Using Multirail Networks in High-Performance Clusters

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Multiple Independent Network Rails

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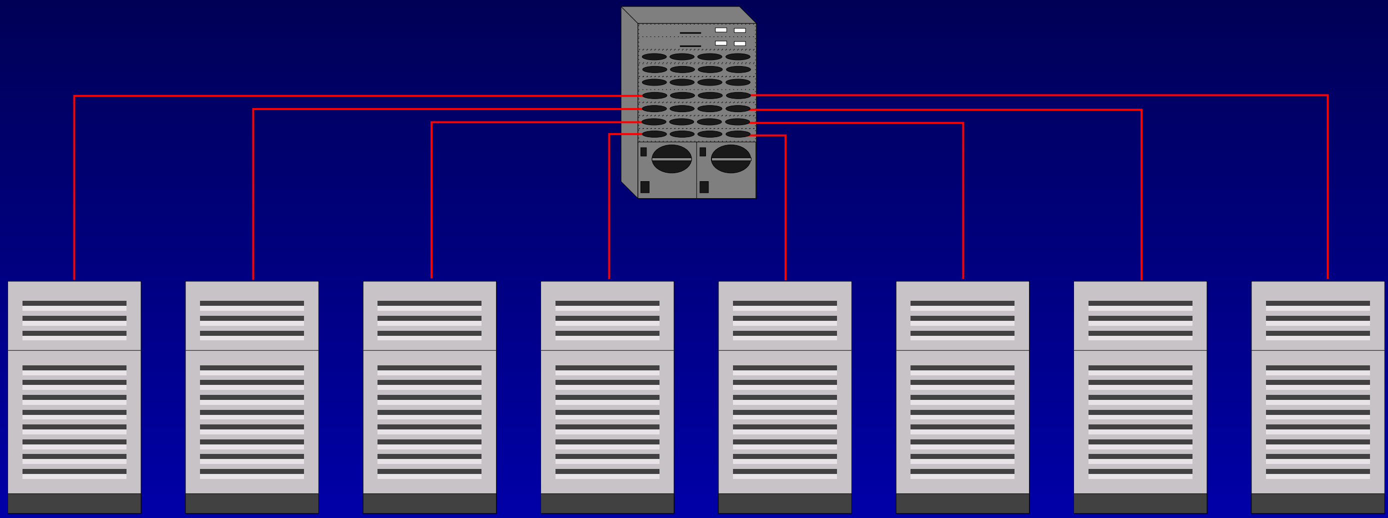

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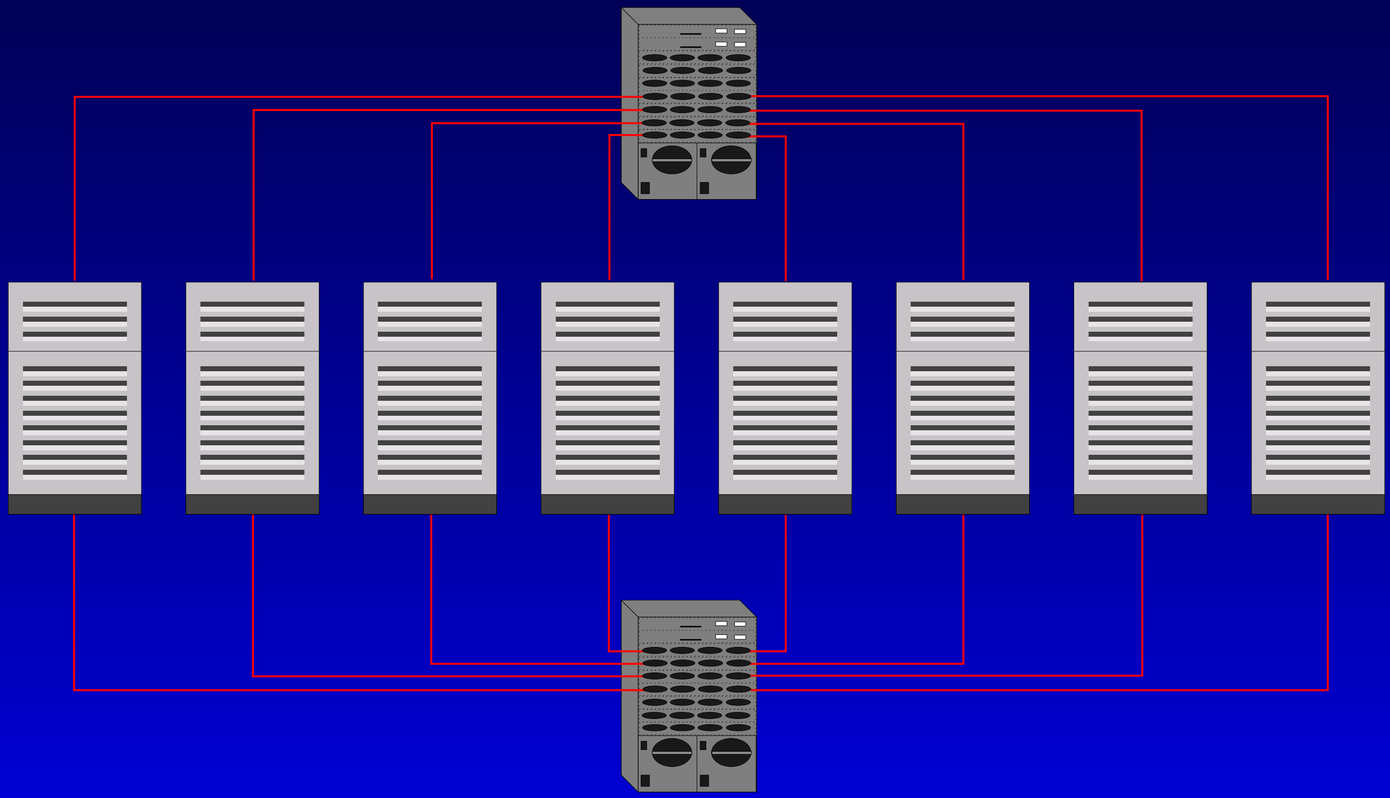


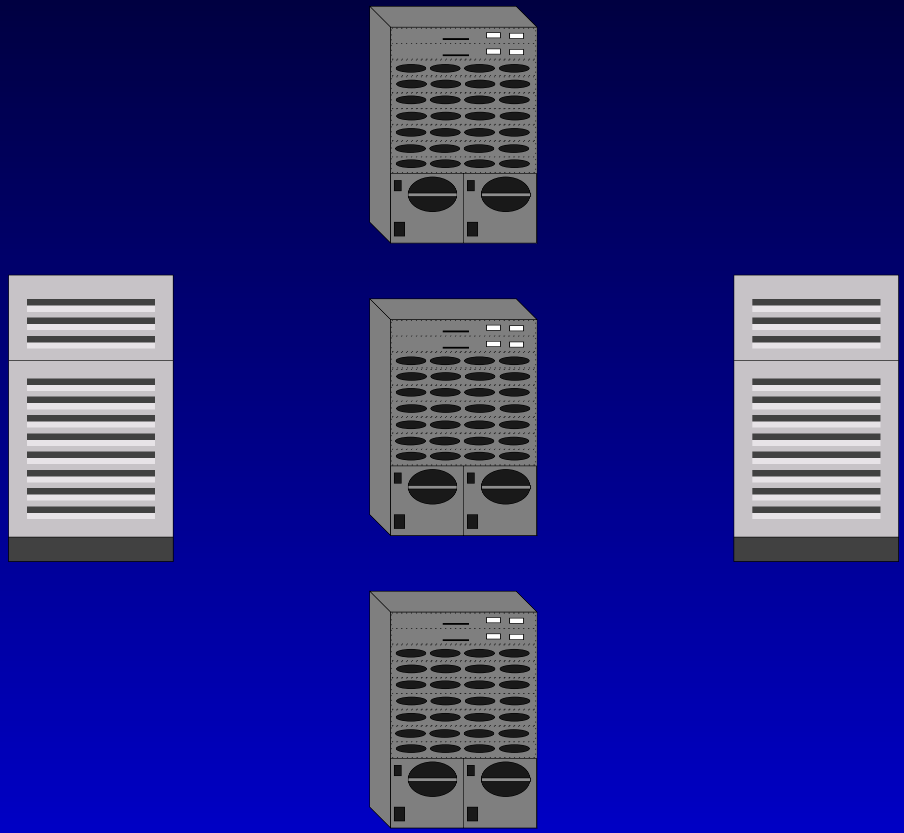
Examples of Multirailed Machines

- ASCI White at Lawrence Livermore National Laboratory – most powerful computer in the world, IBM SP
- The Terascale Computing System (TCS) at the Pittsburgh Supercomputing Center – the second most powerful computer in the world, Quadrics
- ASCI Q machine, currently under development at Los Alamos National Laboratory, Quadrics.
- Infiniband
- Experimental Linux clusters, Quadrics and Myrinet

Open Problems

- Rail assignment
- Striping over multiple rails
- Implementation of communication libraries (e.g., MPI, Cray Shmem)
- Multiple rails and I/O interfaces
- Not much is known on how to use multiple rails

Rail Allocation



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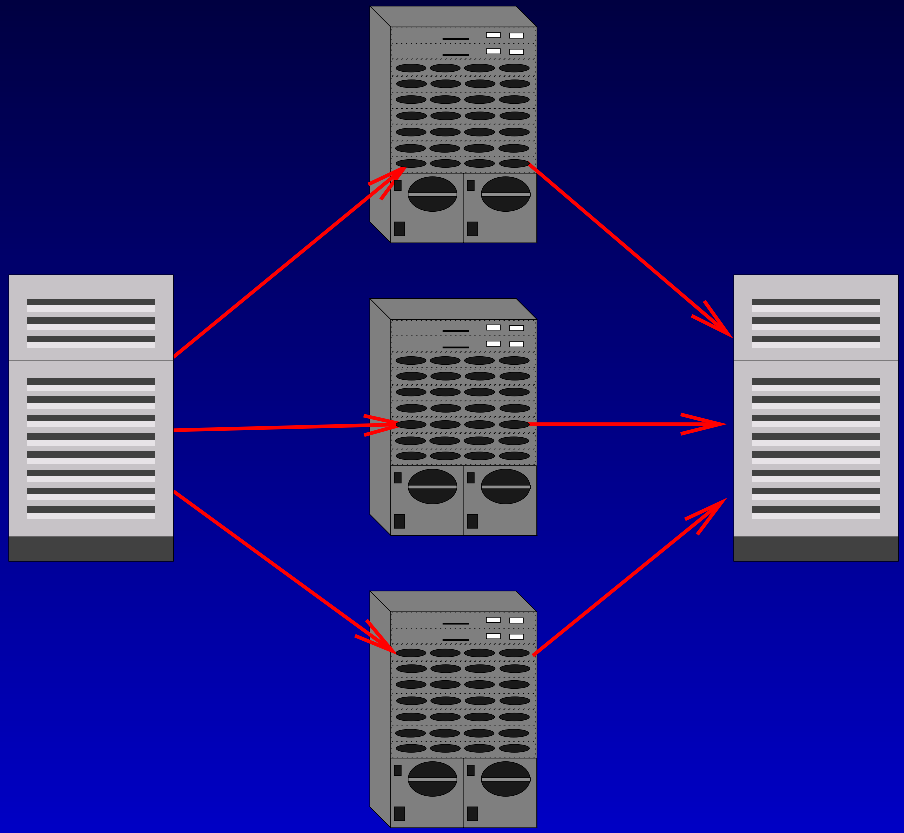

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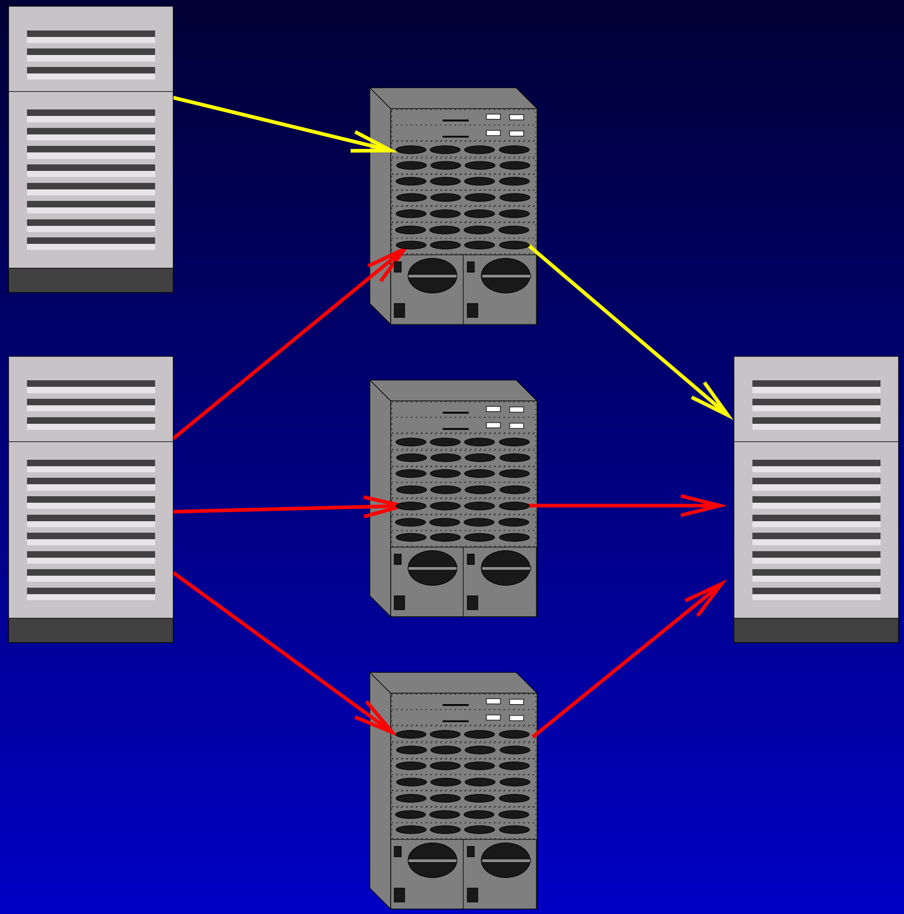

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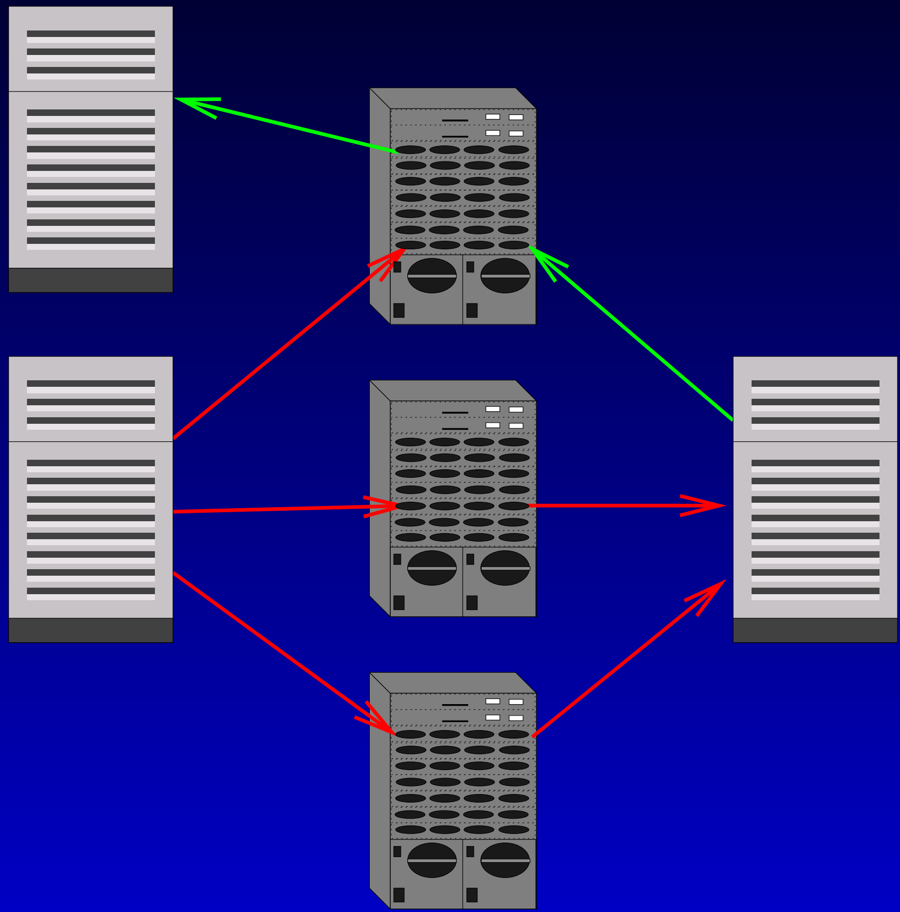

Bidirectional Traffic on the I/O bus

- Most PCI busses cannot efficiently handle bidirectional traffic with high performance networks
- Typically, aggregate bidirectional bandwidth is only 80% of the unidirectional one (Intel 840, Serverworks HE, Compaq Wildfire)
- The same problem is likely to appear in the first Infiniband and PCI-X implementations (e.g., those based on the Intel 870)
- Bidirectional traffic is very common in ASCI applications

State of the Art on Rail Allocation

- A common algorithm to allocate messages to rails is to choose the rail based on the process id of the destination process ($rail = destination\_id \bmod RAILS$)
- Multiple processes can compete for the same rail even if other rails are available
- No message striping
- No attempt to minimize bidirectional traffic

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Outline

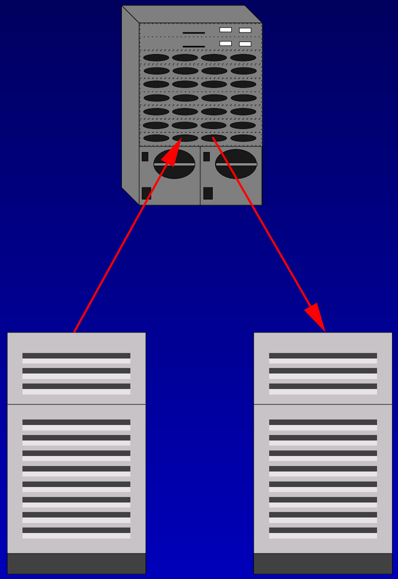
- Basic Algorithm
- Static rail allocation
- Dynamic rail allocation with local information
- Dynamic rail allocation with global information
- Hybrid algorithm
- Experimental evaluation
- Conclusion

Basic Algorithm

- The basic algorithm doesn't use any communication protocol
- Whenever a node needs to send a message,it send it on one rail,choosing it in round-robin fashion
- This base case can serve to illustrate the effects of both the overhead of the other protocols and the penalties of the bidirectional traffic

Static Rail Allocation

- With static rail allocation each network interface can either send or receive messages, and the direction is defined at initialization time.



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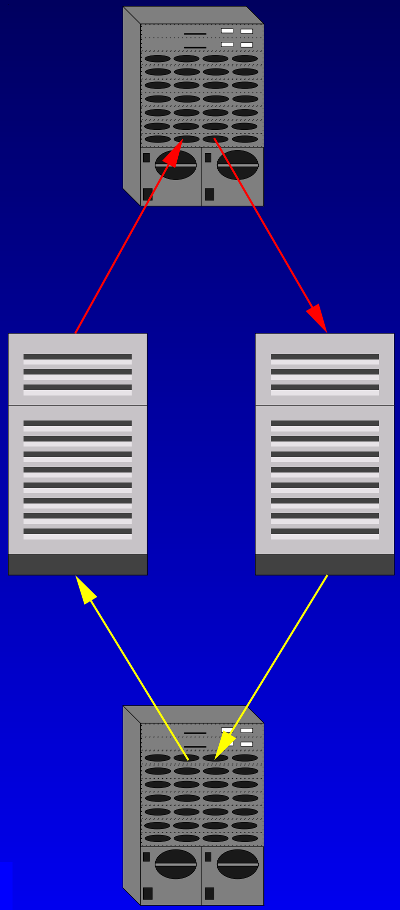

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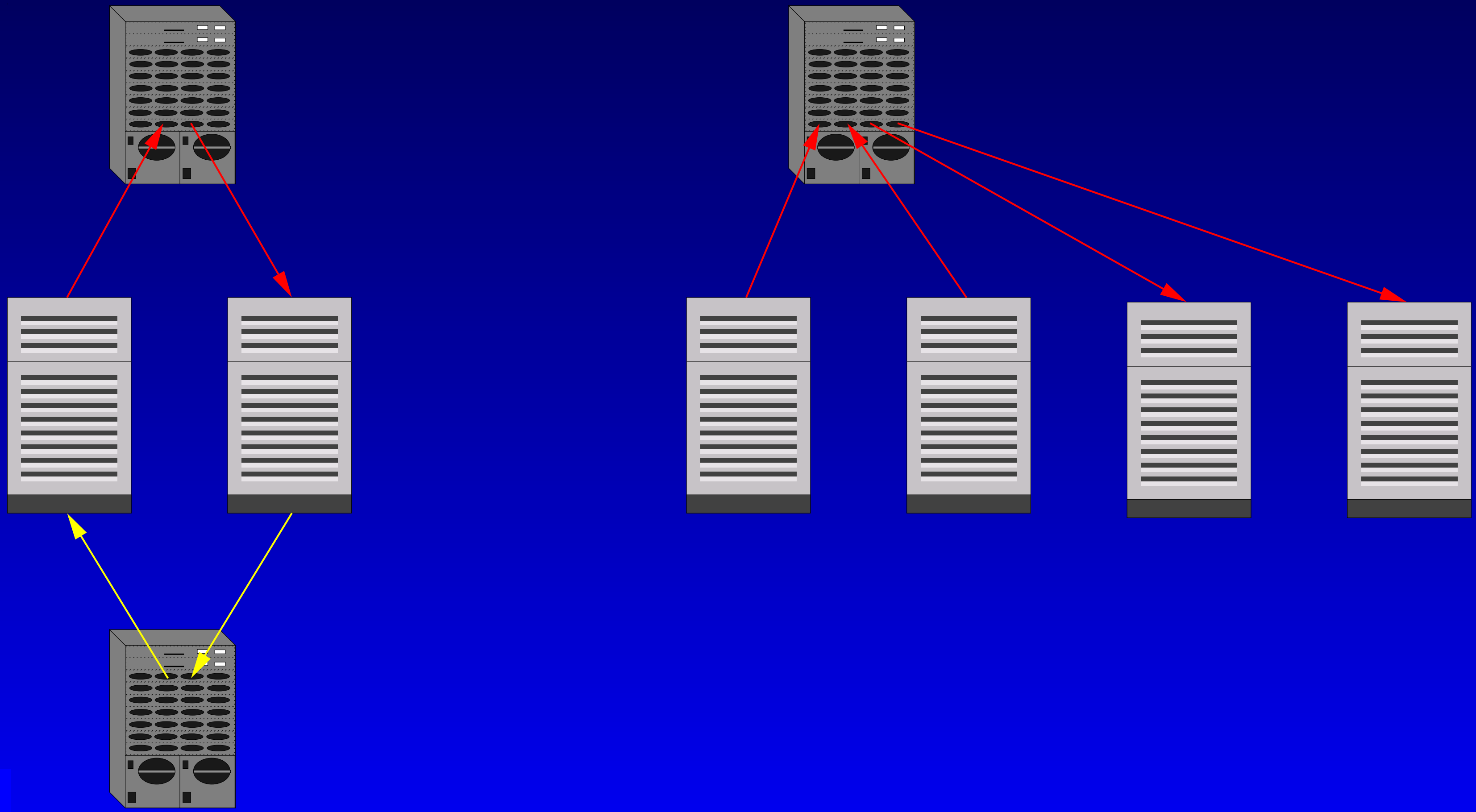

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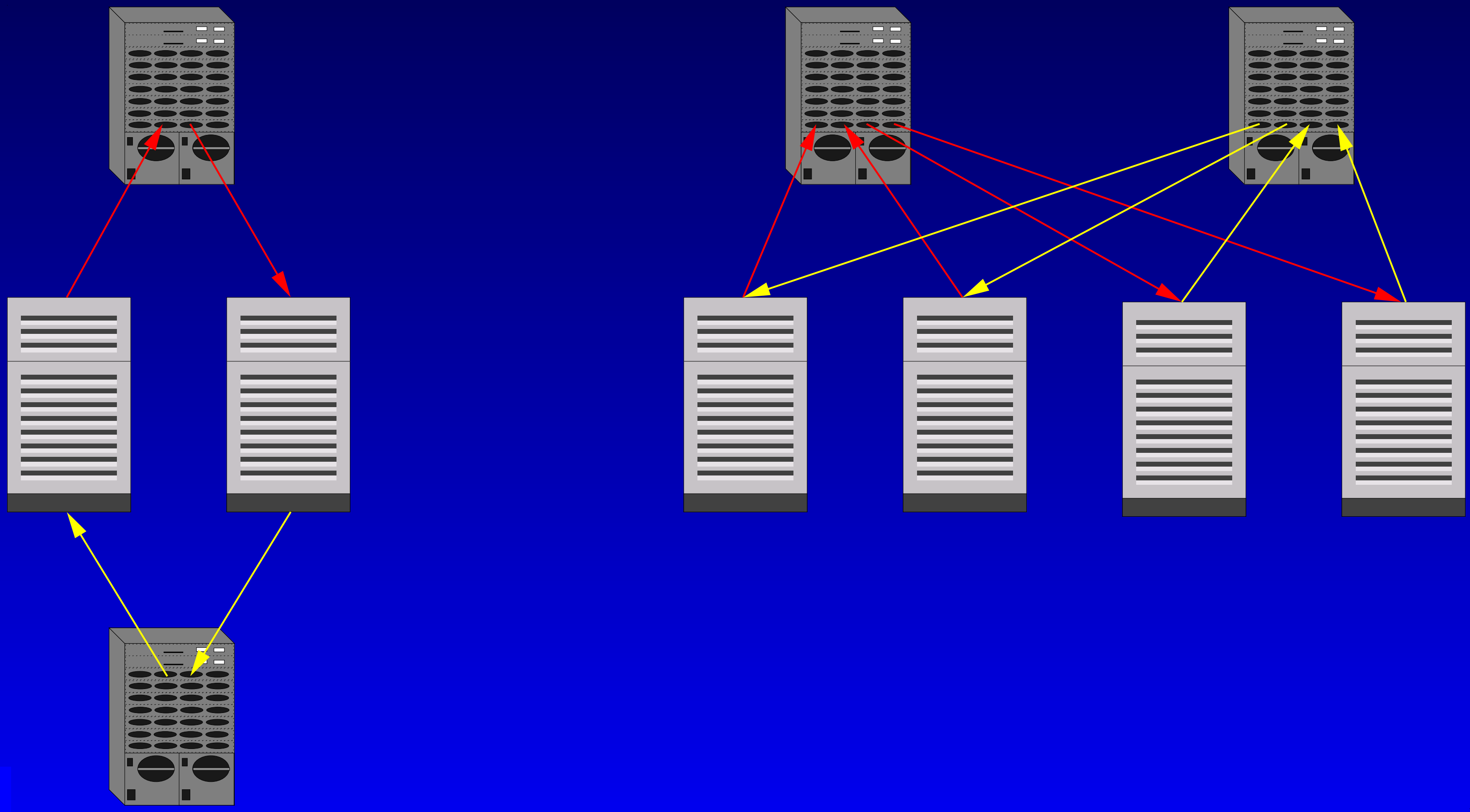

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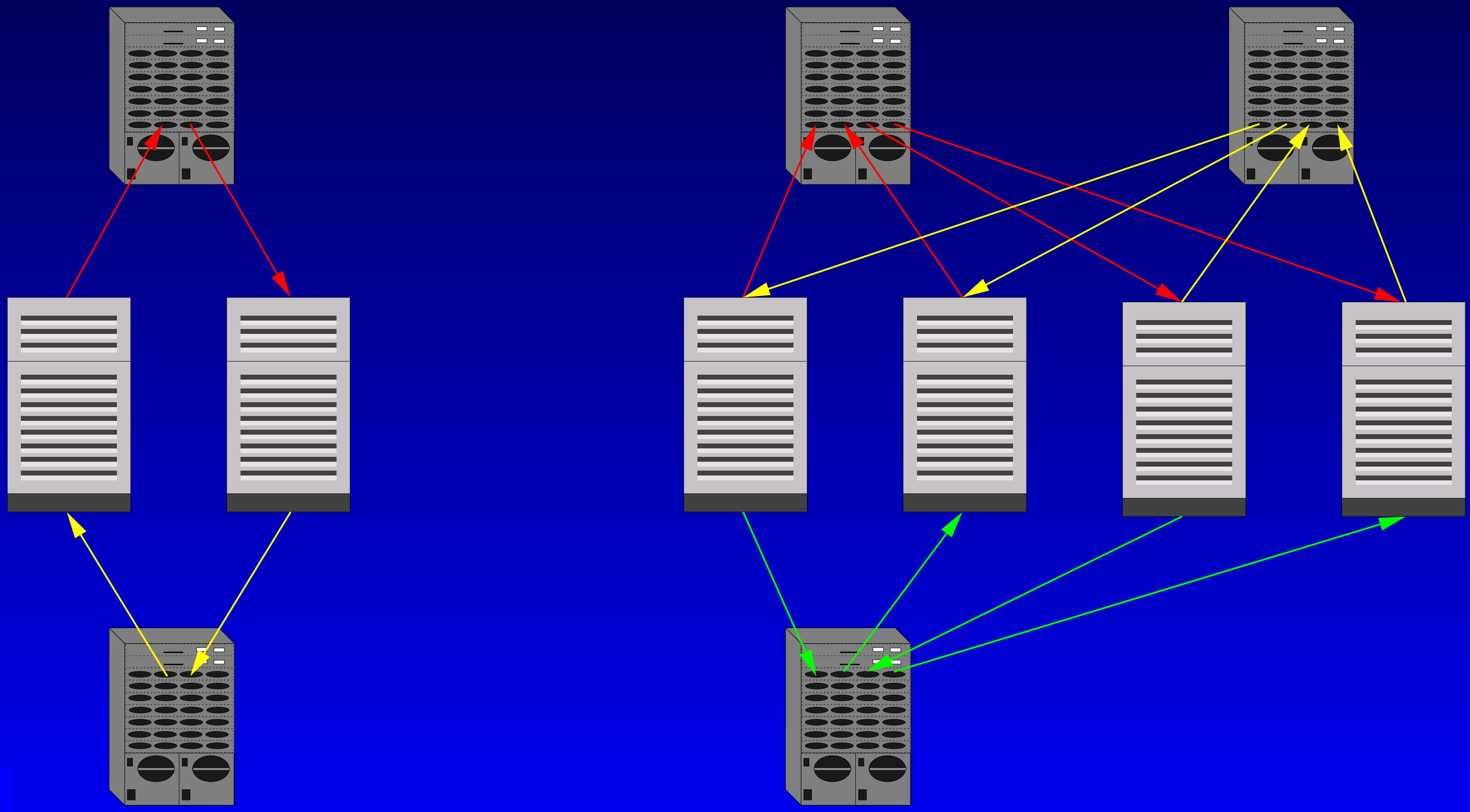

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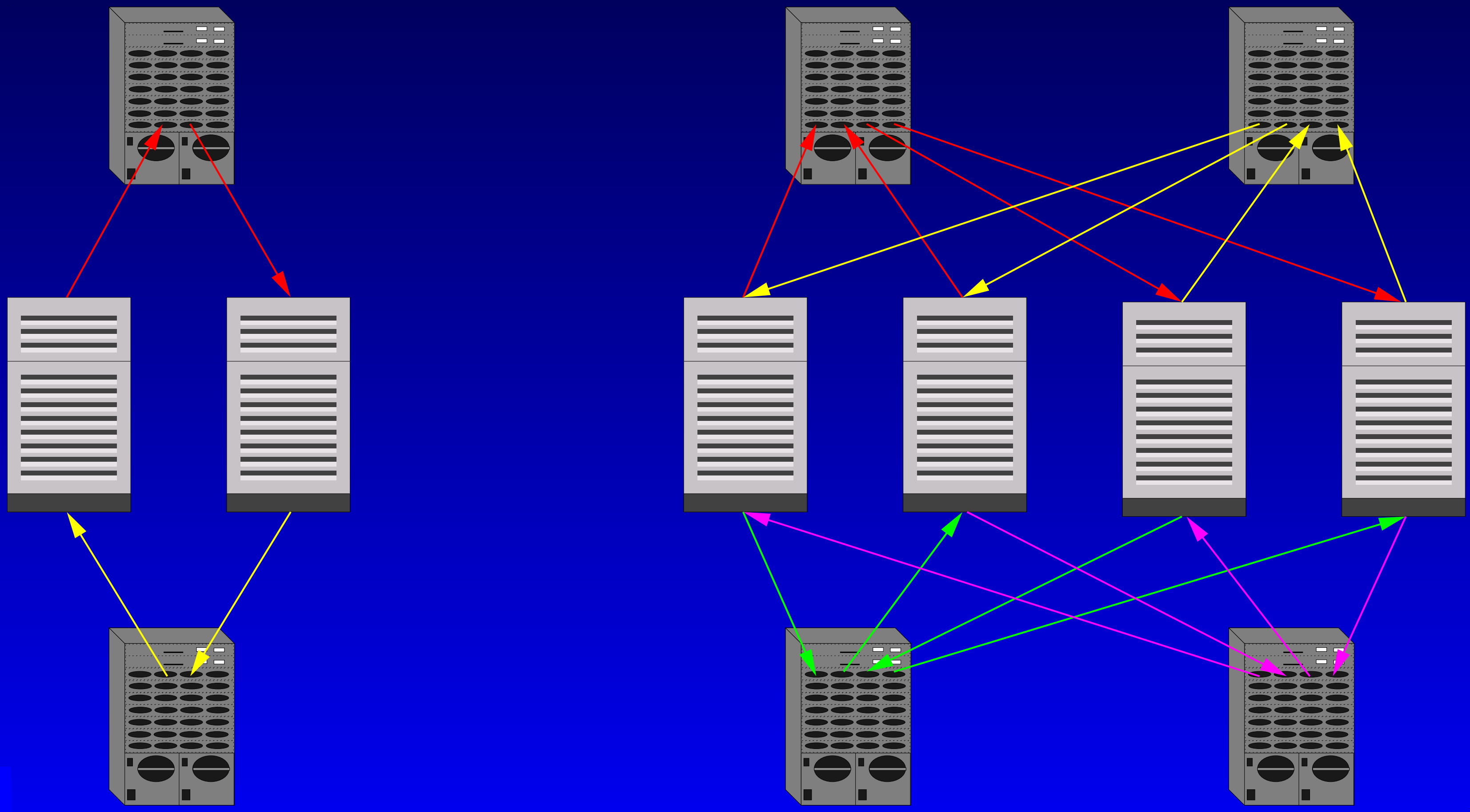

Lower Bound with Static Rail Allocation

A high number of rails is required for statically allocated unidirectional traffic.

A network with r rails can support no more than n nodes, where

$$n \leq \binom{r}{\left\lfloor \frac{r}{2} \right\rfloor}$$

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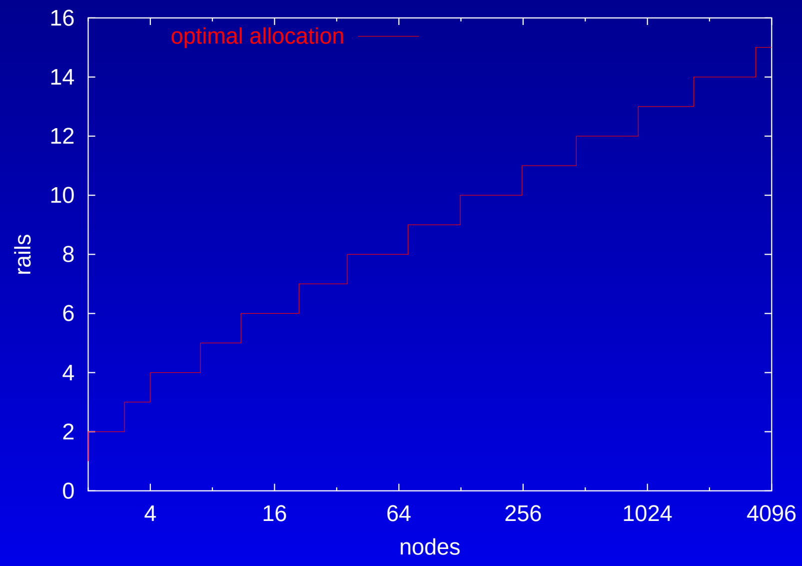

Dynamic Algorithm with Local Information

- With the dynamic algorithms the direction in which each network interface is used can change over time
- The *local-dynamic* algorithm allocates the rails in both directions, using local information available on the sender side
- Messages are sent over rails that not sending or receiving other messages
- Messages can be striped over multiple rails
- There is no guarantee that traffic will be unidirectional

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Dynamic Algorithm with Global Information

- The *dynamic* algorithm tries to reserve both end-points before sending a message
- In its core there is a sophisticated distributed algorithm that (1) ensures unidirectional traffic at both ends and (2) avoids deadlocks, potentially generated by multiple requests with a cyclic dependency

Dynamic Algorithm: Implementation Issues

- The efficient implementation of this algorithm requires some processing power in the network interface, which needs to process control packets and perform the reservation protocol without interfering with the host
- For example, the Quadrics network interface is equipped with a thread processor that can process an incoming packet, do some basic processing and send a reply in as few as 2μs

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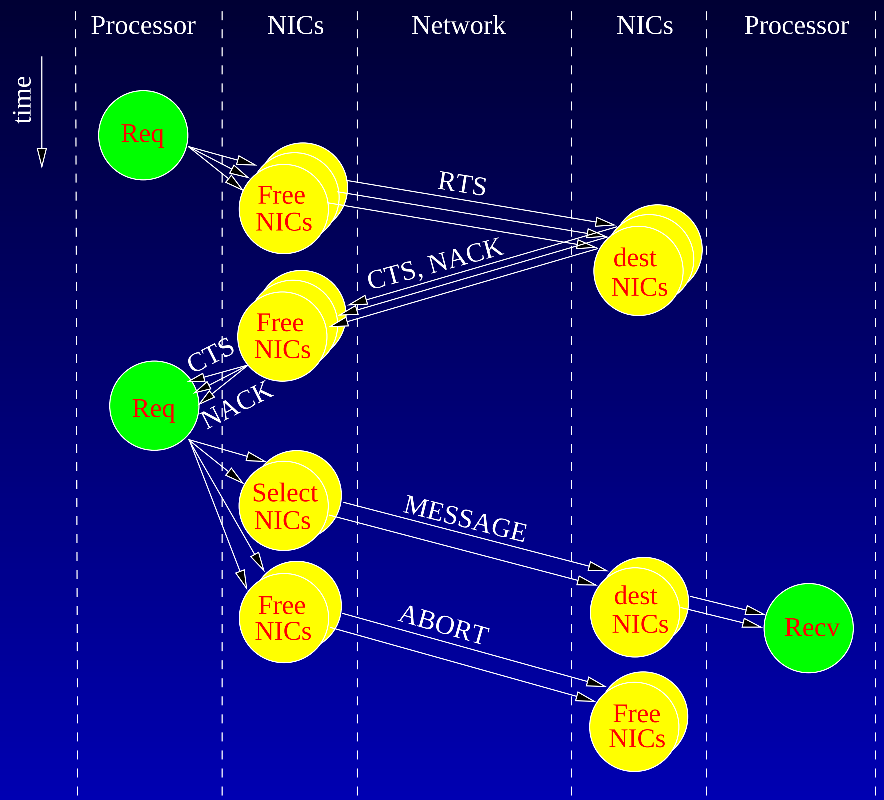
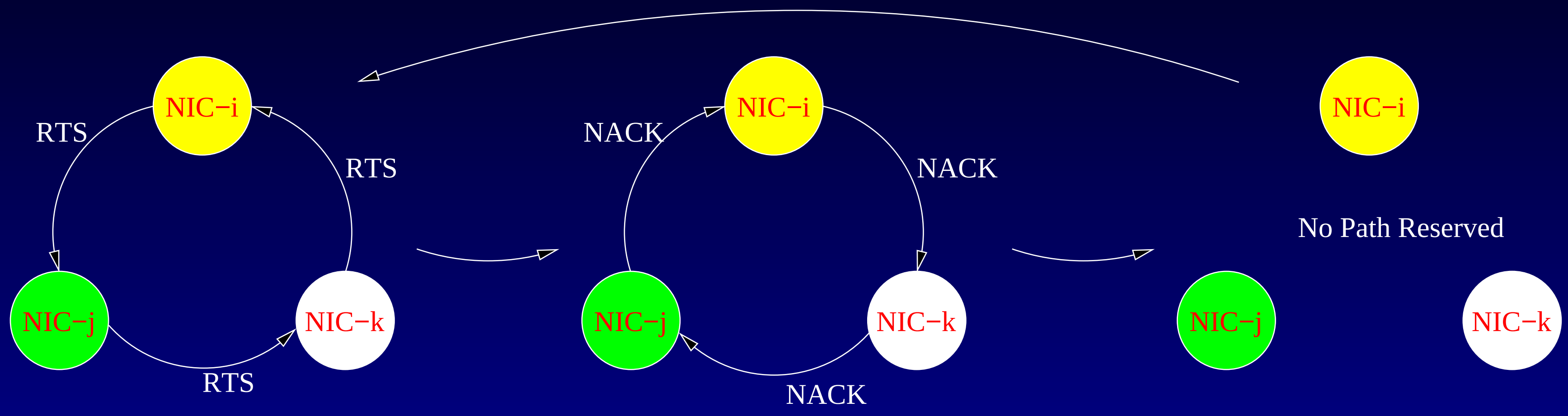
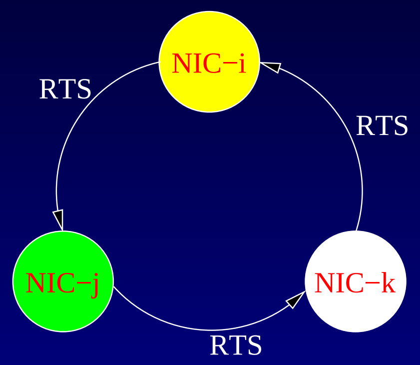
Dynamic Algorithm



Deadlock (Livelock) in the Dynamic Algorithm



Deadlock Avoidance in the Dynamic Algorithm



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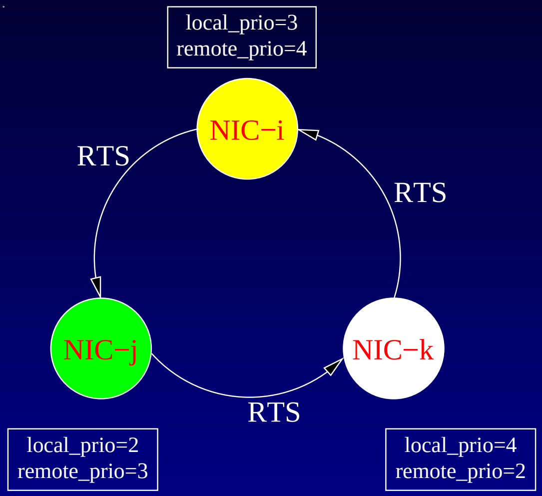

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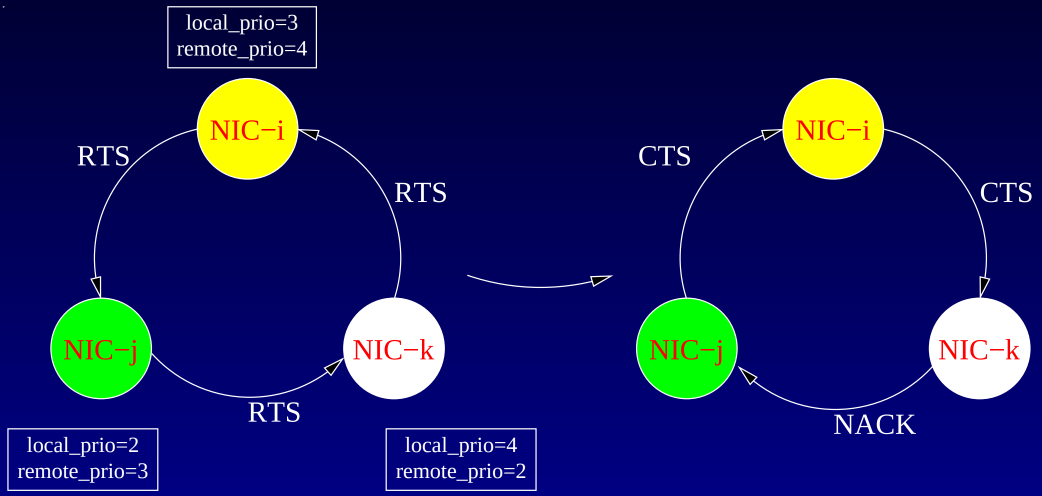

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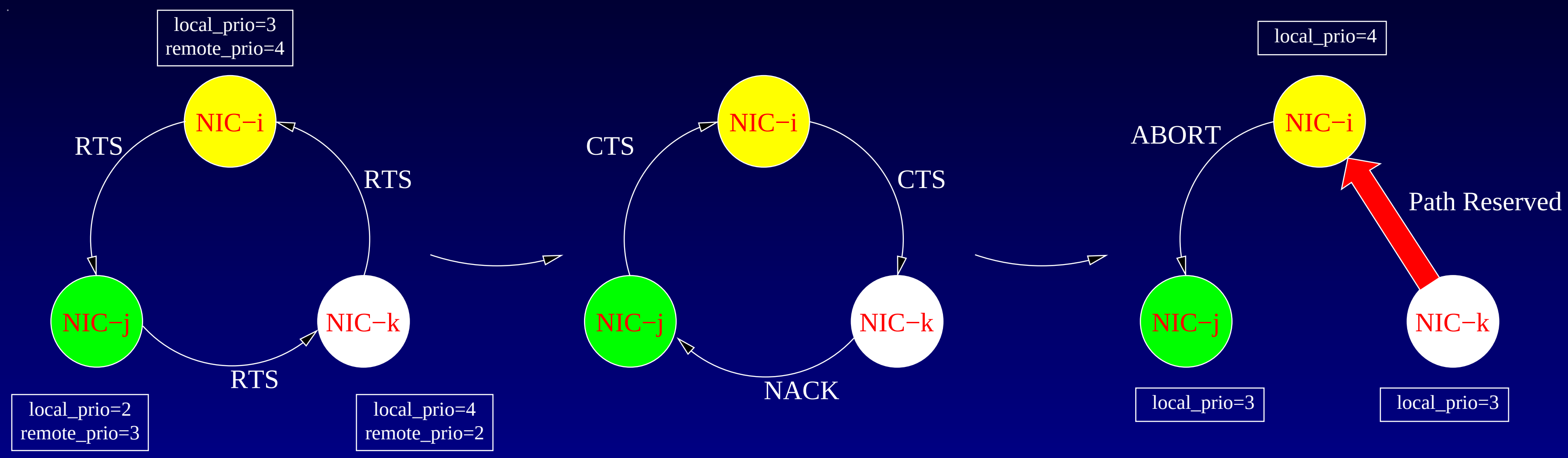

Hybrid Algorithm

- The dynamic algorithm incurs a substantial overhead, for every message size.
- The hybrid algorithm sends short message without a reservation protocol
- Short messages are not striped
- It can cause bidirectional traffic for a short time

Experimental Framework

- We focus our attention on a family of fat-trees interconnection networks, ranging from 32 to 128 processing nodes
- Up to 8 independent rails
- Low level simulation of the network (network model based on the Quadrics network)
- We simulate the communication processor in the network interface
- We test the network using a synthetic communication benchmark
- We assess the network performance by using to parameters, the overall *accepted bandwidth* and the message *latency*

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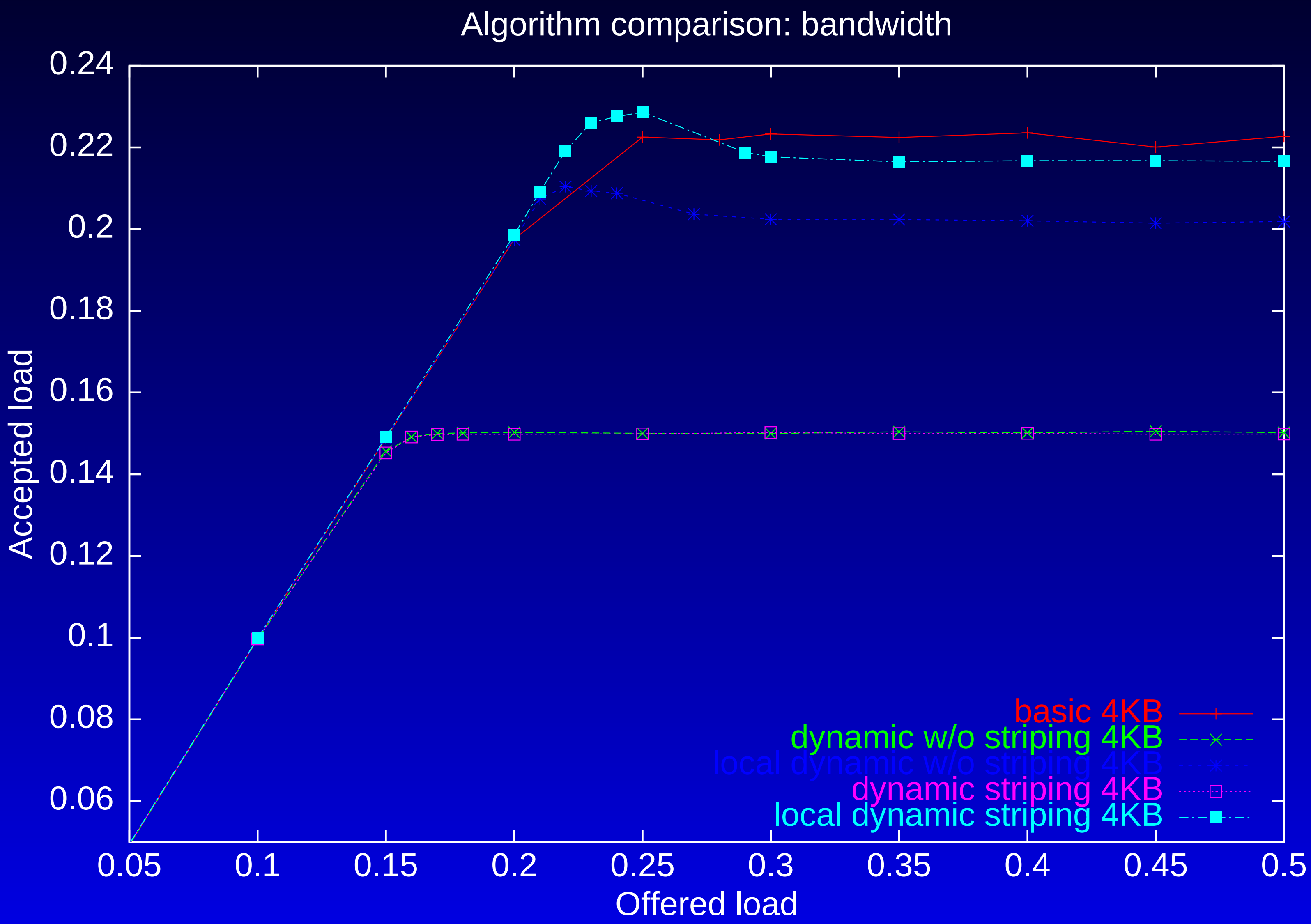
Results - Bandwidth, 4KB messages



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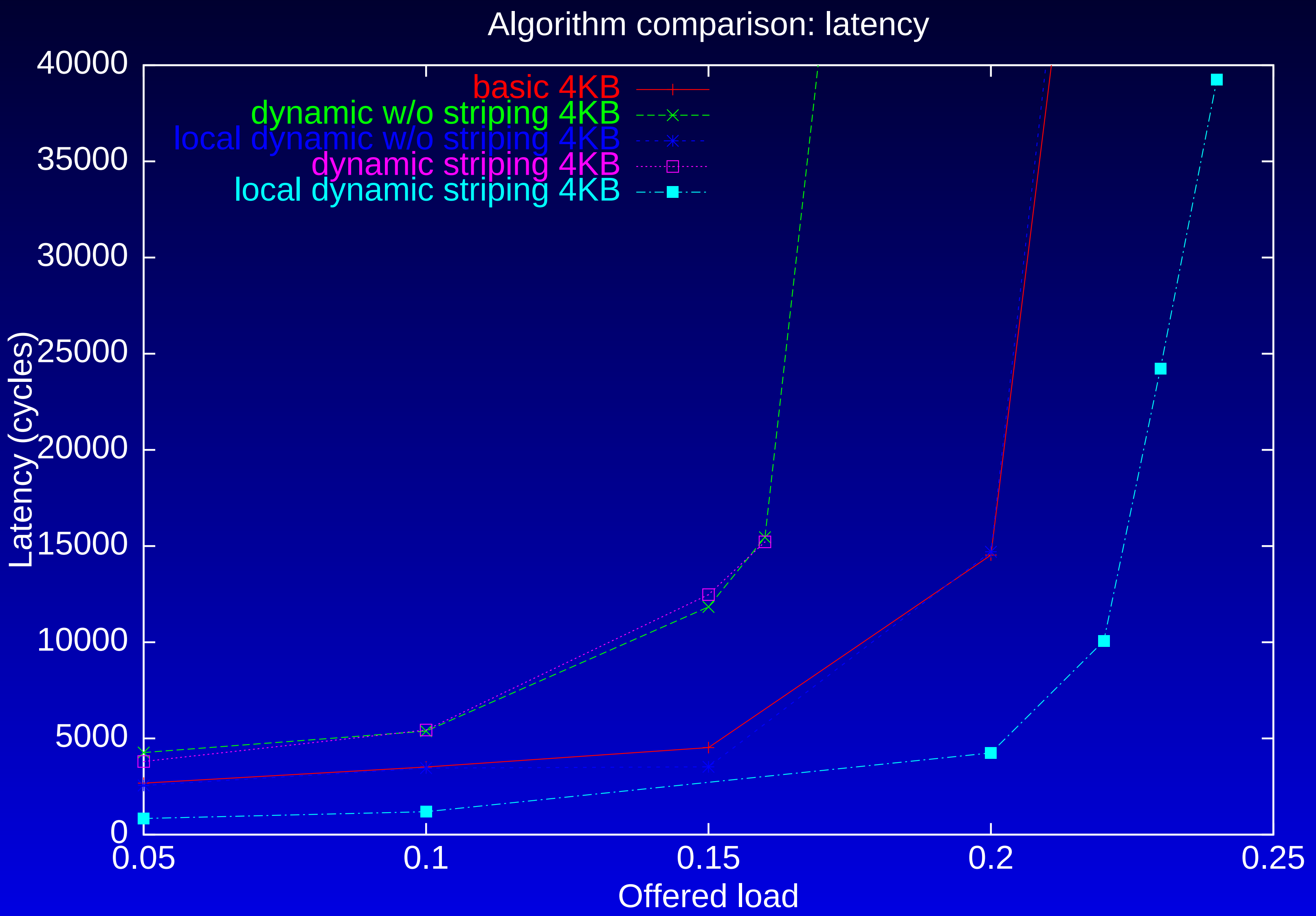
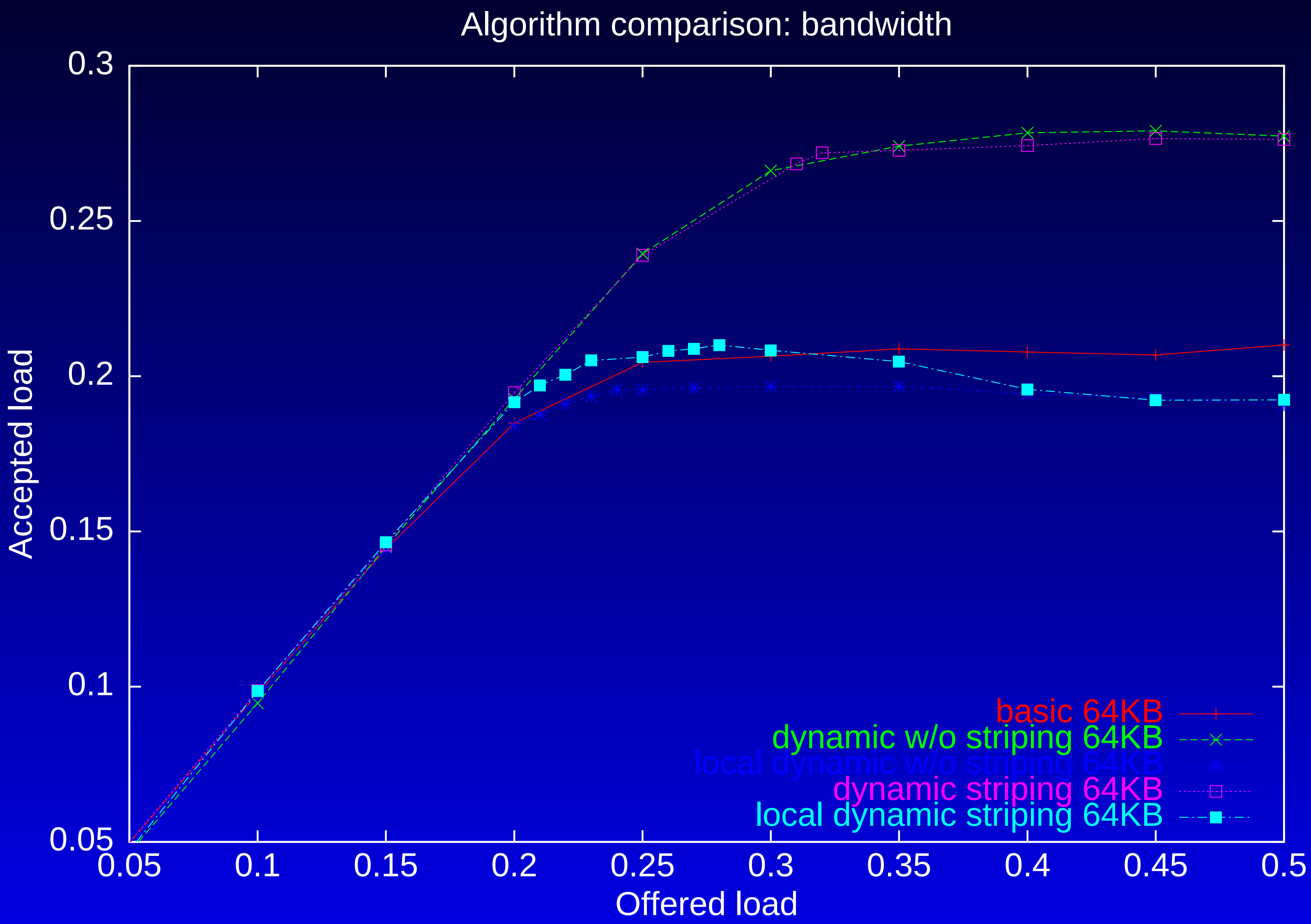


Results - Bandwidth, 64KB messages



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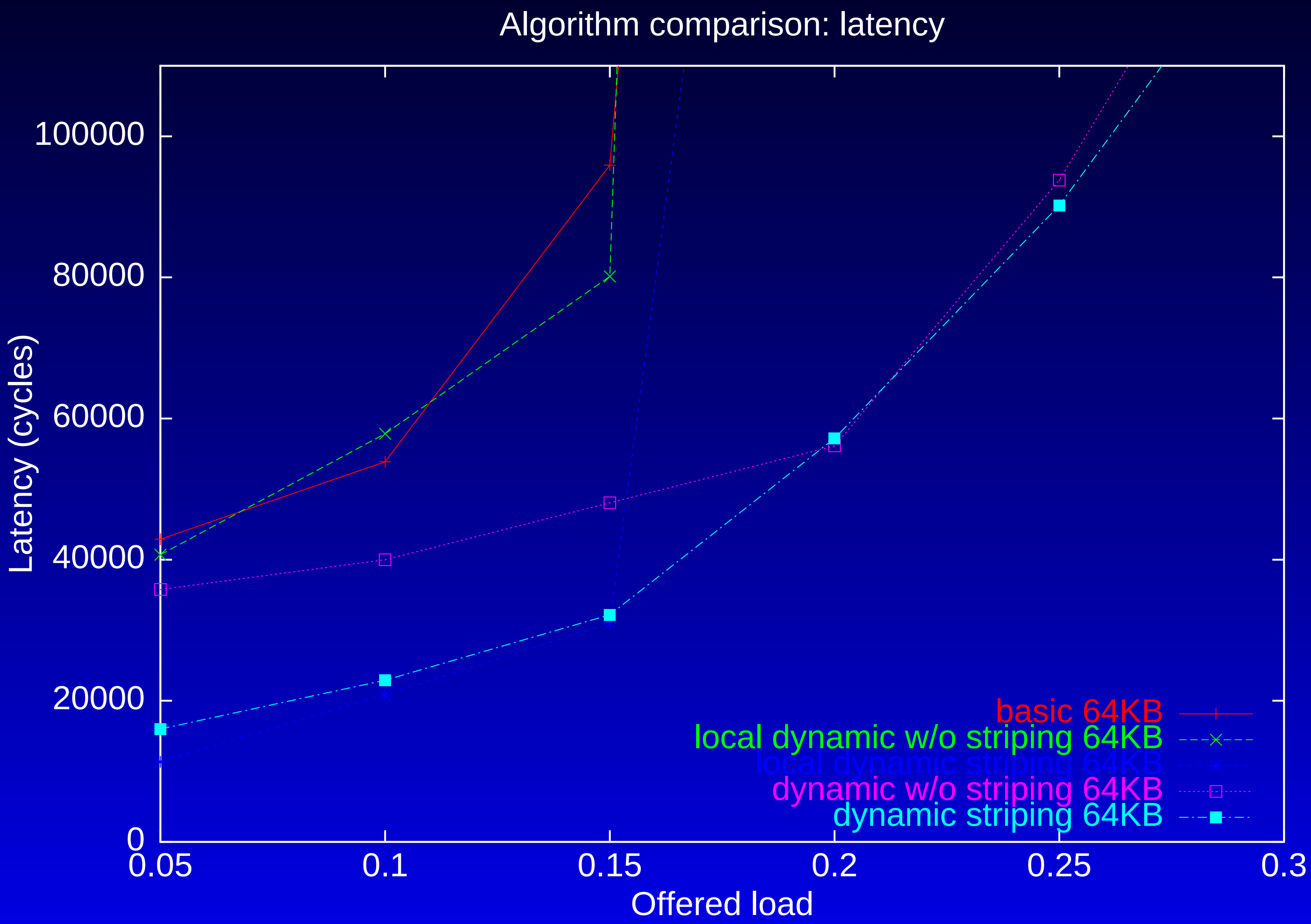
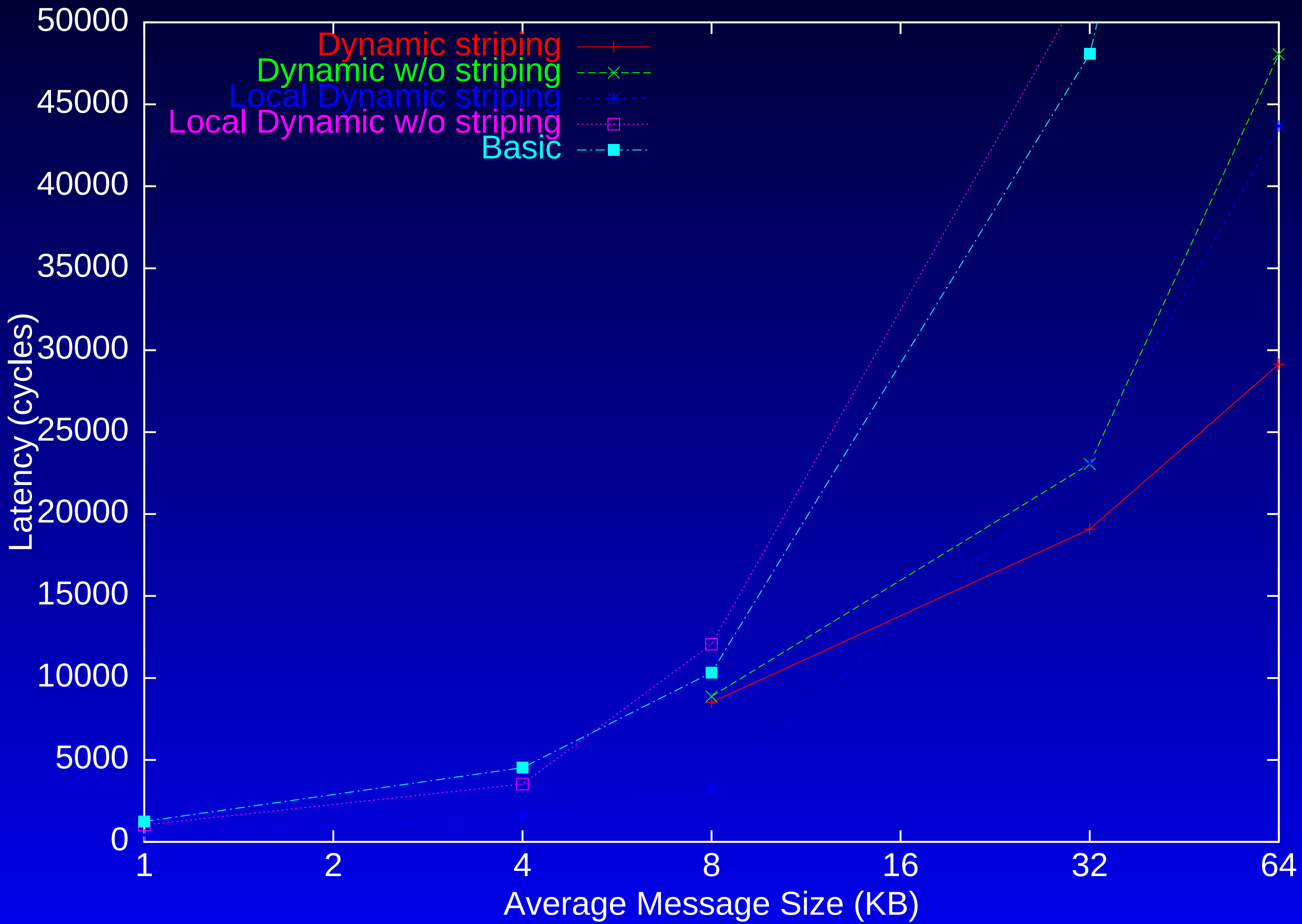
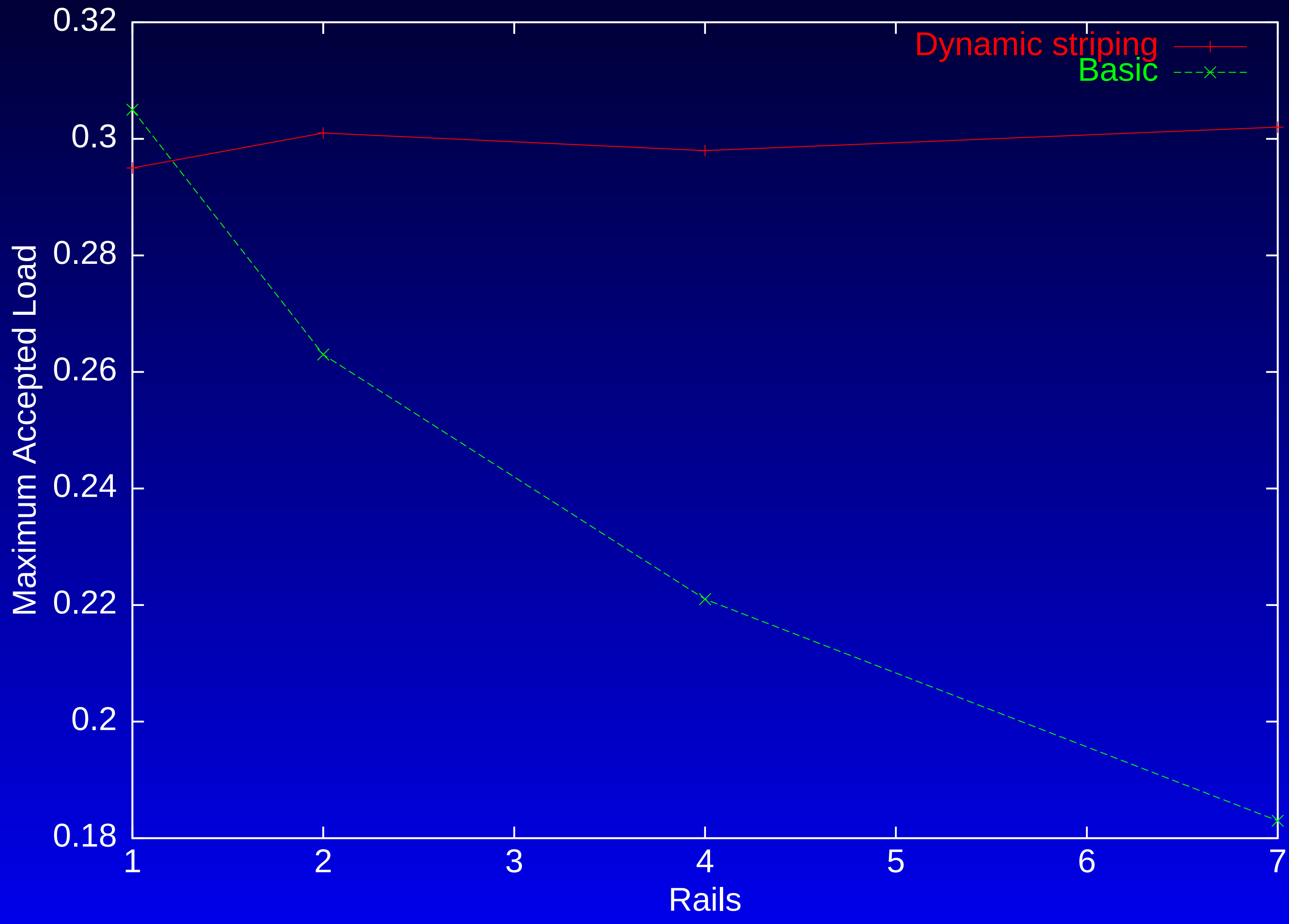


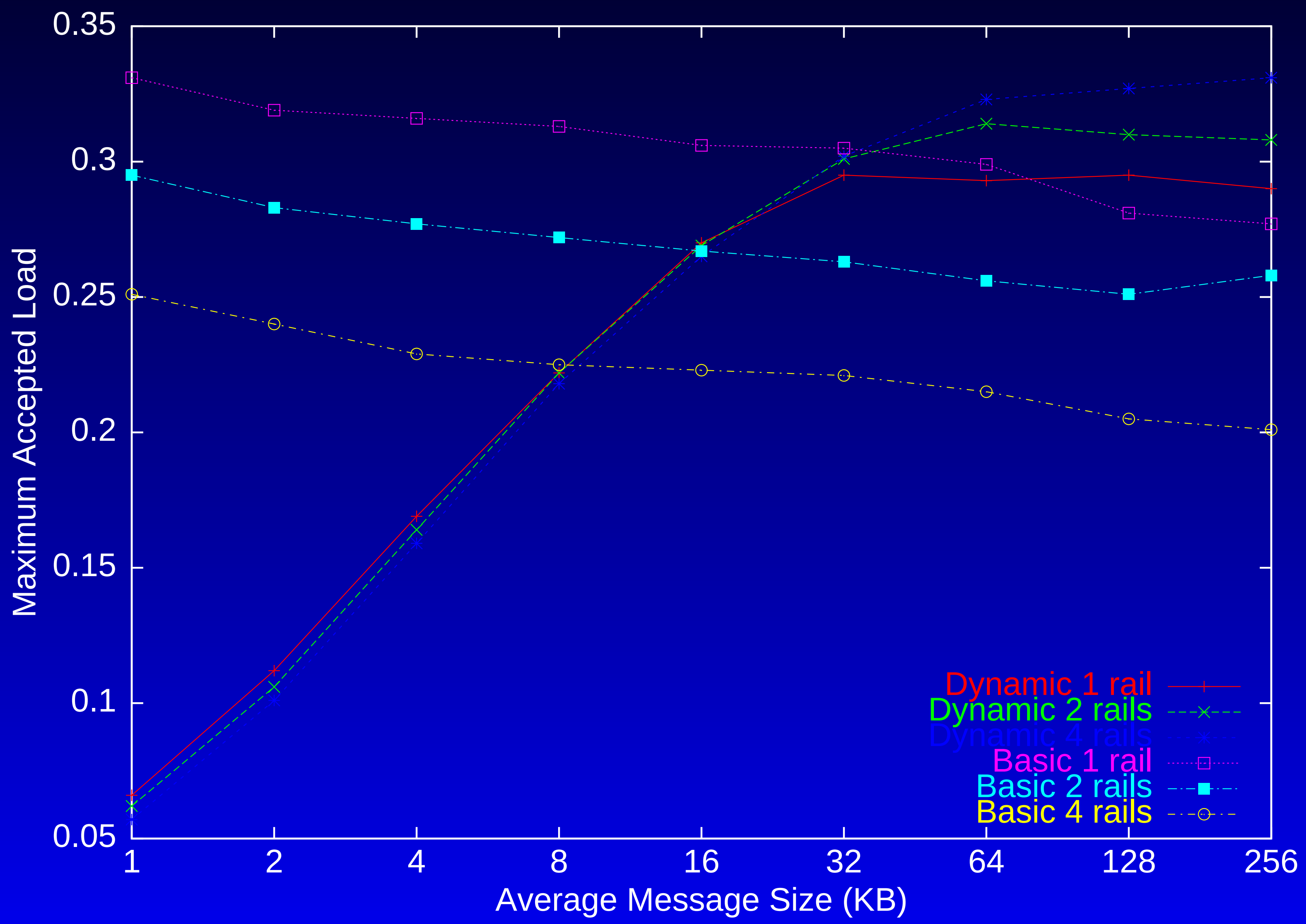
Results - Latency vs Message Size



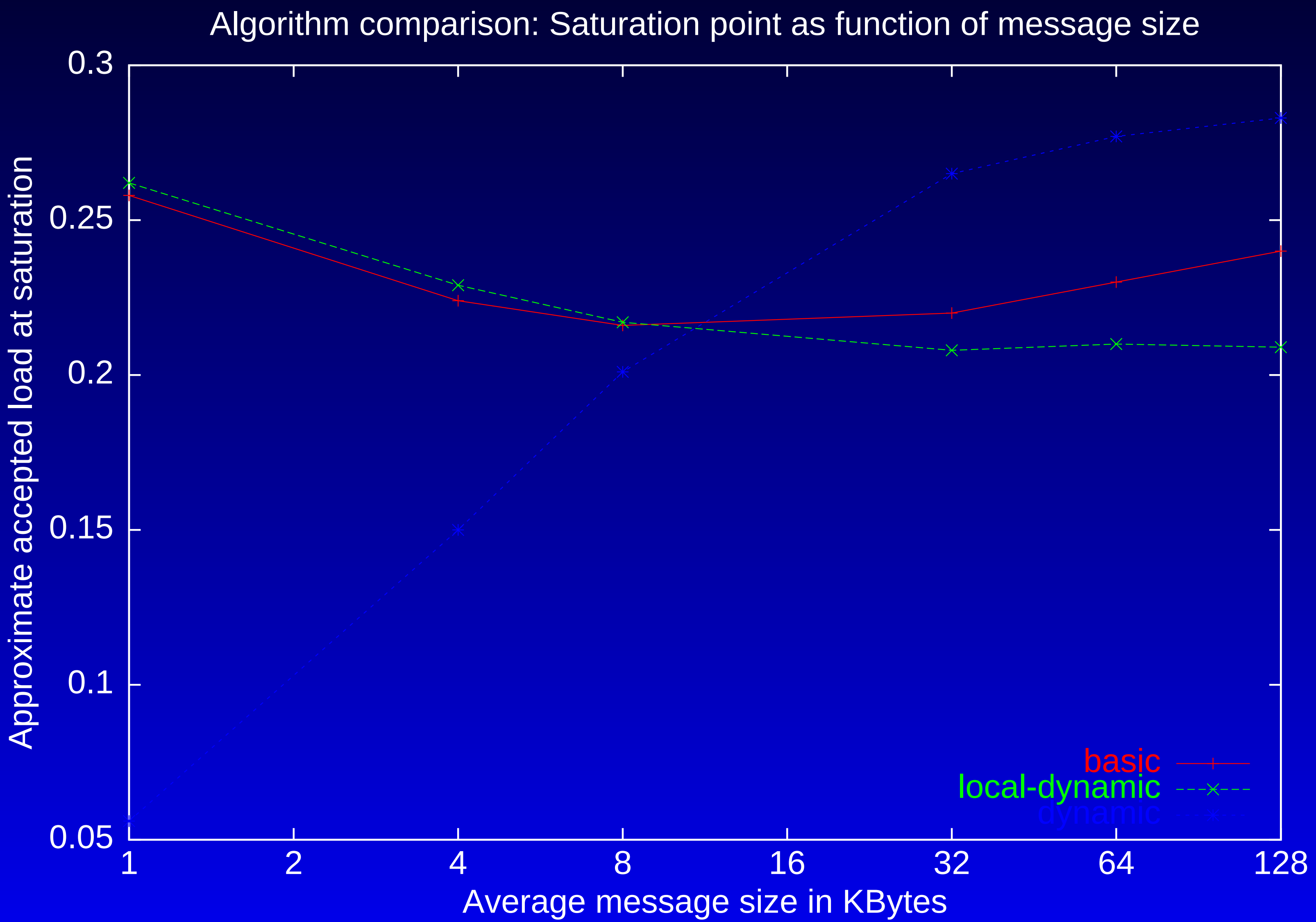
Results - Bandwidth vs Number of Rails



Results - Rail Scalability vs Message Size



Results - Saturation Points vs Message Size



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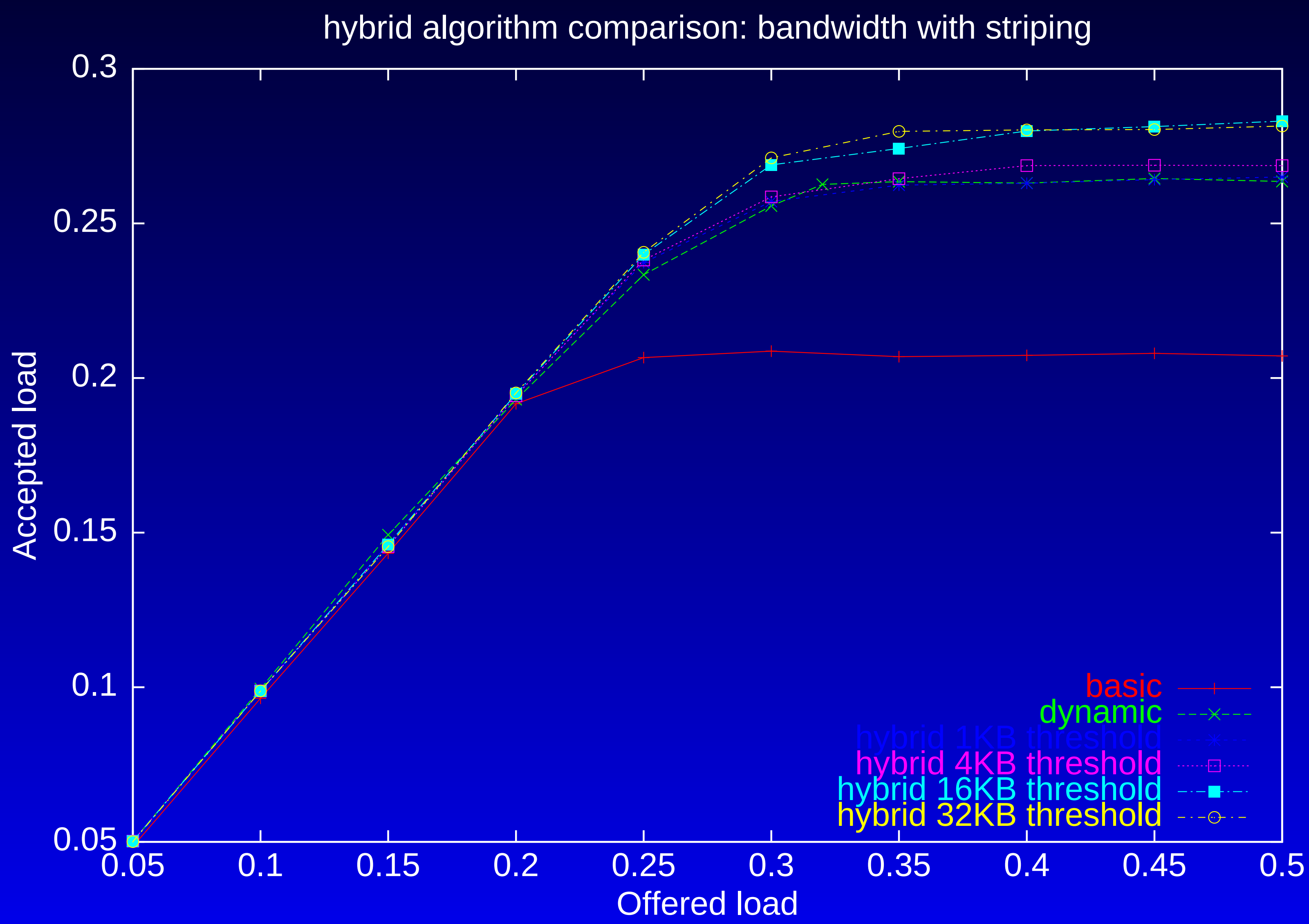

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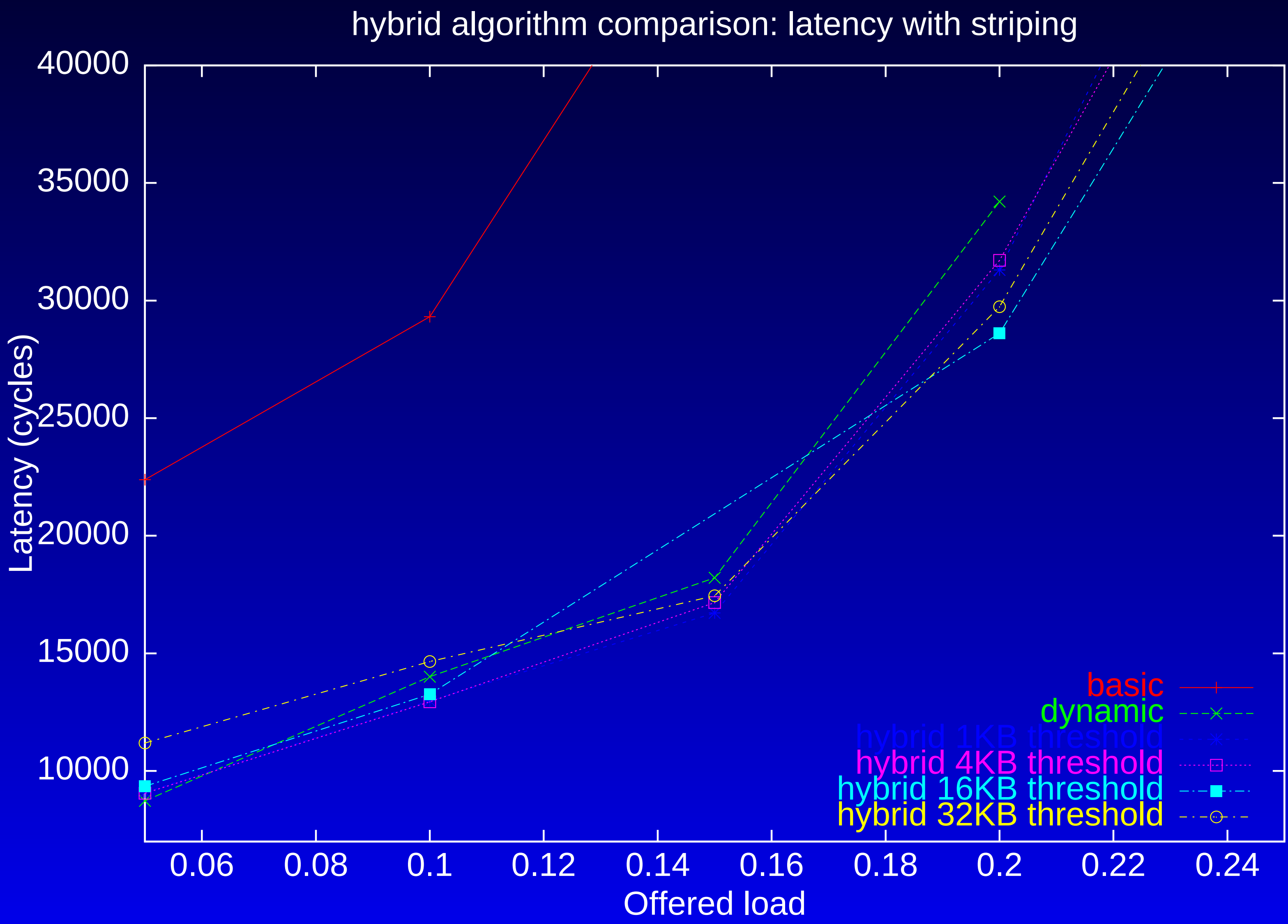

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- The dynamic algorithm performs relatively well for relatively large message sizes
- This algorithm is scalable with the number of rails
- Incorporating protocol-free short message handling in the hybrid algorithm furtherly increases performance of the dynamic algorithm

Resources

- More information can be found at or

http://www.c3.lanl.gov/~fabrizio

- Or by sending an email to

fabrizio@lanl.gov or **eitanf@lanl.gov**