Guaranteed Service Independent of the Task Placement in NoCs with Torus Topology

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Systems and Networking

RTNS
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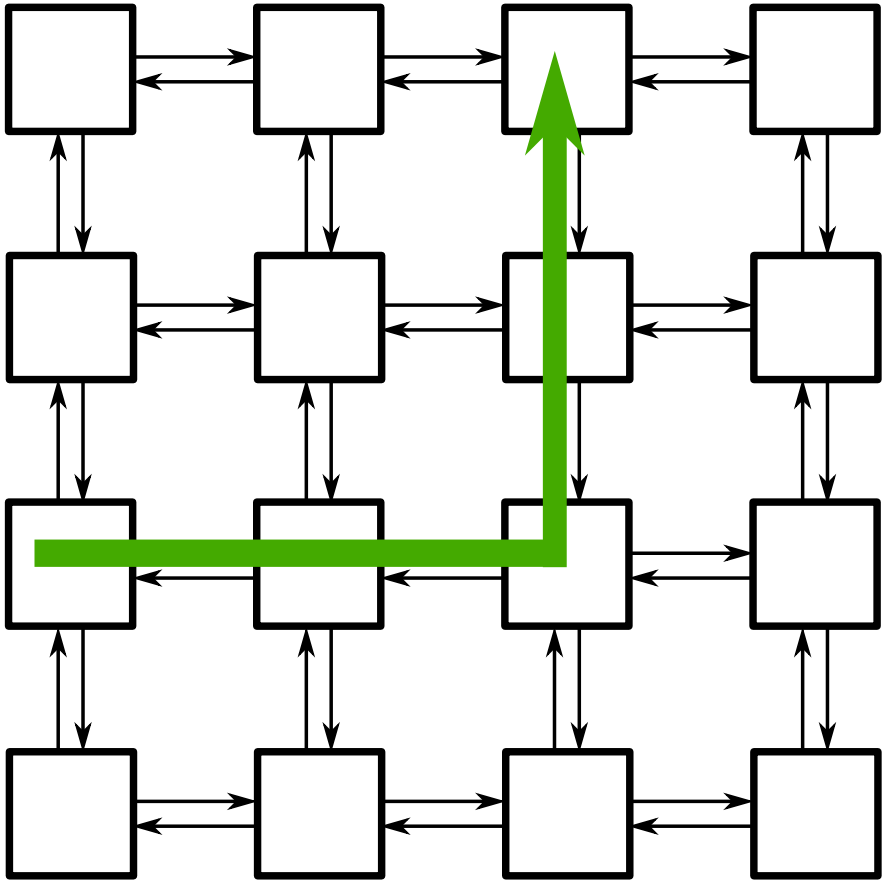
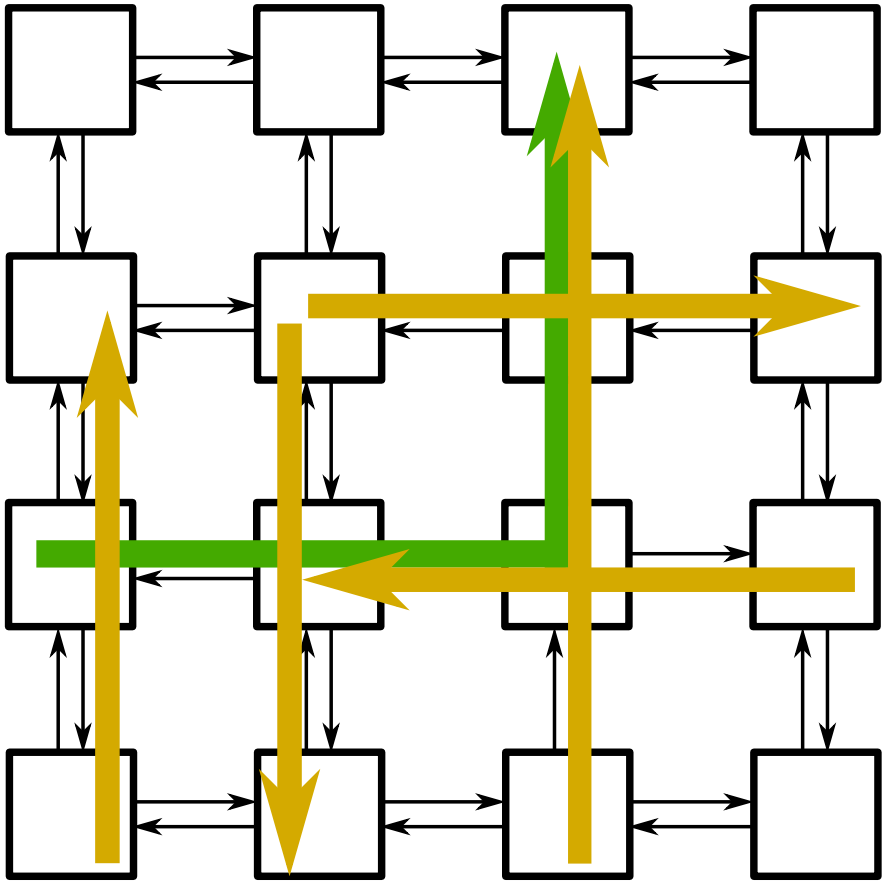
WCTT in a Real-time NoC



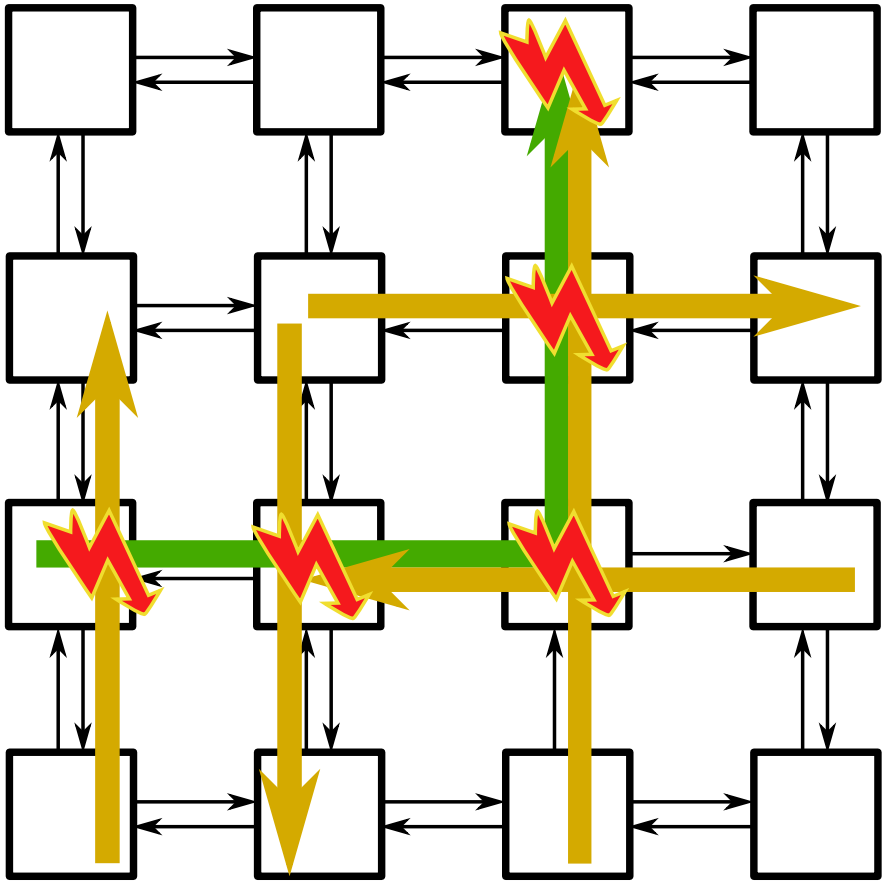
- Real-time system with a Network on Chip (NoC)
- $n \times n$ nodes
- Compute the Worst Case Traversal Time (WCTT) of one Flow

Problem: Interference With Other Flows



Two major solutions:

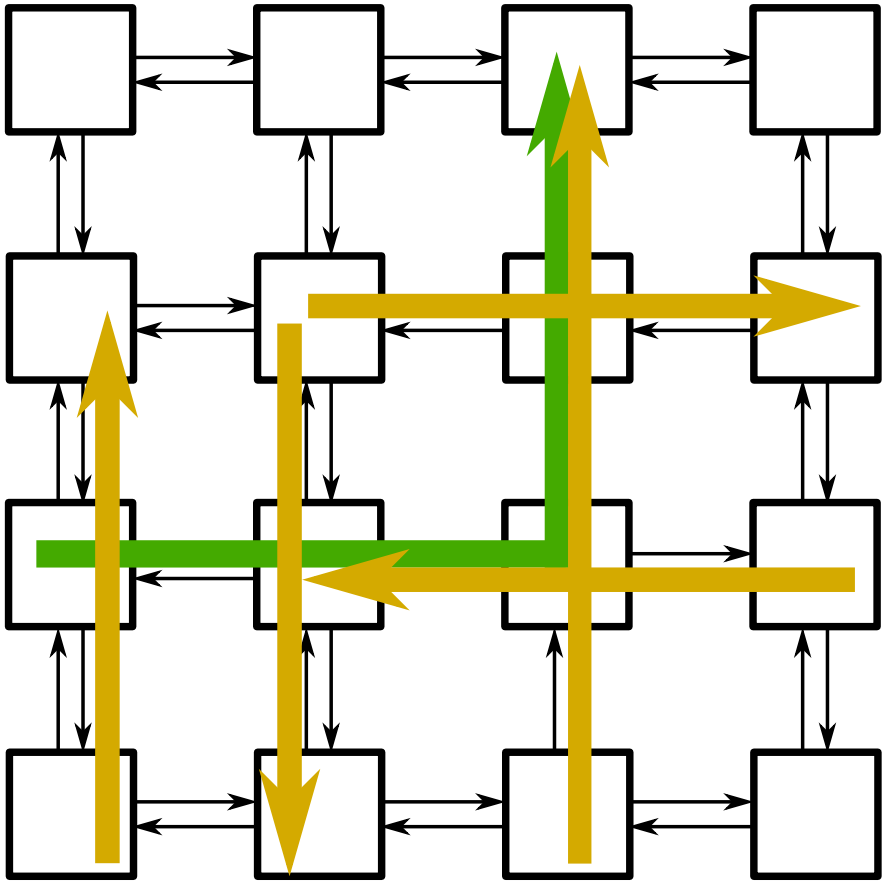
Problem: Interference With Other Flows



Two major solutions:

1. Compute upper bound for the number of conflicts

Problem: Interference With Other Flows



Two major solutions:

1. Compute upper bound for the number of conflicts
2. Avoid conflicts by special arrangement of flows: Time Division Multiplexing (TDM)

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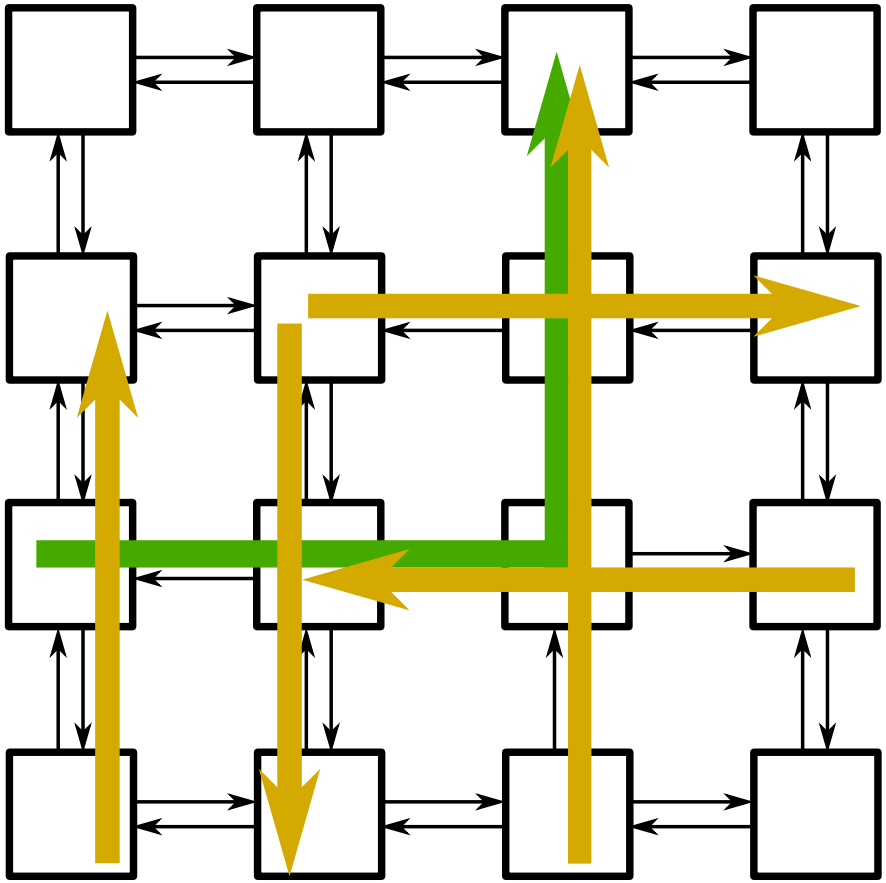


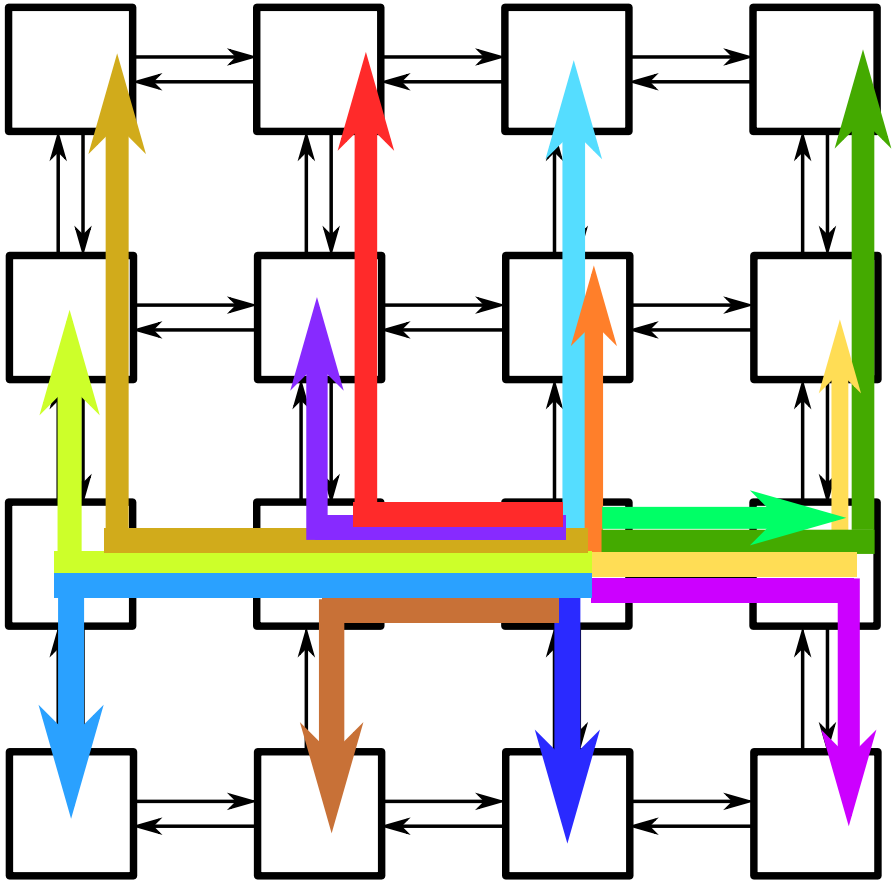
Two major solutions:

1. Compute upper bound for the number of conflicts
2. Avoid conflicts by special arrangement of flows: Time Division Multiplexing (TDM)

Either way:

- All flows must be known a priori
- Task placement is fixed

Alternative: All-To-All Communication Schedule



Schoeberl and Brandner (RTNS 2012):

- Provide all possible flows in a periodic schedule
- But period length is very long

Our approach: One-To-All

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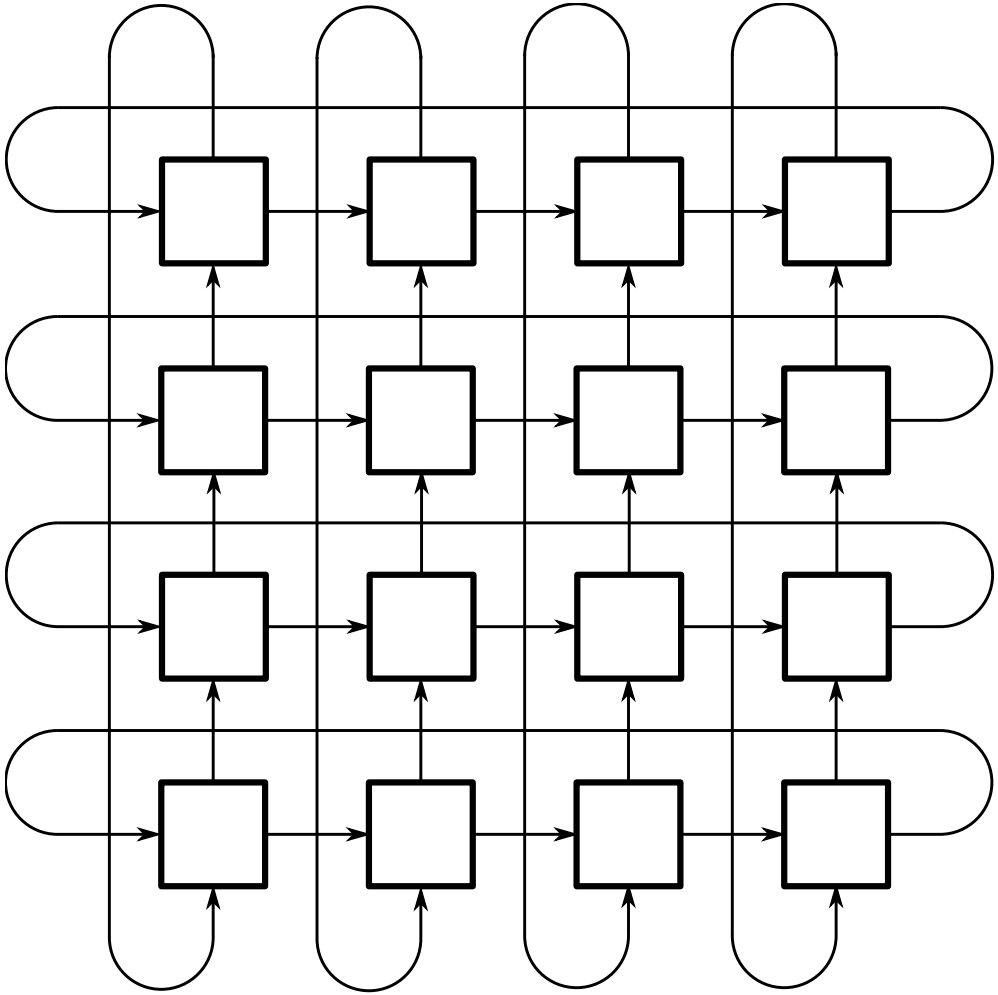
- Send 1 message per period to an arbitrary node
- Send time within period depends on destination
- A single node can receive up to $n \times n$ messages

Implementation

- unidirectional $n \times n$ torus
- first x-transport in horizontal ring,
  then y-transport in vertical ring
- message length is 1 flit

One-To-All in a Unidirectional $n \times n$ Torus



- Destination is given by x and y distance
- Inject flit in cycle $n(x-1)$ to horizontal ring
- If $x = 0$ directly start vertical transport
- Flit is at destination column at cycle nx and transported to the destination row within n cycles
- $\Rightarrow$ period is $n \times n$ cycles

Alternative to TDM: One-To-One Communication Schedule

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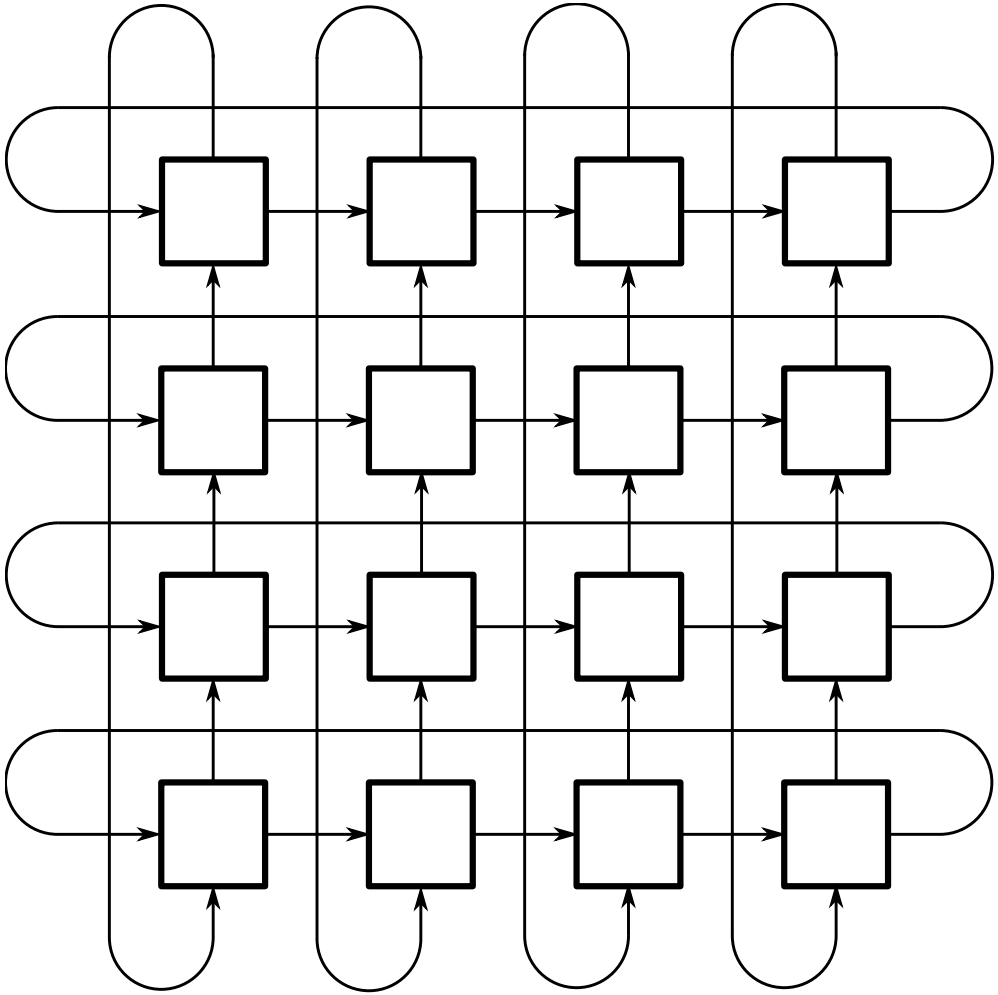
- Send only one message per core
- Receive only one message per core
- It is hard to provide the receive requirement
- But very short period possible

One-To-One in a Unidirectional $n \times n$ Torus



- Send all flits at the same time
- Buffer flits when they reach the destination column
- Start vertical transport after n cycles
- Horizontal and vertical phase can be overlapped
  $\Rightarrow$ period is n cycles

How to provide the receive requirement?

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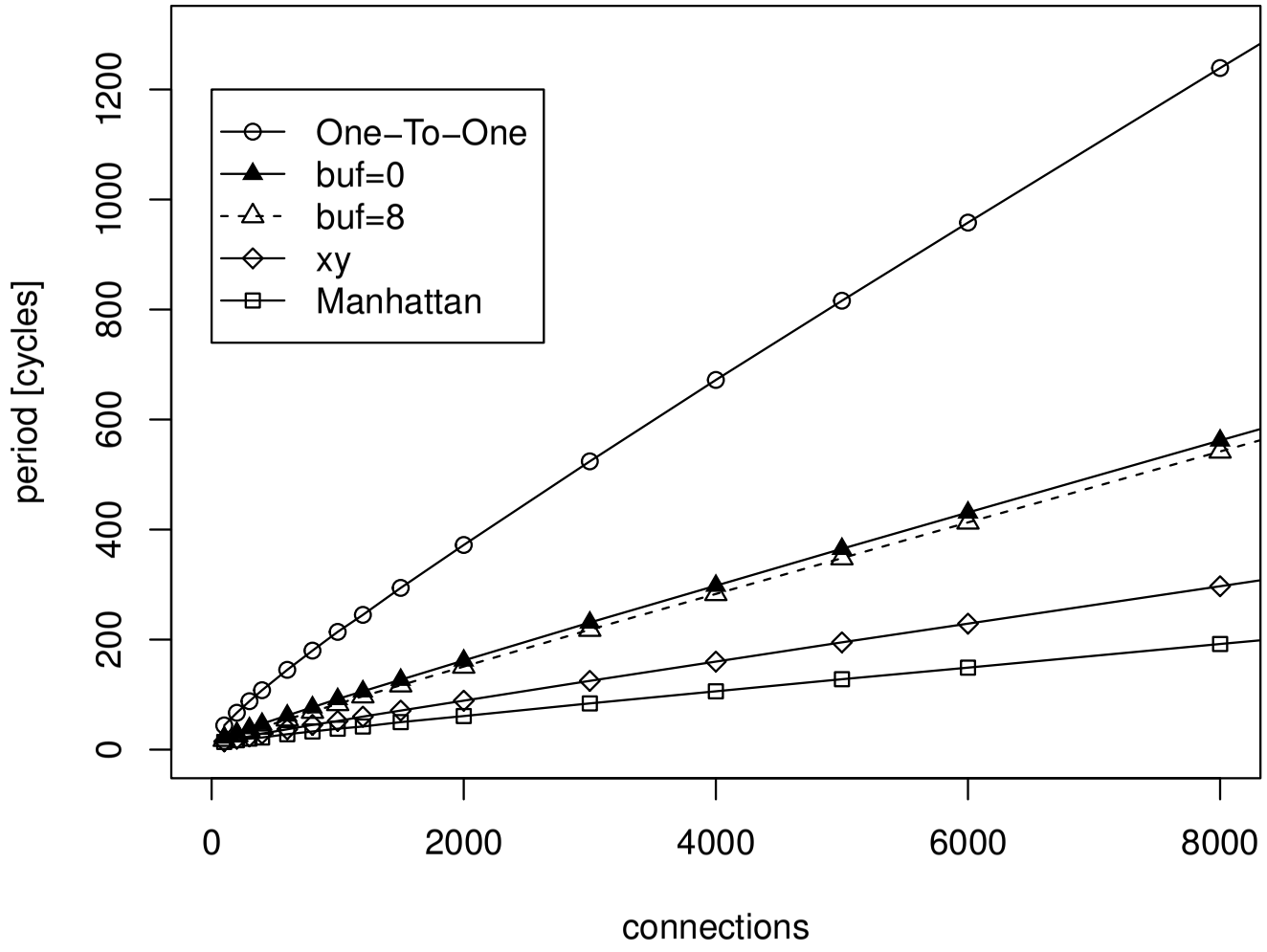
- A single One-To-One round for every communication partner
- Hyperperiod consists of χ' rounds
- With $\chi' =$ maximum number of communication partners of one node
- Drawback: all flows must be known
- But: location of node within NoC doesn't matter

One-To-One vs. TDM



One-To-One:

- 6× period
- placement independent
- fast schedule computation
- simpler hardware

One-To-All vs. All-To-All

	mesh		bidir. torus		unidir. torus			
nodes	heur.	ILP	heur.	ILP	heur.	ILP	**AA**	**1A**
3×3	28	10	11	10	12	11	**9**	**9**
4×4	59	18	20	18	28	26	**24**	**16**
5×5	112	34	28	28	57	52	**50**	**25**
8×8	481	-	88	-	246	-	**224**	**64**
10×10	974	-	158	-	501	-	**450**	**100**
15×15	3467	-	481	-	1821	-	**1575**	**225**
20×20	-	-	1164	-	-	-	**3800**	**400**

	period	WCTT
All-To-All	$\frac{n^3-n^2}{2}$	$\frac{n^3+3n-4}{2}$
One-To-All	n^2	n^2+2n-2

Summary

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- A unidirectional torus can be used to implement alternative communication schedules for real-time NoCs
- Under most circumstances, the WCTT of One-To-All is better than All-To-All
- The One-To-One WCTT is 6× the WCTT of a TDM NoC, but provides independence of task placement