Cyclic-Reservation Beats all MACs

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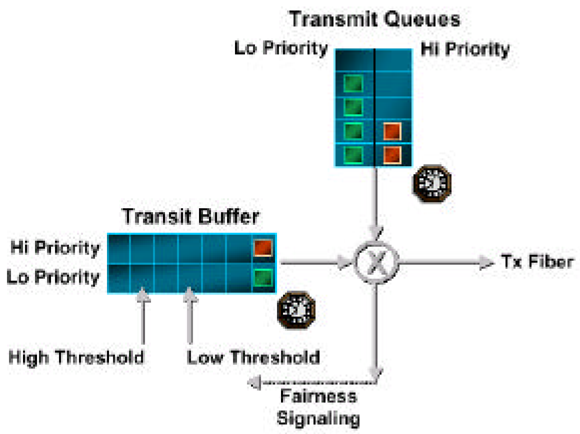
Overview

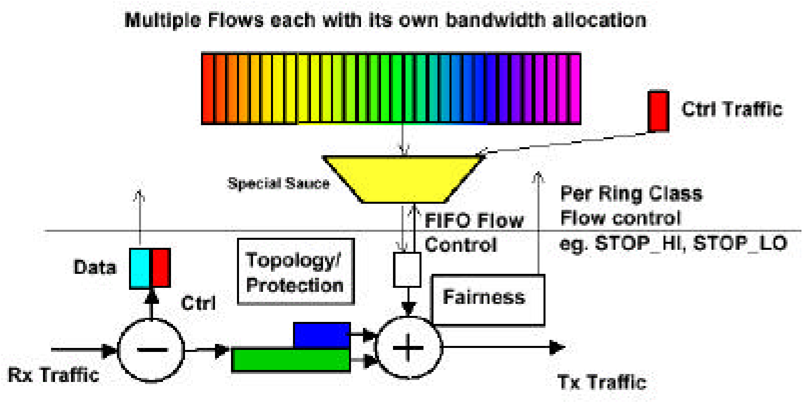
- **Mechanisms and properties of**
  - Gandalf
  - Darwin
  - Alladin
  - DVJ

- **Mechanisms and properties of the Cyclic Reservation MAC**
  - IKNv1 (presented in July 2001)
  - IKNv2 (improvement)

- **Performance of the Cyclic Reservation MAC**

Gandalf: Main Mechanisms





Transit buffers:

- Used for collision avoidance, high-priority bypassing, and packet scheduling

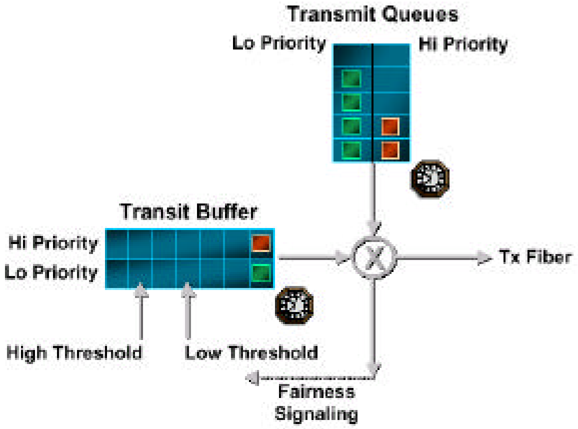
Buffer thresholds:

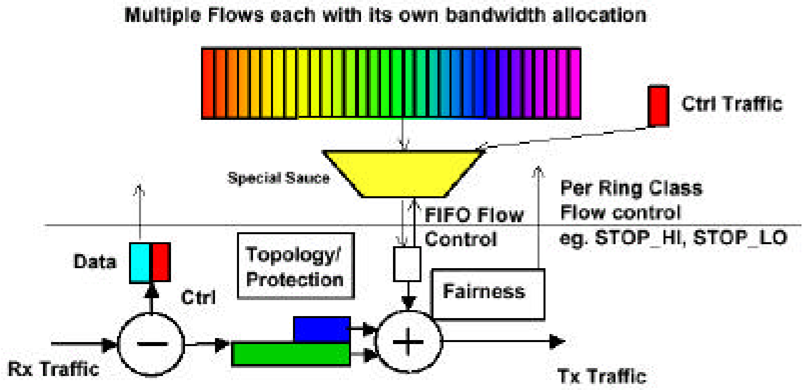
- Rules? Heuristic determination? Depending on traffic pattern?
- Depending on buffer occupancy transfer time on medium may vary strongly

Reactive fairness control

- Bottleneck link fairness control is triggered by backpressure packets
- Individual packets; no packet coordination; temporary explosion?
- Fairness not well achieved
- Flows not passing bottleneck may flow. 4 Bottleneck areas provided. Why 4 and not x ?

Darwin: Main Mechanisms





Transit buffers:

- Used for collision avoidance, high-priority bypassing, and packet scheduling

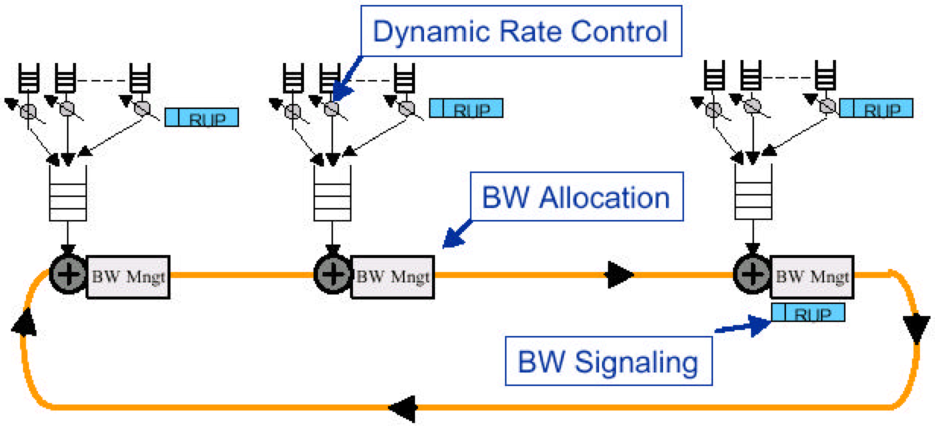
Buffer thresholds:

- Rules? Heuristic determination? Depending on traffic pattern?
- Depending on buffer occupancy transfer time on medium may vary strongly

Proactive and reactive fairness control

- **Load demand is advertised. Mechanism using that information not clear.**
- Bottleneck link fairness control is triggered by backpressure packets
- Fairness achieved ?

Alladin: Main Mechanisms

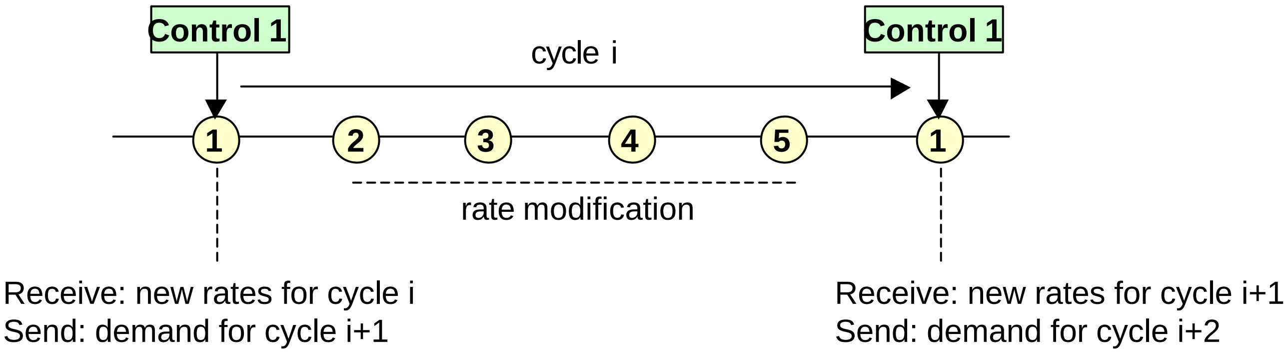


Transit buffers:
- Only used for collision avoidance and high-priority bypassing

Proactive fairness control
- Each node monitors its output link to measure rates of each flow
- Control packet is circulating
- Each node is notified about the fair source/destination rates

Drawbacks: - rate scheduling is done based on old information
- Throughput only suboptimal
- dynamic traffic causes even more throughput loss

DVJ: Main Mechanisms

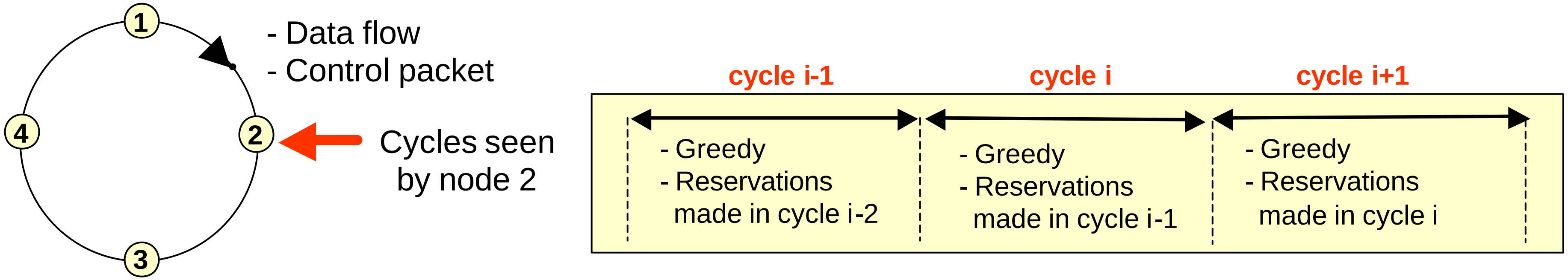


Transit buffers:
- Only used for collision avoidance and high-priority bypassing

Proactive and reactive fairness control
- Control packet with traffic demand circulates for each node
- All other nodes modify flow rates in this control packet according to the bottlenecks
- Upon return, the issuing node obtains the allowed rate for each of its flows

Drawbacks: - Circulating control packet for each node
- Information of other ring flows are not used, causing throughput loss
- Dynamic traffic causes throughput loss

IKN: Main Mechanisms



Transit buffers:
Only used for collision avoidance and high-priority bypassing

Proactive fairness control
Control packet with traffic demand matrix is circulating

Greedy access: in same cycle i for flows over links which are no bottleneck
Reservation access: in next cycle i+1 for bottleneck flows

Maximal performance because rate scheduling is done on waiting traffic demand,
i.e., the mechanism also works when traffic pattern completely changes in every cycle

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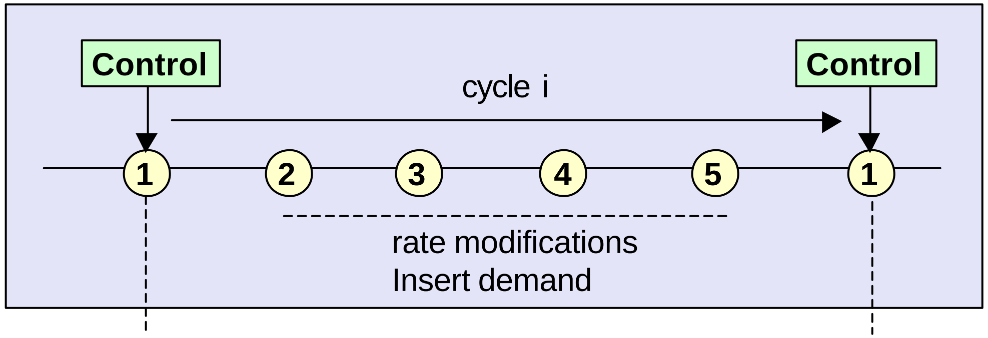
IKN: Improvement of July 2001 Version

IKNv1
July 2001

Control information is modified by all nodes



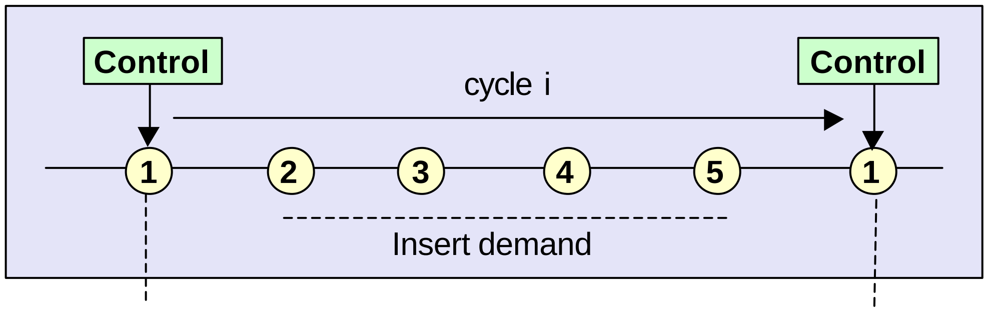
- **Receive:** new rates for cycle i
- **Send:** demand for cycle i+1

- **Receive:** new rates for cycle i+1
- **Send:** demand for cycle i+2

IKNv2
Jan 2002

Control information is not modified

optimal scheduling possible



- **Receive:** demand matrix for cycle i
- Rate calculation for cycle i
- **Send:** demand for cycle i+1

- **Receive:** demand matrix for cycle i+1
- Rate calculation for cycle i+1
- **Send:** demand for cycle i+2

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IKN: Main Properties

Support of
- Multiple traffic classes (real-time strict, real-time loose, best-effort)
- Service Level Agreements
- Heterogeneous link speeds on same ring

Control flow and data flow in same direction
(easy for single ring and any configuration of multiple rings)

Simple and predictive operation
- Simple and straightforward algorithm
- No heuristic thresholds
- No traffic measurements

Best performance
- Optimal bottleneck fairness
- Near to fair theoretical throughputs for each flow
- Guaranteed delays
- Very dynamic traffic adaptation

IKN: Properties of MAC Protocol

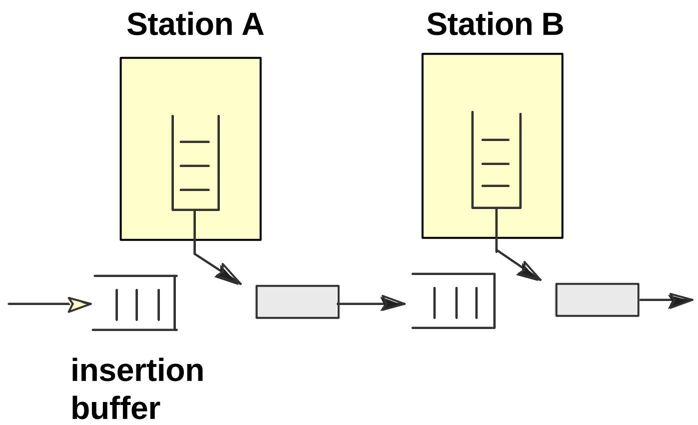
Performance properties:

- Control of flow-based source-destination traffic
- No HOL blocking
- Very high ring throughput
- Node throughputs approximate theoretical fairness values

- Low delays
- No losses on medium
- Small insertion buffer occupancies

- Greedy and reserved access
- Unfairness due to greedy access can be corrected
- Greedy access in case of loss of fairness control packet

Simultaneous Access by Buffer Insertion



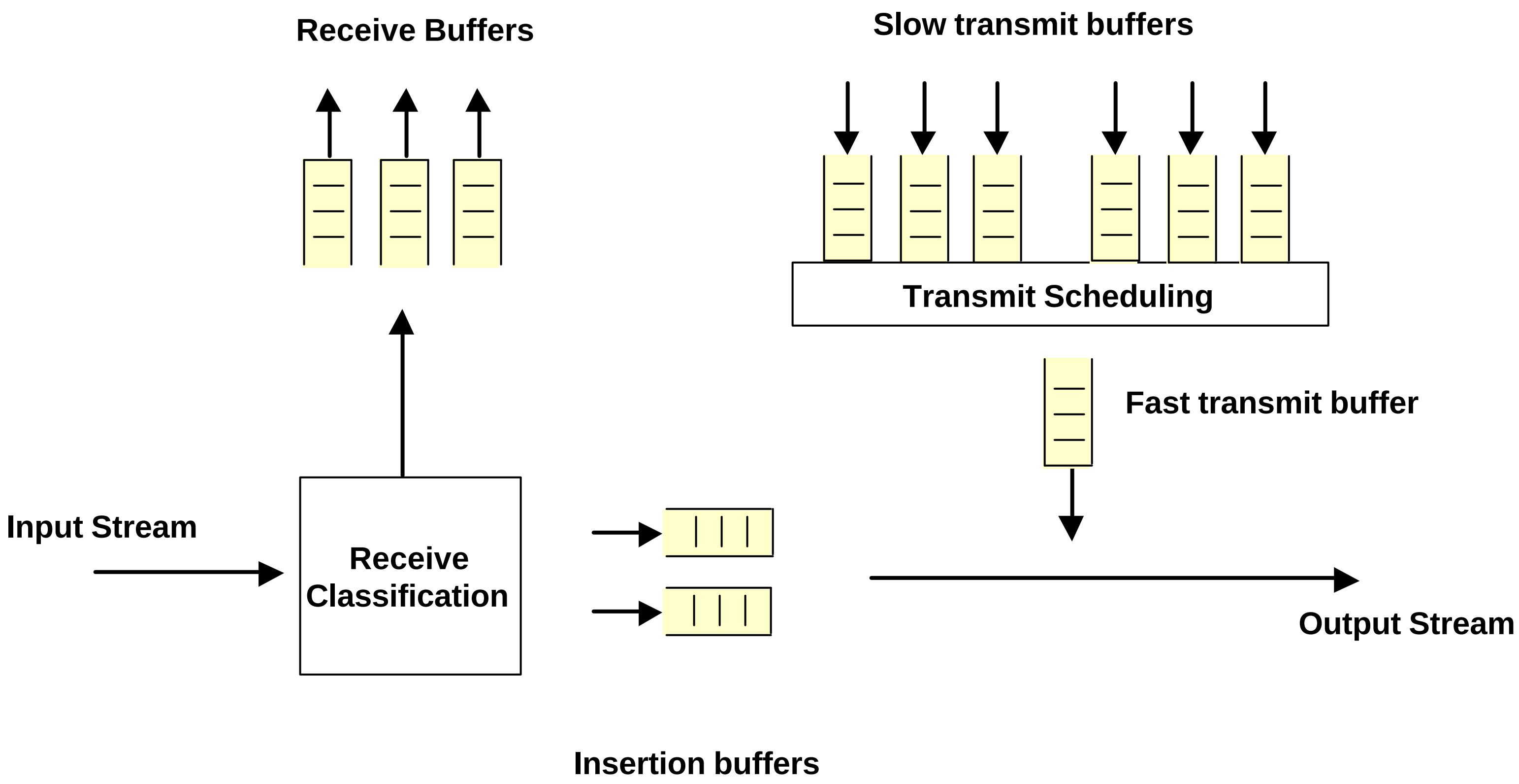
- Insertion buffer in transmit path is only used to resolve collision during packet transmission

- Cut-through mode

- Maximum size of insertion buffer is 1 MTU

- Insertion buffers (low and high) must both be empty before medium access takes place

Node Structure



- Ring priority
- Priority bypassing on ring

Access Mechanism

- Insertion buffer solves only packet collision problem. Not used for scheduling.

- Transmission path is used as a pure transmission link, i.e. ring priority

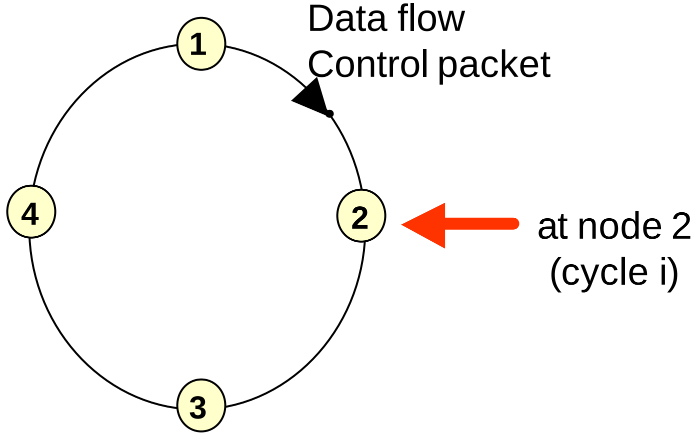
- Insertion buffer must be emptied before accessing the ring

- Greedy access for underutilized links

- Reserved access for bottleneck links

Fairness Mechanism (1)

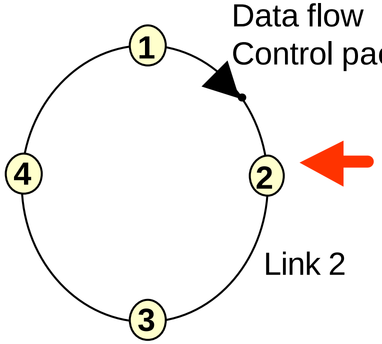
Example for single ring



Flow	High	Low	
1 -> 2	H12	L12	cycle i
1 -> 3	H13	L13	
1 -> 4	H14	L14	
2 -> 3	H23	L23	cycle i -1
2 -> 4	H24	L24	
2 -> 1	H21	L21	
3 -> 4	H34	L34	
3 -> 1	H31	L31	
3 -> 2	H32	L32	
4 -> 1	H41	L41	
4 -> 2	H42	L42	
4 -> 3	H43	L43	

- On each ring, a control packet circulates in data direction
- One entry for each traffic type and for each source-destination flow
- Circulating information is based on waiting load in each node (not on old measurements)

Fairness Mechanism (2)



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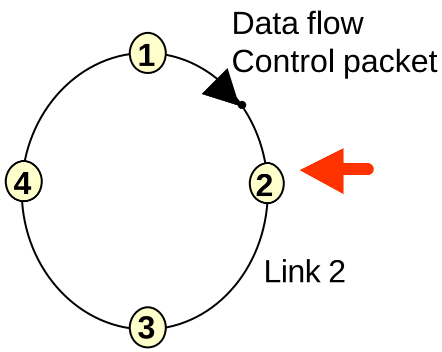
3 -> 1	H31	L31	
3 -> 2	H32	L32	
4 -> 1	H41	L41	
4 -> 2	H42	L42	
4 -> 3	H43	L43	

Actions in node 2:

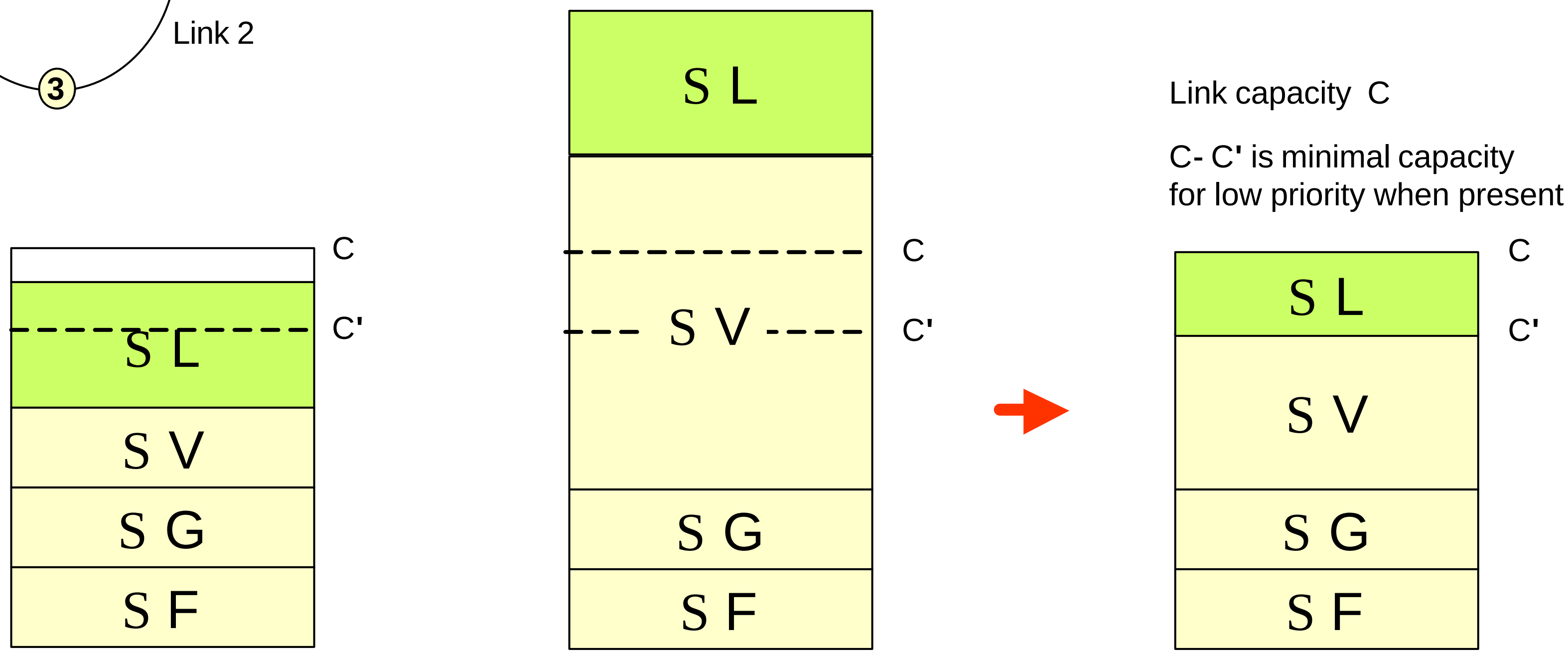
- Determine fair rates for all classes and for all flows from node 2
- Write new demand of node 2 into control packet
- Send control packet to next node at the scheduled time

- Transmit reserved traffic according to calculated fair flow rates
- Transmit greedy traffic up to fair flow rates rate

Fairness Mechanism (3)



S L : all low-traffic flows
S V : all non-guaranteed high-traffic flows
S G : all guaranteed high-traffic flows
S F : all CBR traffic flows
$V_i = H_i - G_i$: variable part of high-priority traffic flow



No correction

Link bottleneck
Correction required

Link bottleneck
Coordinated flows

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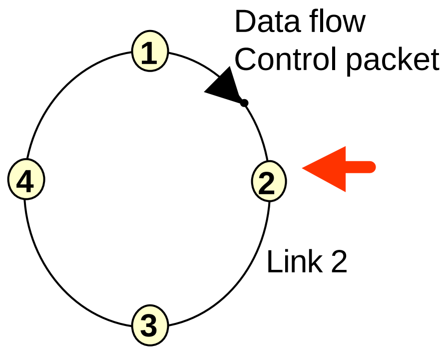
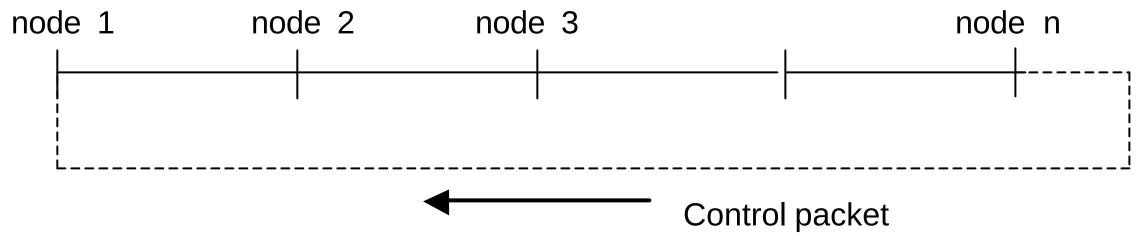
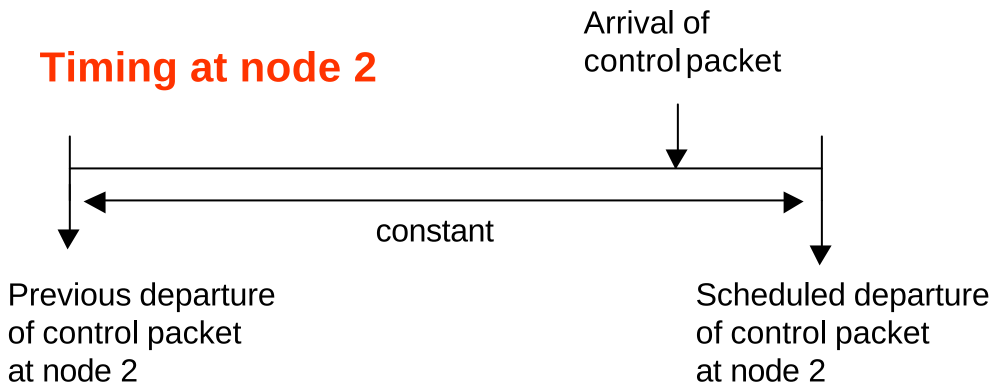
Fairness Mechanism (4)



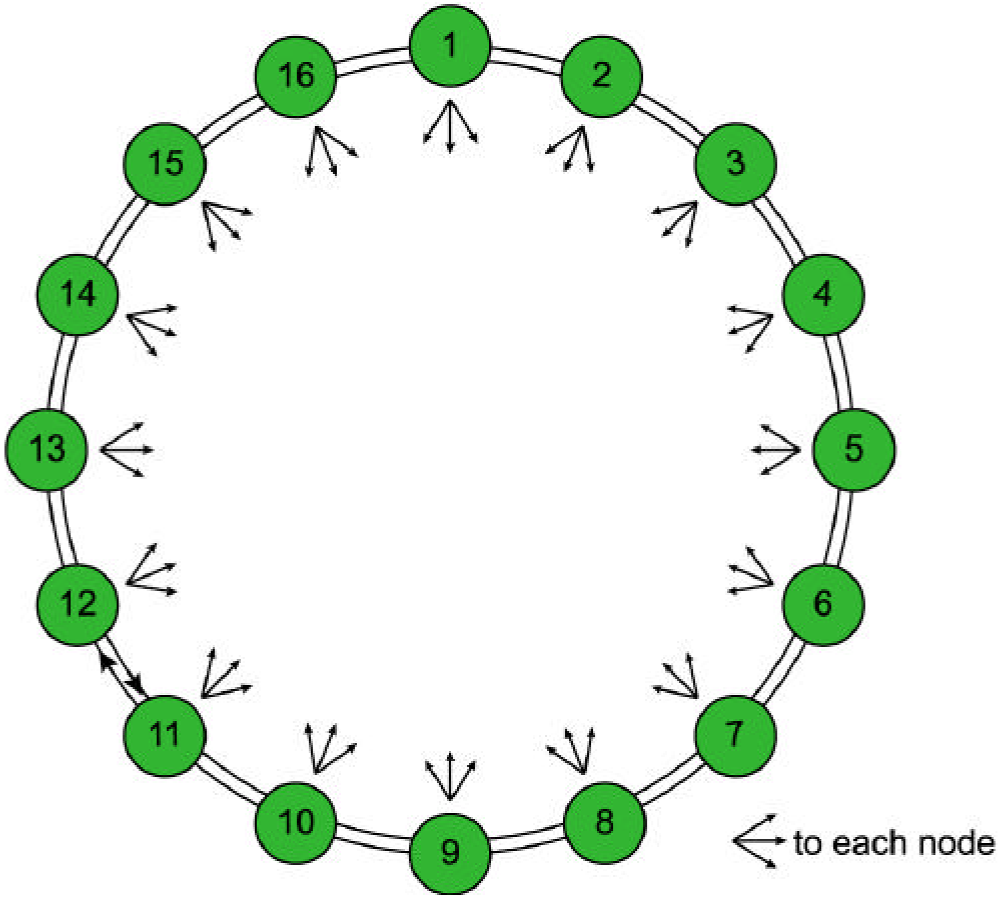
Fairness cycle



Timing at node 2



Dual-Ring - Traffic Scenario 1

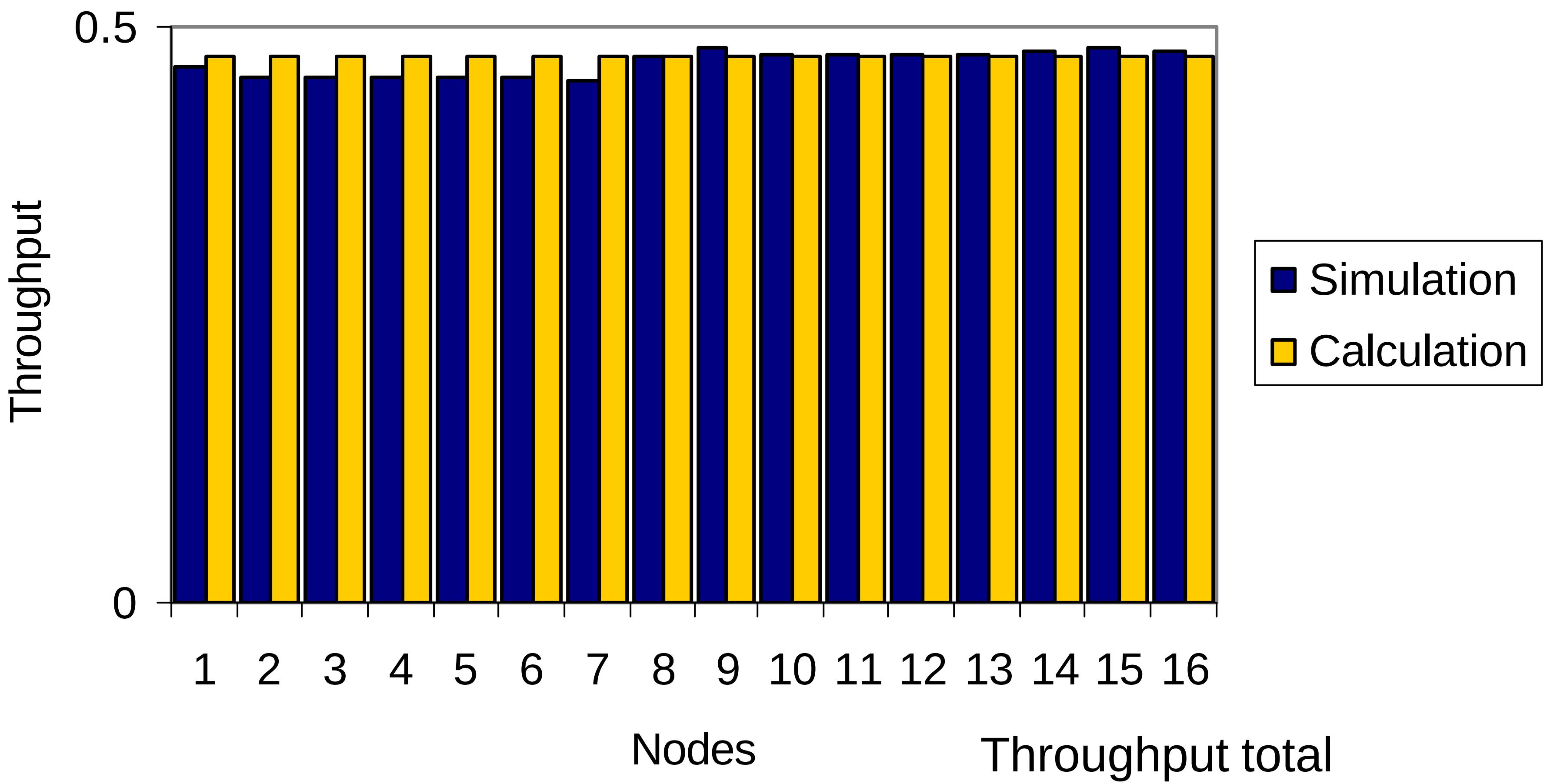


Uniform traffic
Saturated sources
16 nodes

Constant packets
8000 bits

Cyclic reservation protocol

Dual-Ring - Traffic Scenario 1



Throughput total
Simulation : 7.5
Calculation : 7.55

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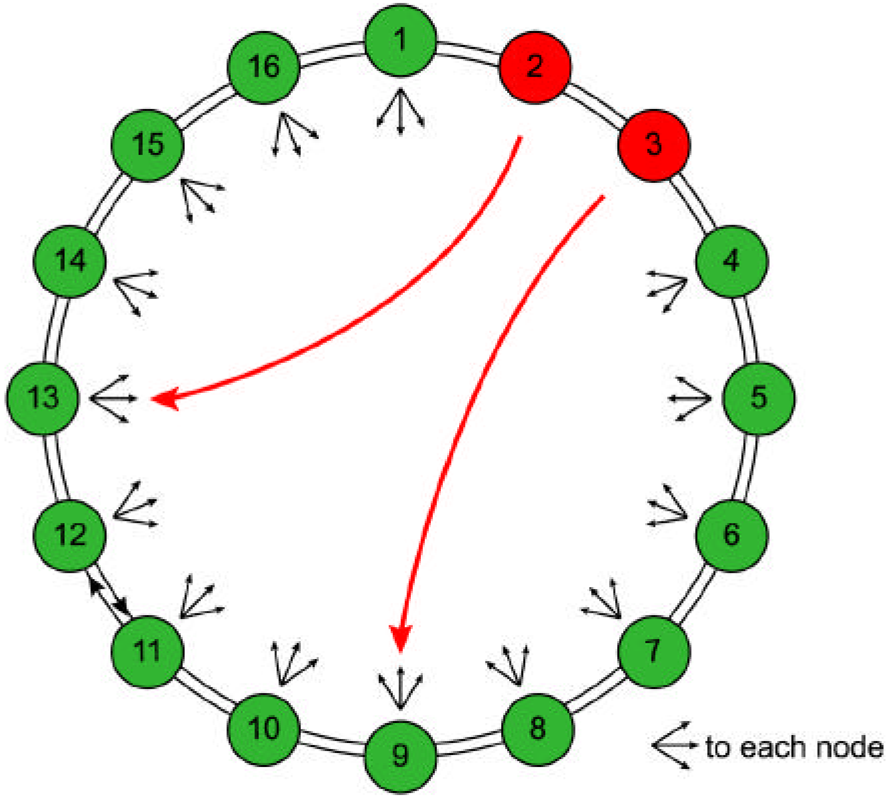
Dual-Ring – Traffic Scenario 2



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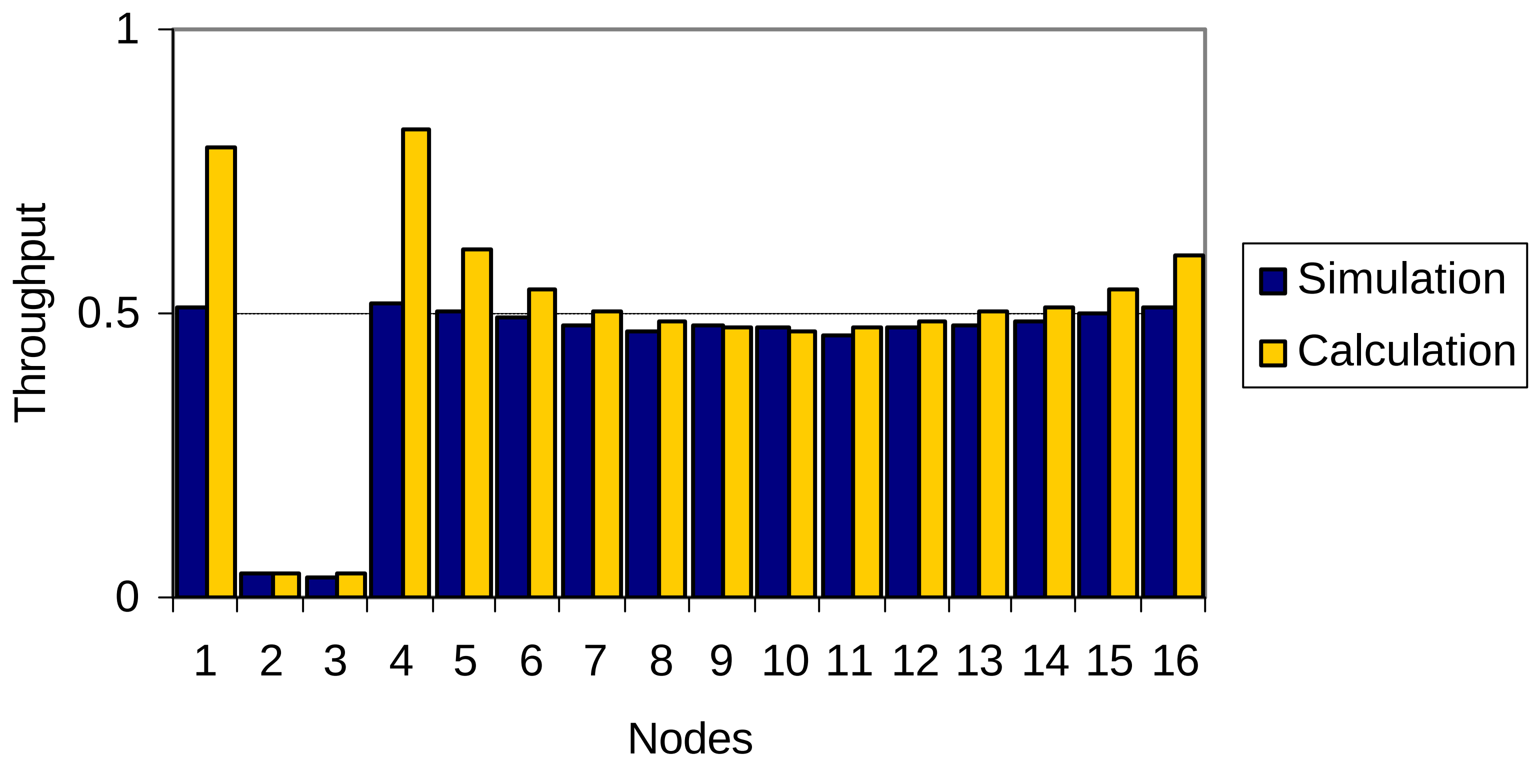
Dual-Ring – Traffic Scenario 2



IKNv1, July 2001

Throughput total
Simulation : 6.92
Calculation : 7.91

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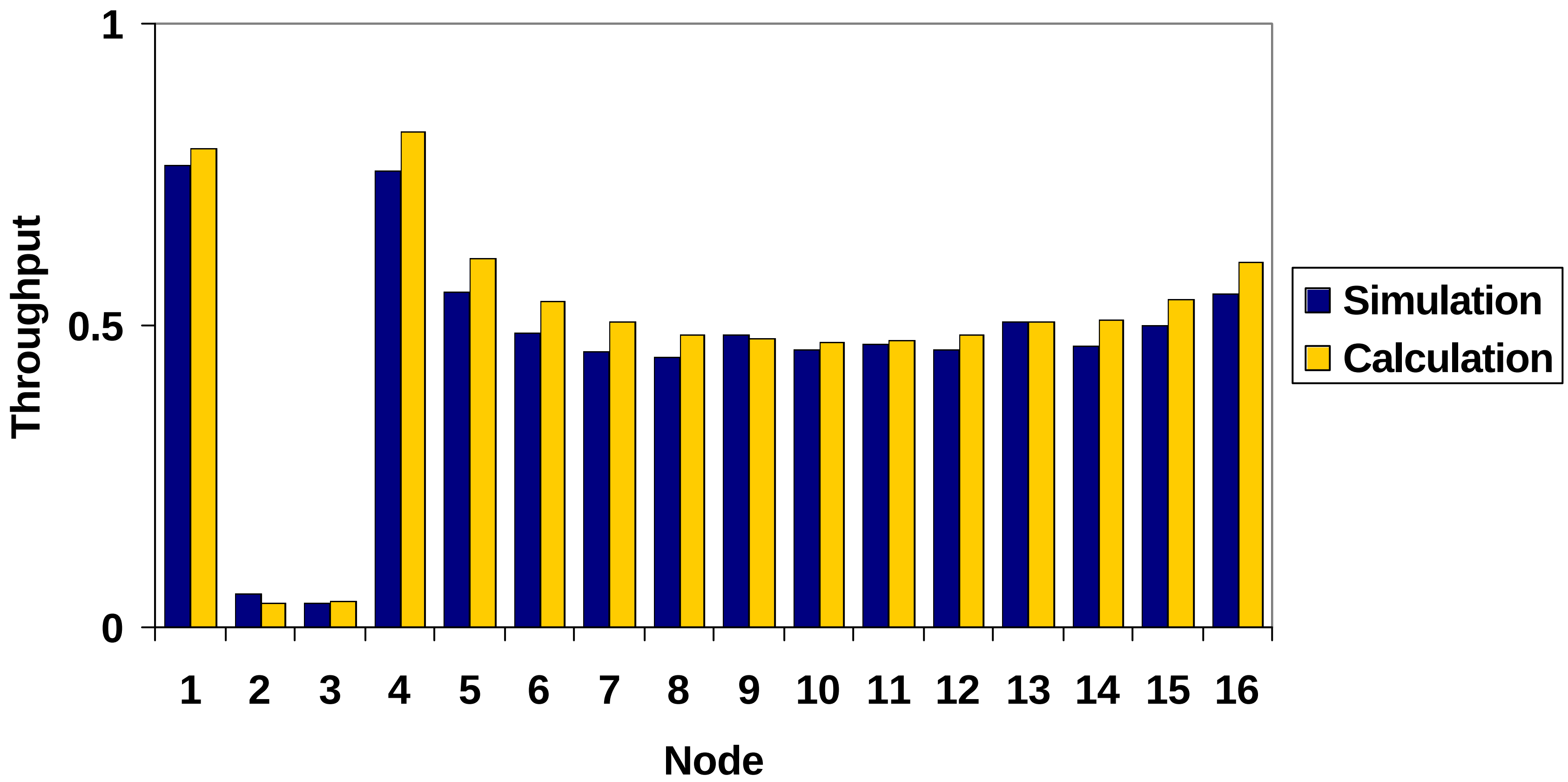
Dual-Ring – Traffic Scenario 2



Throughput total

Simulation : 7.46

Calculation : 7.91

IKNv2, Jan 2002

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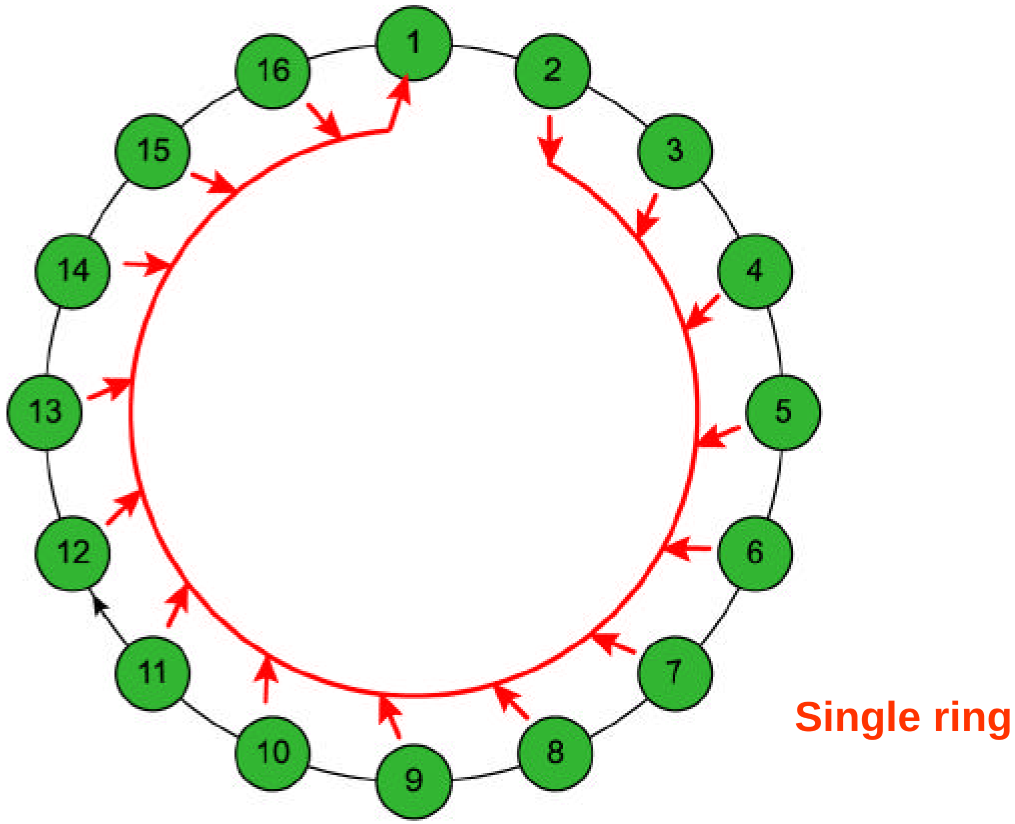
Single Ring-Traffic Scenario 3



Uniform traffic
Saturated sources
16 nodes

Constant packets
8000 bits

Cyclic reservation protocol

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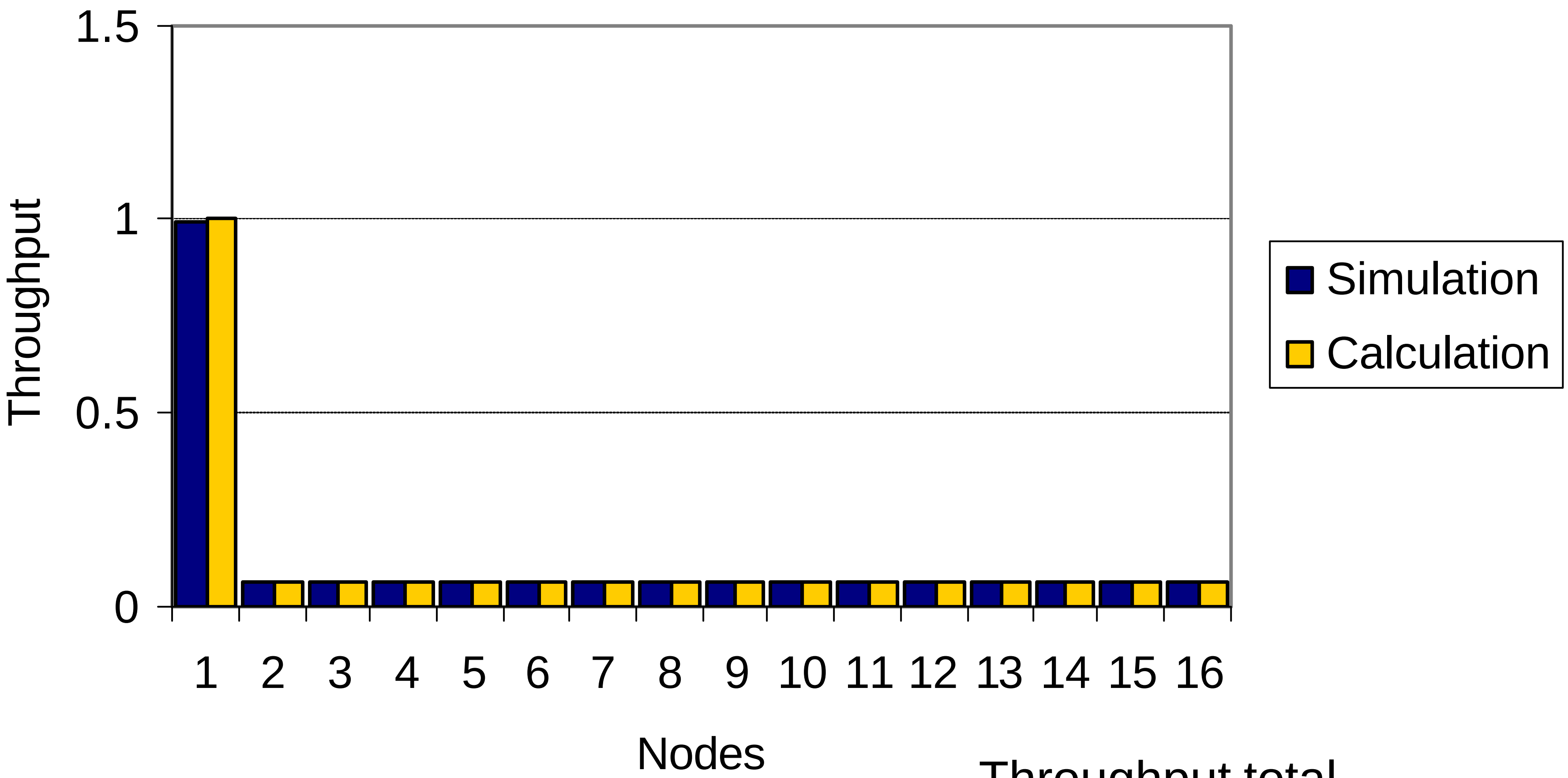
Single Ring-Traffic Scenario 3



Throughput total
Simulation : 1.98
Calculation : 1.99

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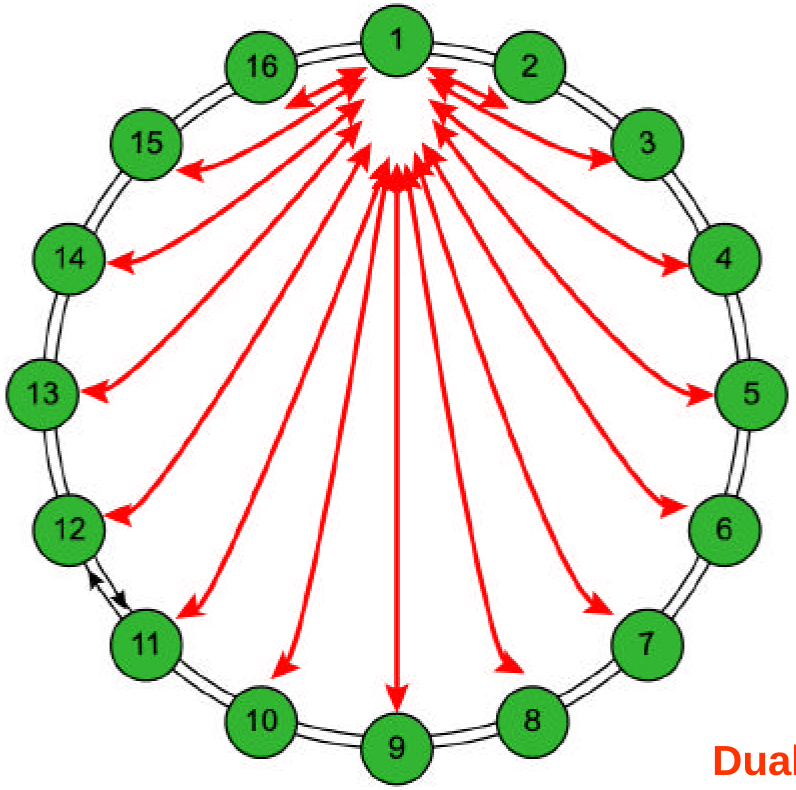
Dual-Ring – Traffic Scenario 4



Dual ring

Uniform traffic
Saturated sources
16 nodes

Constant packets
8000 bits

Cyclic reservation protocol

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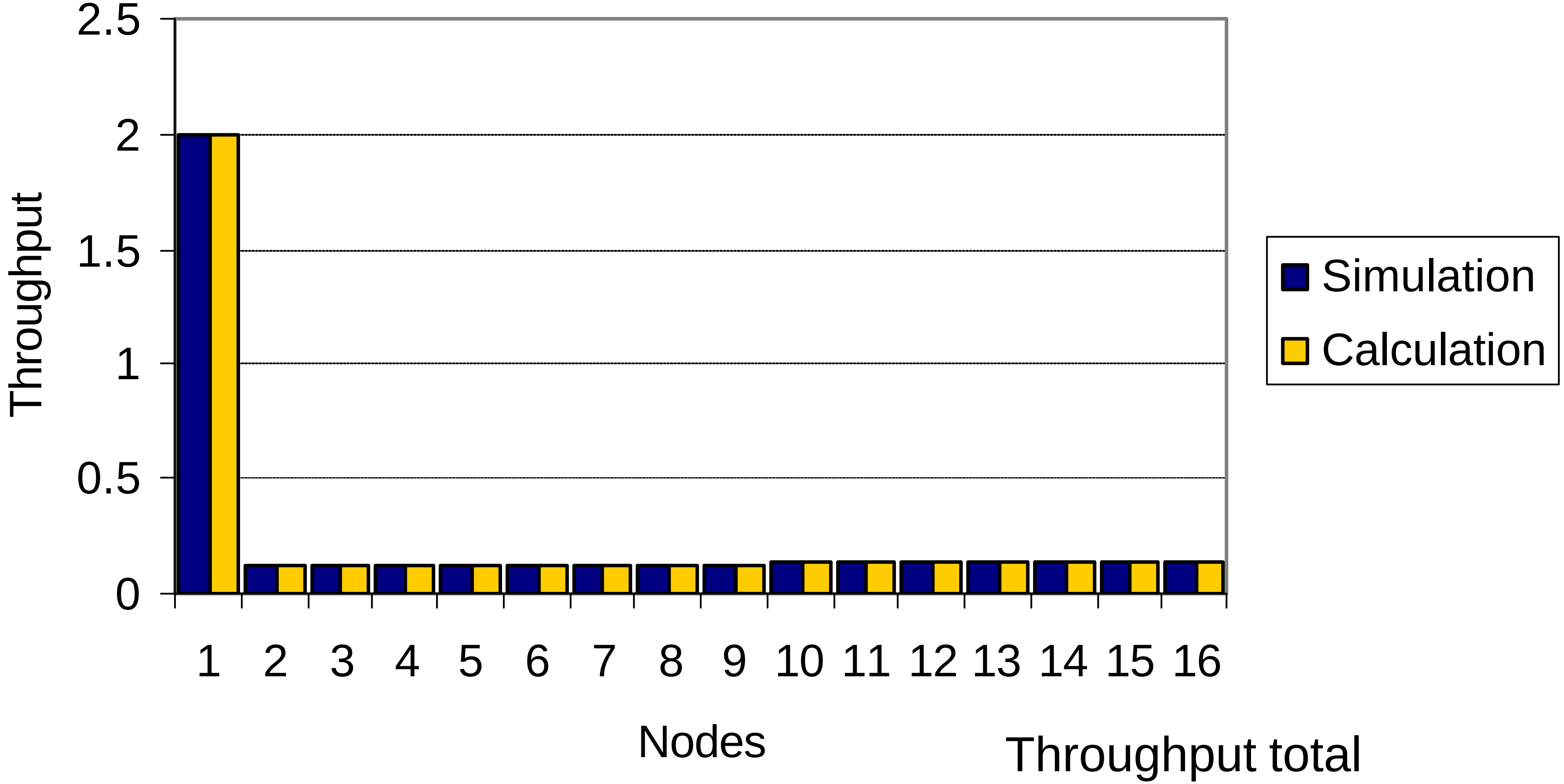
Dual-Ring – Traffic Scenario 4



Throughput total
Simulation : 3.98
Calculation : 3.99

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Conclusion

Combined greedy and cyclic reservation access performs at the theoretical fair limits

Excellent performance in terms of

- Throughput
- MAC end-to-end delay
- SLA guarantees
- Traffic dynamics

Some other features

- Multiple service classes
- Simple straightforward access mechanism
- Self-adaptive mechanism
- No measurements
- Heterogeneous link rates

