# Interconnection networks simulations for computing systems dedicated to scientific applications at the exascale

Flavio Pisani

University of Bologna
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# Growth of computing power and exascale

- The available computing power is exponentially growing
- The next frontier is the exascale $10^{18}$ FLOPS (Floating Point Operation Per Second)
- This computing power will be available interconnecting together $\sim 10^6$ computing nodes
- The interconnection network becomes extremely complex and fundamental for the system

$$\Downarrow$$

Simulations of the network system are required

# Simulation's requirements

- Low level network description
- Parallel computing capabilities
- Quick implementation of new topologies
- Quick swap of routing algorithms
- Capability of generating both synthetic and real application traffic
- Perform statistical analysis of network performances

By using the OMNet++ framework we can fulfill all the requirements

# OMNet++

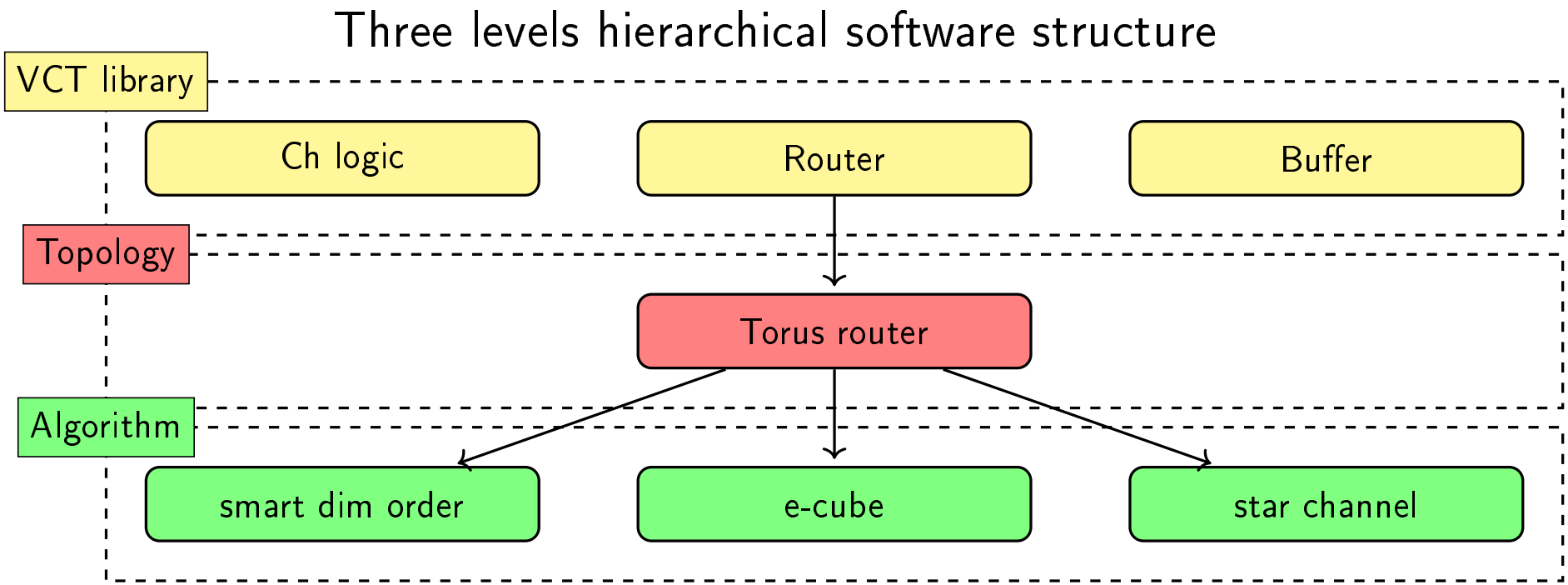
## What OMNeT++ is?

Discrete event simulation Framework written in C++

## What does it offer?

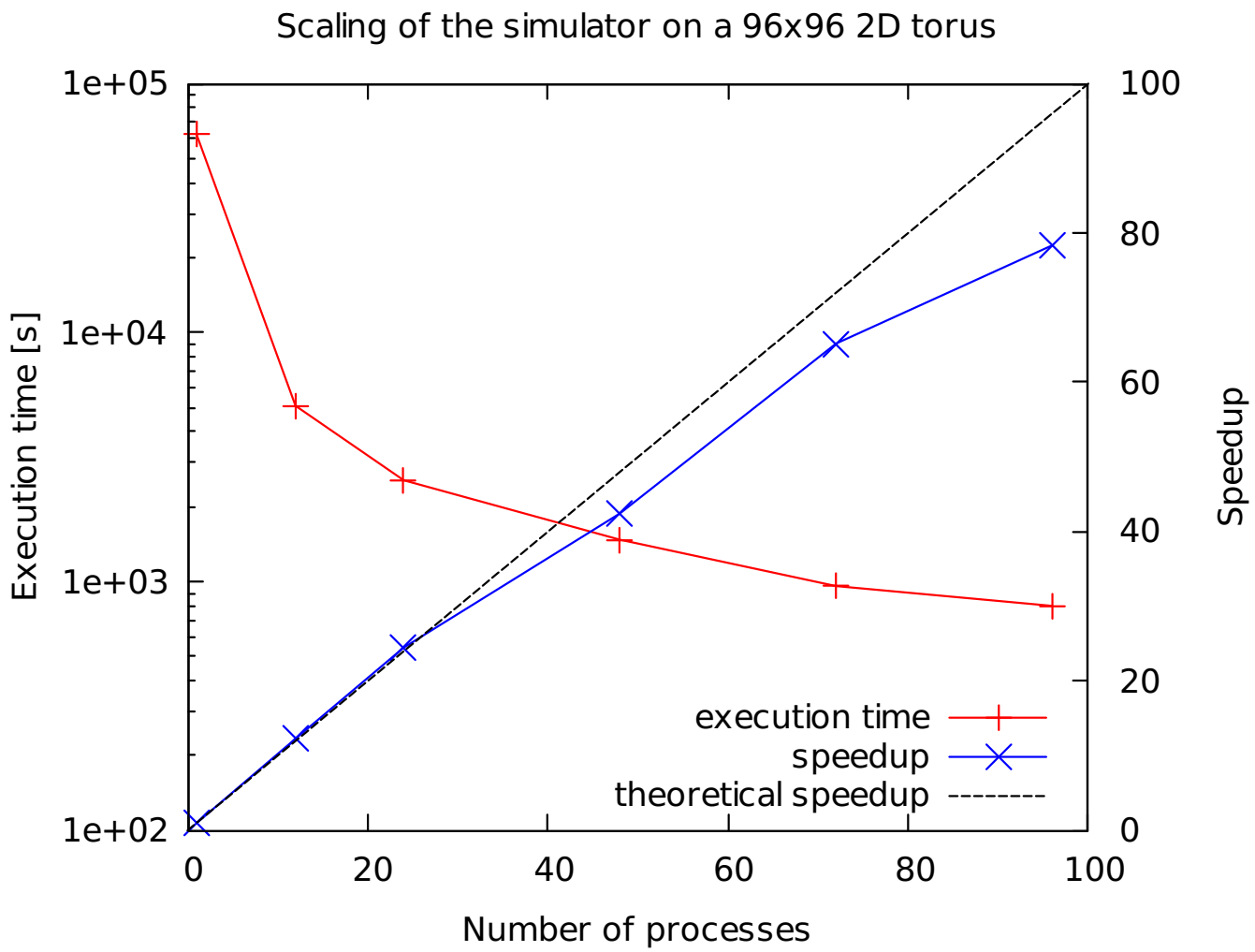
- A flexible and configurable object-oriented structure
- A scripting language for easy definition of network topologies
- The possibility of collecting statistics during the simulation
- Native support to parallel processing through OpenMPI

# Structure of the simulation software

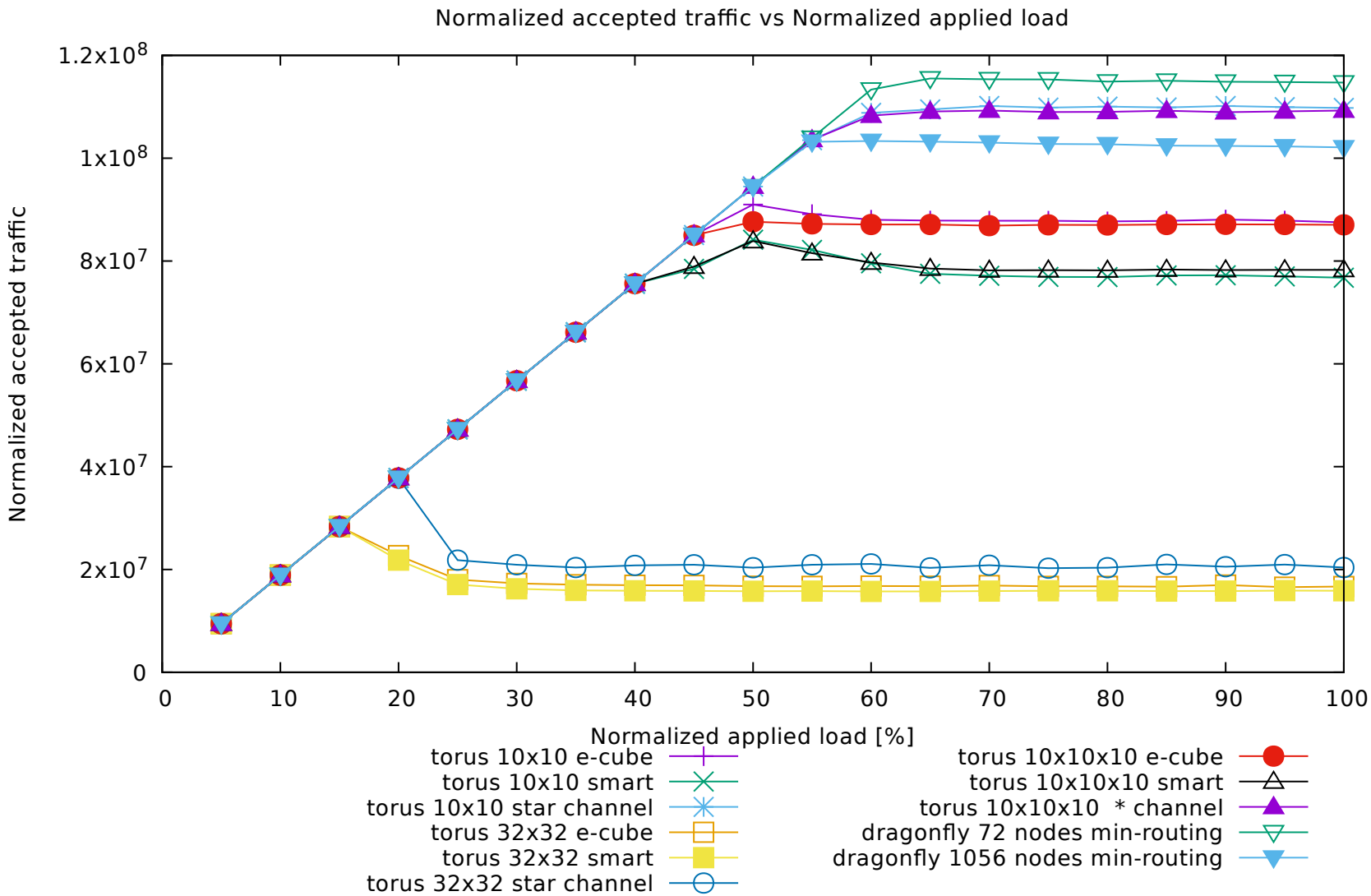


# Scaling of the simulator

Scaling of the simulator on an intel cluster with infiniband interconnection.



# Random uniform traffic



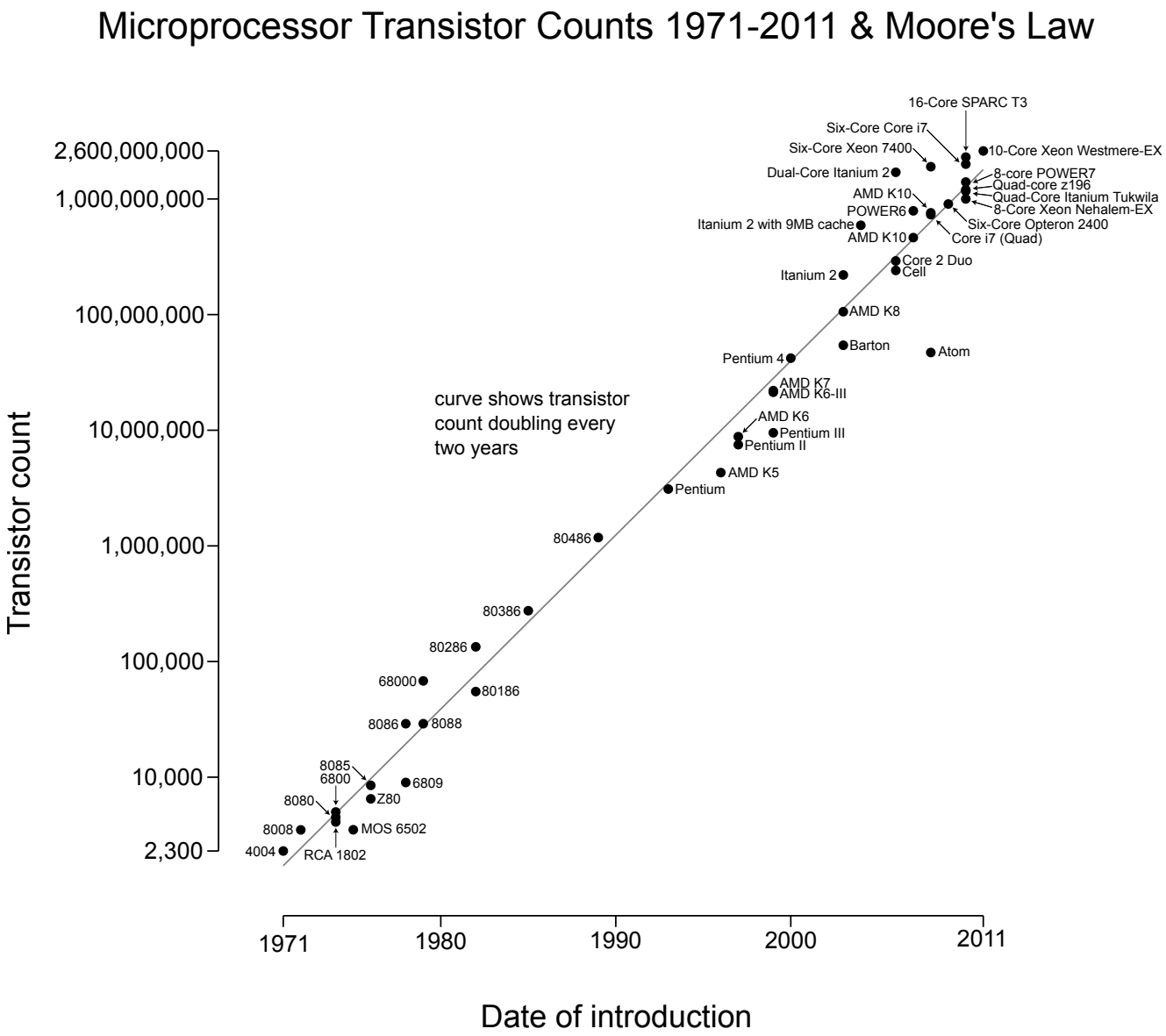
# Conclusions

- The design of an interconnection network is a complex and critical task
- Development of an accurate, flexible and scalable network simulator
- N-dimensional tori can sustain uniform traffic
- Adaptive routing algorithms improve significantly the performances
- Non-minimal partly adaptive routing algorithms do not provide significant improvements
- Dragonfly networks are efficient for uniform traffic

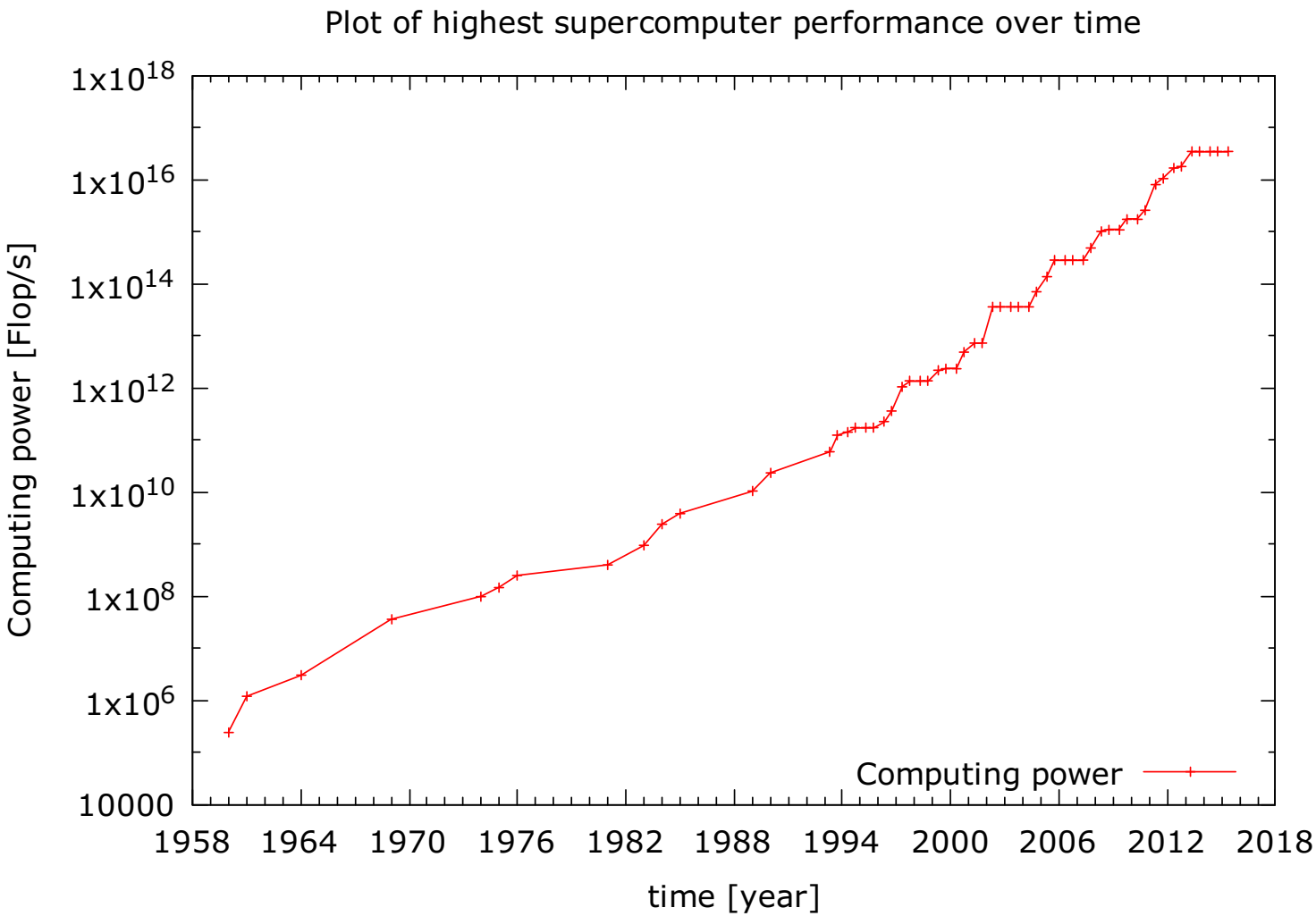
# THANK YOU FOR YOUR ATTENTION

# BACKUP SLIDES

# Moore's law


Microprocessor Transistor Counts 1971-2011 & Moore's Law
Transistor count
2,600,000,000
1,000,000,000
100,000,000
10,000,000
1,000,000
100,000
10,000
2,300
1971
1980
1990
2000
2011
Date of introduction
curve shows transistor count doubling every two years
16-Core SPARC T3
Six-Core Core i7
Six-Core Xeon 7400
10-Core Xeon Westmere-EX
Dual-Core Itanium 2
8-core POWER7
Quad-core z196
AMD K10
Quad-Core Itanium Tukwila
POWER6
8-Core Xeon Nehalem-EX
Itanium 2 with 9MB cache
Six-Core Opteron 2400
AMD K10
Core i7 (Quad)
Core 2 Duo
Itanium 2
Cell
AMD K8
Barton
Atom
Pentium 4
AMD K7
AMD K6-III
AMD K6
Pentium III
Pentium II
AMD K5
Pentium
80486
80386
80286
68000
80186
8086
8088
8085
6800
6809
8080
Z80
8008
MOS 6502
4004
RCA 1802

# top500


Plot of highest supercomputer performance over time
Computing power [Flop/s]
1x10^18
1x10^16
1x10^14
1x10^12
1x10^10
1x10^8
1x10^6
10000
1958
1964
1970
1976
1982
1988
1994
2000
2006
2012
2018
time [year]
Computing power

# Neuronal models

## LIFCA dynamic model for spikes generation

$$
V_m < V_{th} \begin{cases} \dot{V}_m &= -\frac{V_m - E_L}{\mathrm{T}} - \frac{g_w w}{C_m} + \frac{I_e}{C_m} \\ \dot{w} &= -\frac{w}{\tau_w} \end{cases}
$$

$$
V_m \geq V_{th} \begin{cases} V_m &= V_{reset} \\ w &= w + A_C \end{cases}
$$

## Column connection model

$$
A e^{-\frac{r}{\lambda}}
$$

# Cluster specifications

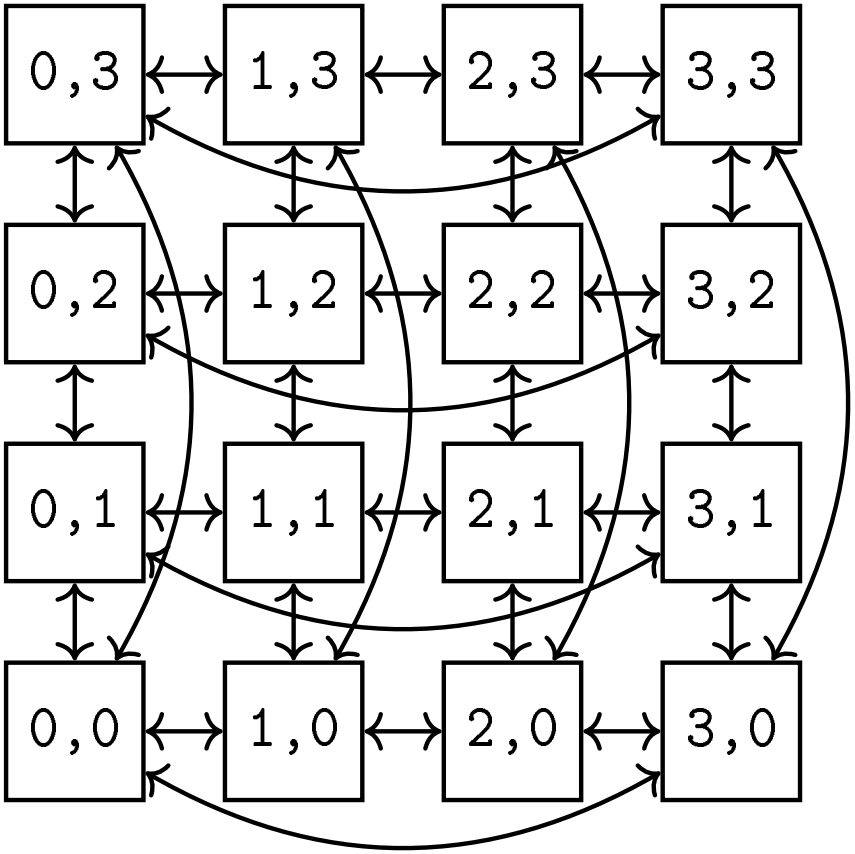
| | |
|---|---|
| CPU | 2 x Intel Xeon CPU E5620 @ 2.40 GHz |
| Memory | 48 GB |
| Network card | Mellanox MT26428 Connectx2 |
| OpenMPI version | 1.10.3 |
| Linux version | CentOS 7.2 kernel 3.10.0-327.22.2 |

# Routing algorithms

## Routing algorithm's classification

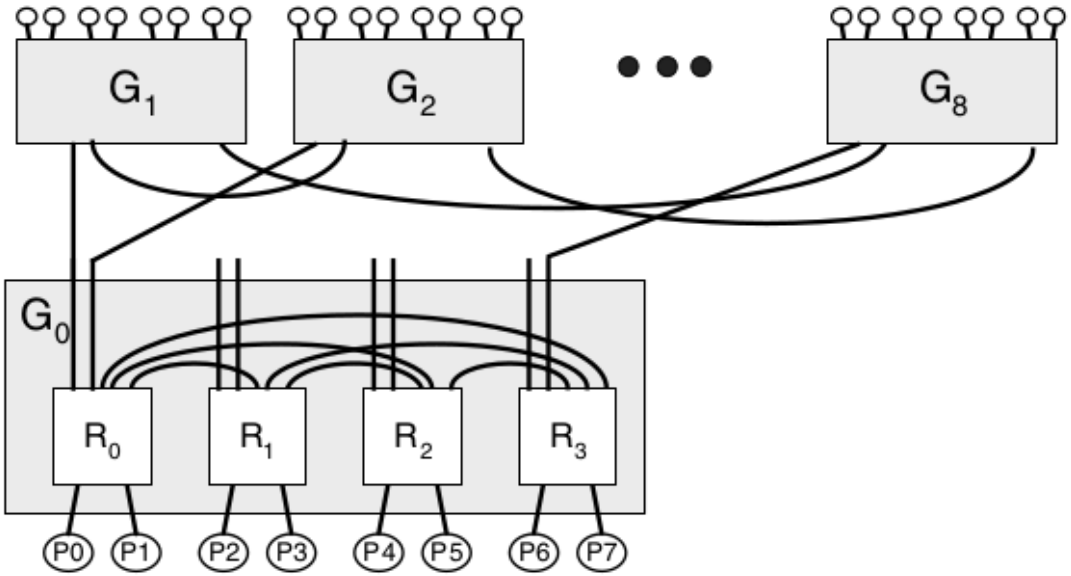
- Minimal: it selects only the shortest path between two nodes.
- Deterministic: It selects only one among the available paths.
- Partly adaptive: It selects several of the available paths.
- Fully adaptive: It selects several of available paths.

# N-dimensional Tori



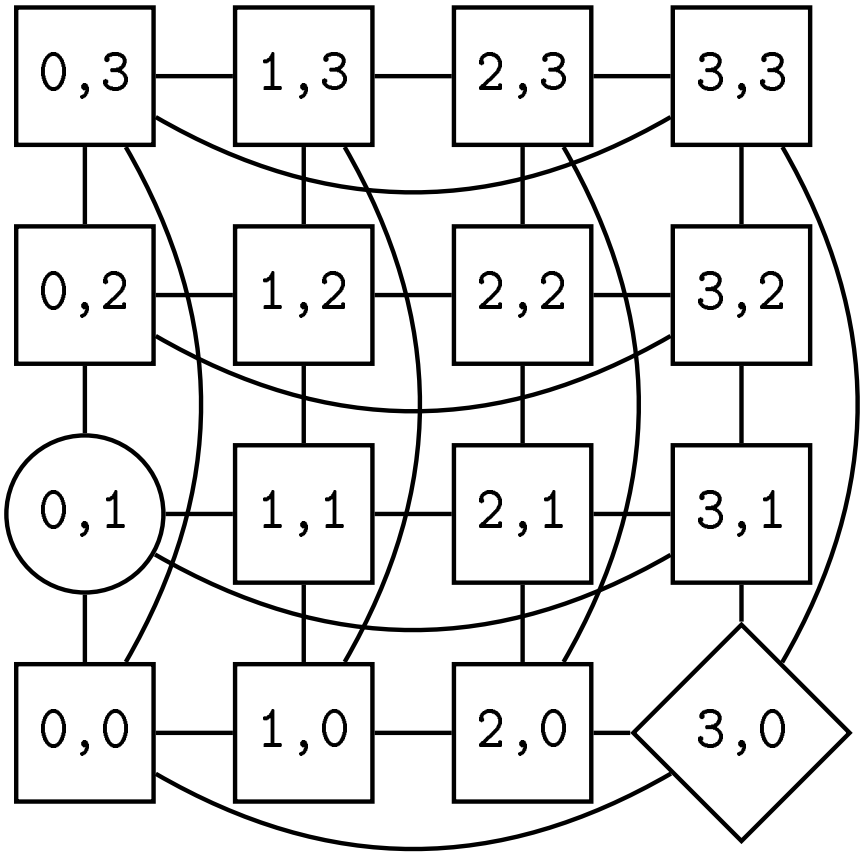

- N-dimensional grid with periodic boundaries connections
- Every node has $2N$ neighbours
- Good scalability
- Optimized for short ranged traffic

# Dragonfly




- Three layer hierarchical network: router, group e system
- $P_i$ end nodes
- $R_i$ routers in every group
- $h$ channel for inter groups communication
- $G_i$ groups in the system
- More complex scalability

# Examples of routing algorithms for tori



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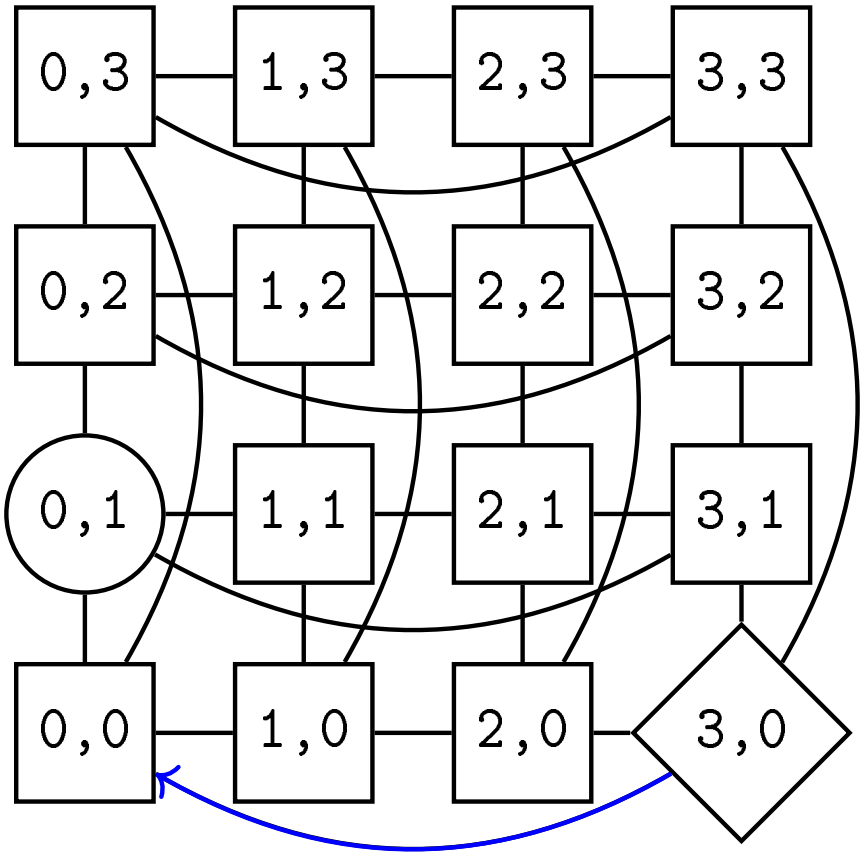


Minimal deterministic

e-cube

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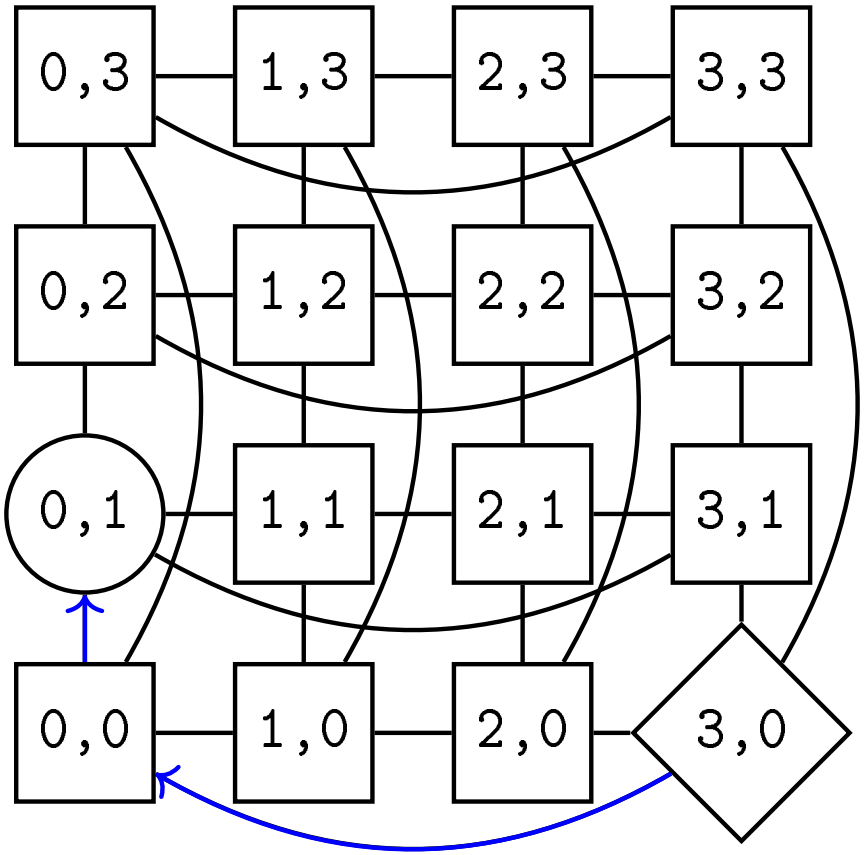


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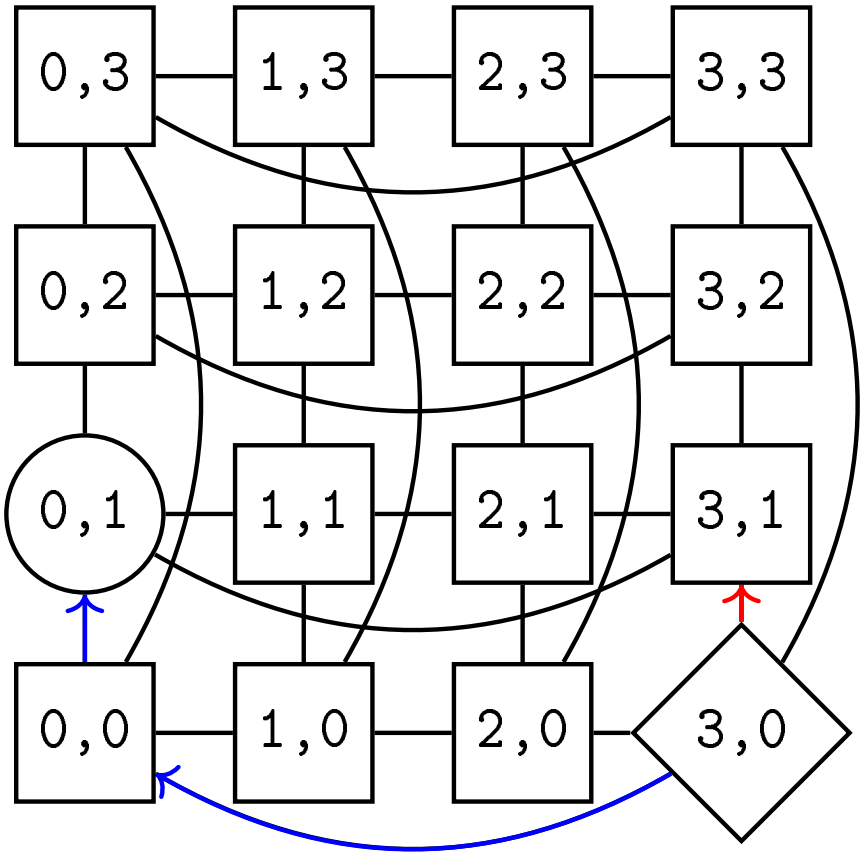


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e-cube

Minimal fully adaptive

star-channel

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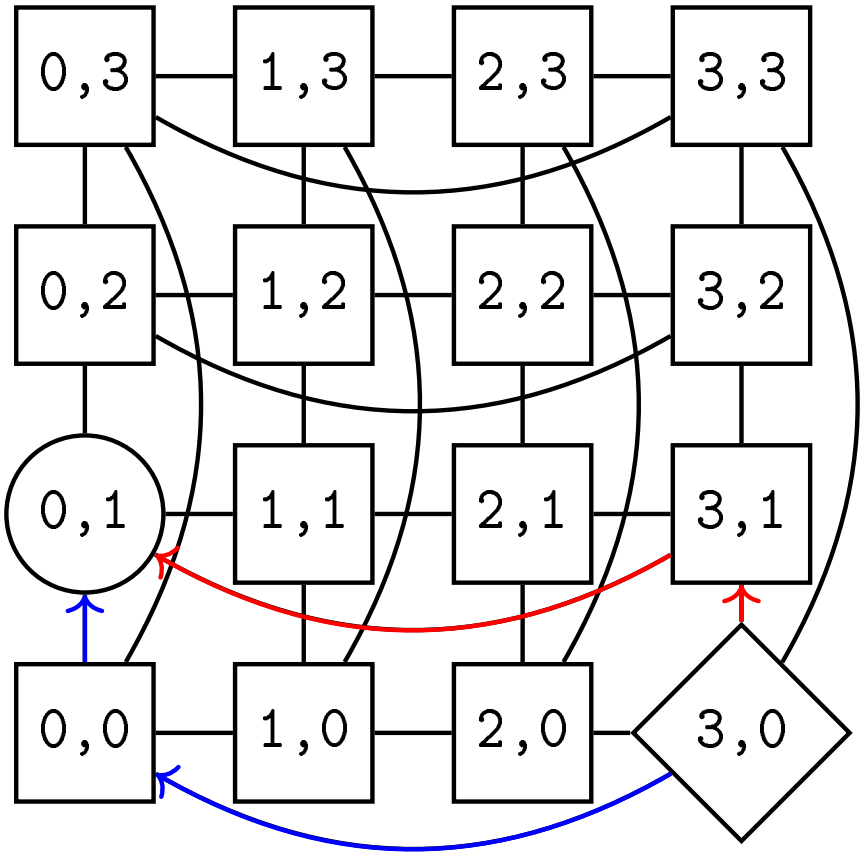


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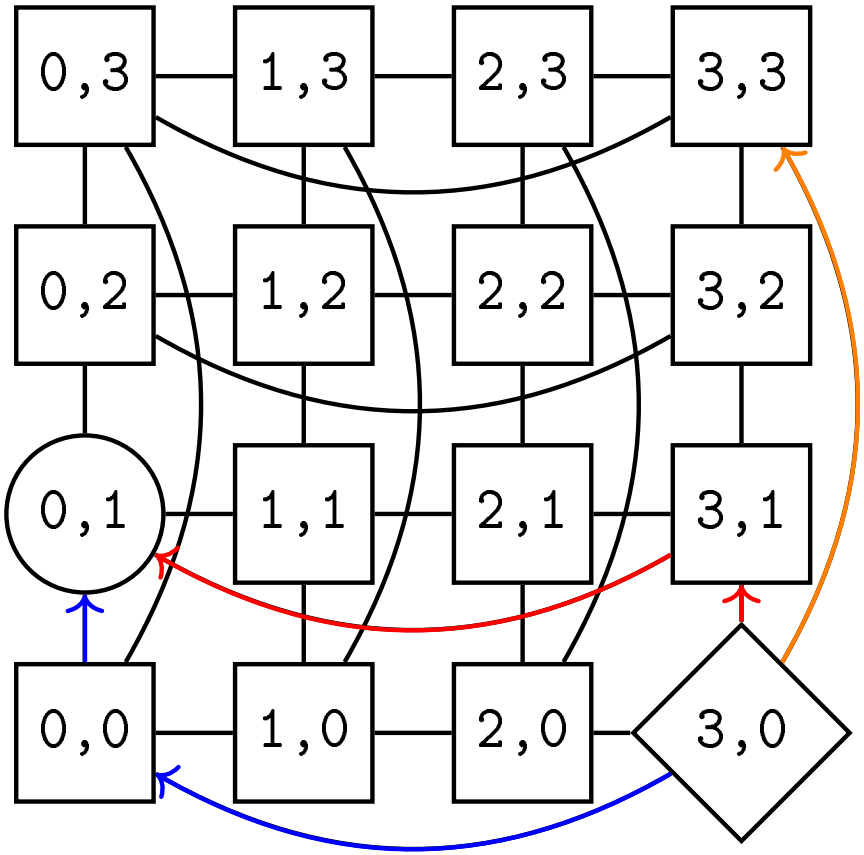


Minimal deterministic

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Minimal fully adaptive

star-channel

Non minimal partly adaptive

smart dimension-order

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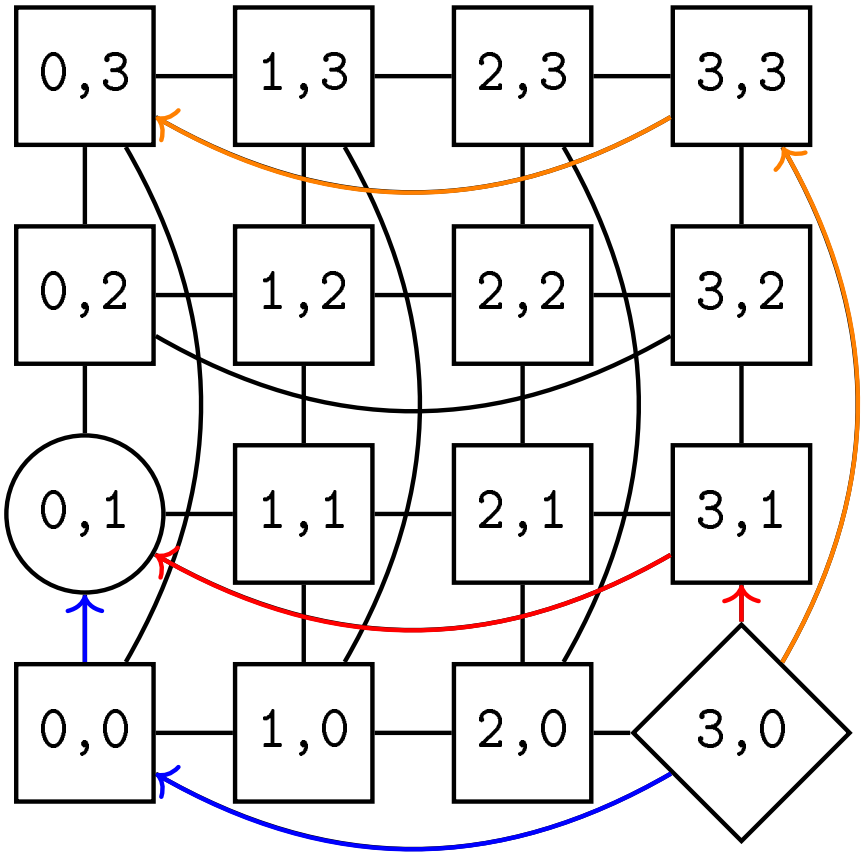


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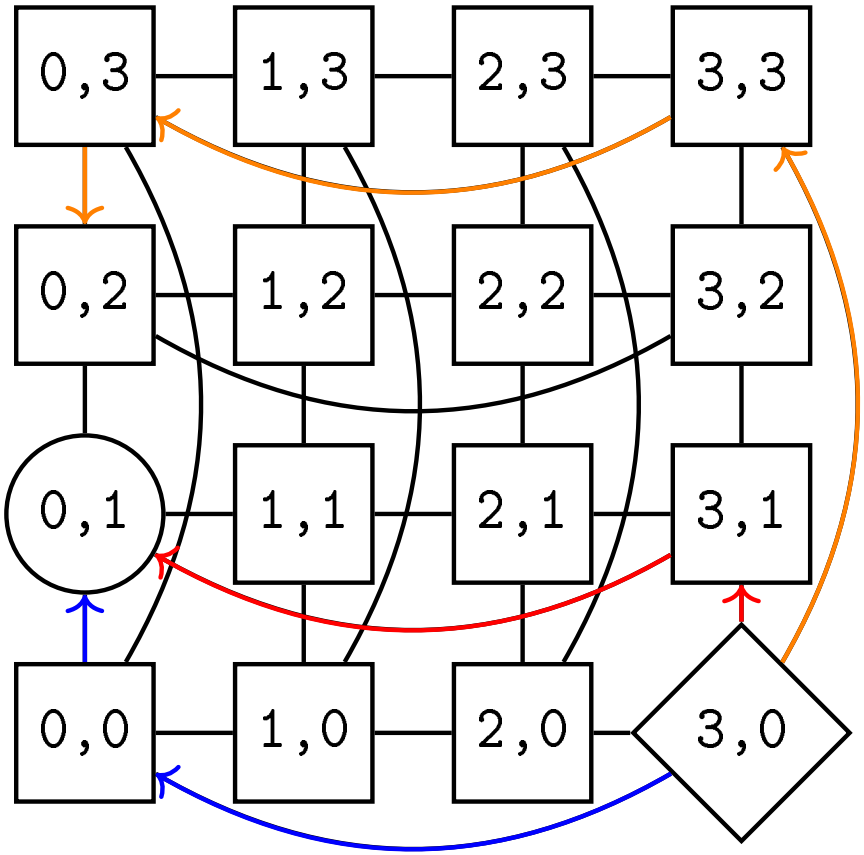


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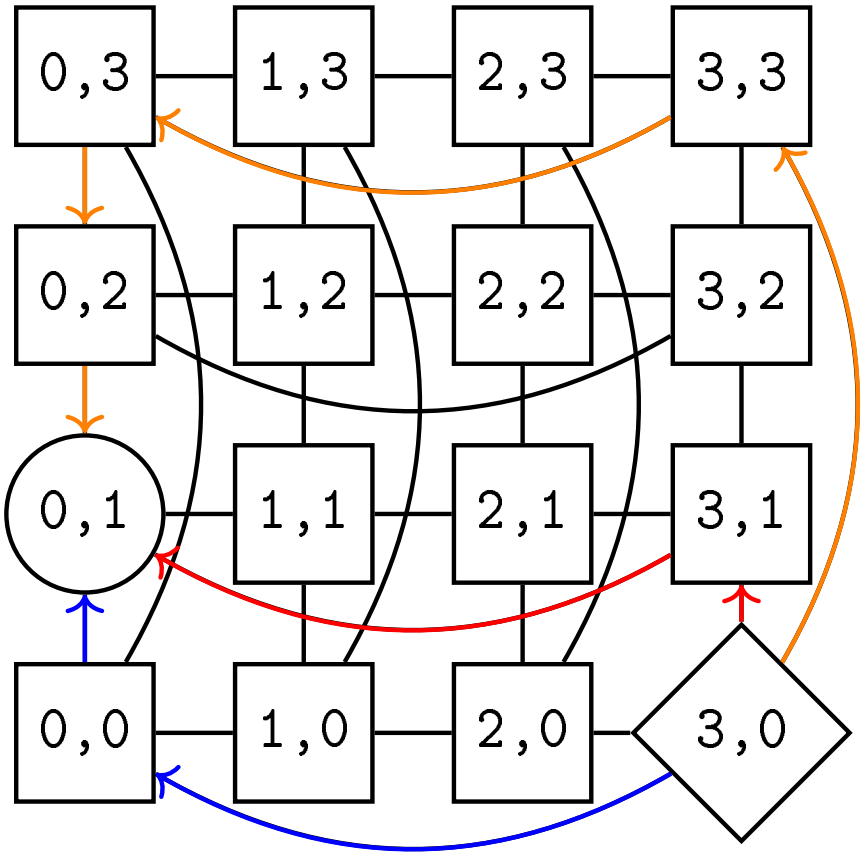


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# Random uniform traffic