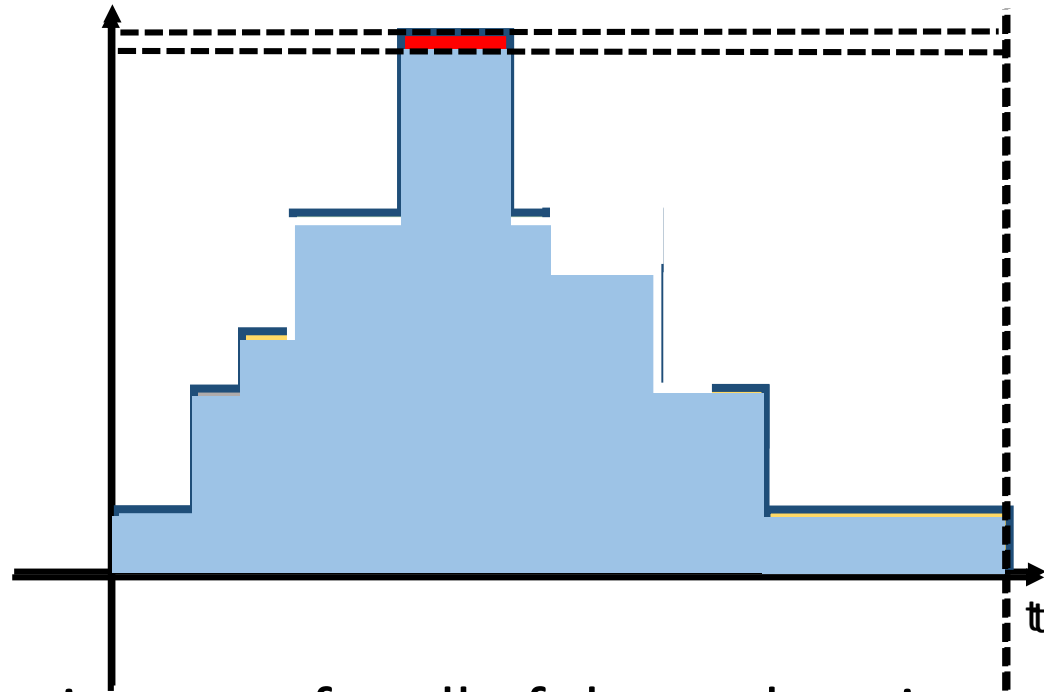
- Routing and bandwidth scheduling problem in VBAR with the objective of minimizing the data transfer time.
- Three heuristic algorithms
- Two performance evaluation scenarios:
 - A single request under a given network state.
 - dynamic traffic.

New idea

- **Goal:** make network accommodate as much traffic as possible.
- **Three steps:**
 - Prediction-based routing.
 - Network bandwidth resource allocation according to routing assignment.
 - Request-level bandwidth adjustment when allocated bandwidth is not enough to accommodate a new request.

Prediction-based routing

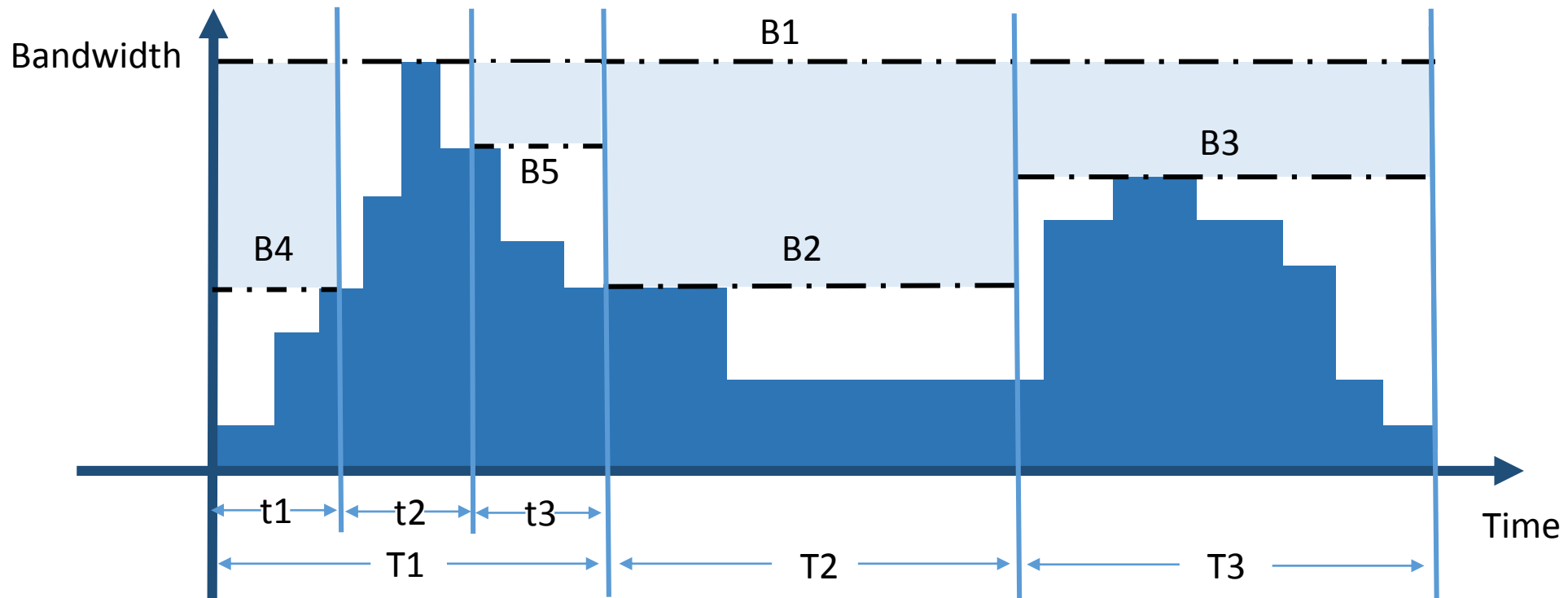
- Given any time interval, the peak demand (maximum amount of bandwidth demand) between a node pair is predictable.



- The routing assignment for all of the node pairs can be done using predicted peak demand for each node pair at the same time interval.

Prediction-based routing

- Assuming the predictions are correct. Reducing the prediction interval size can improve bandwidth utilization.

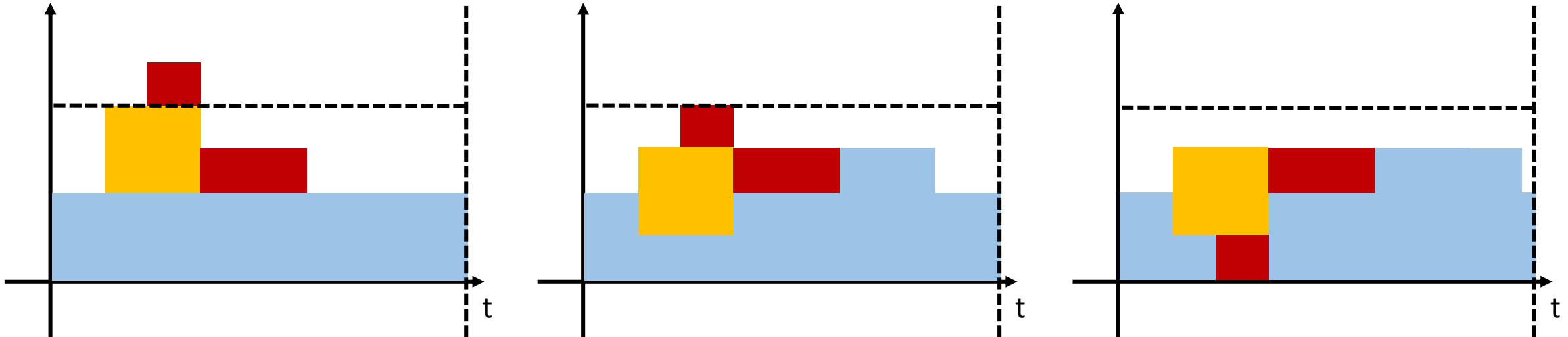


Network bandwidth resource allocation

- If routing succeeds, allocate bandwidth according to the routing assignment result for each node pair.
- If routing fails, it means current network cannot support bandwidth demand for each node pair. In this case, reroute the traffic at the cost of affecting the least number of node pairs.
 - E.g., reducing least amount of demanded bandwidth in total from selected node pairs.
- Note that up until this point, the inaccuracies of the provisioned bandwidth come from two places:
 - **Prediction inaccuracy**
 - **Rerouting**

Request-level bandwidth adjustment

- Peak demand may exceed the provisioned bandwidth due to the abovementioned two inaccuracies.
- Thus, request-level bandwidth adjustment is needed.



Request-level bandwidth adjustment

- If no further request-level bandwidth adjustment can be made, the service request elongation is triggered.
- In the following example, there must be a request needed to be elongated. We let it be the red one.

