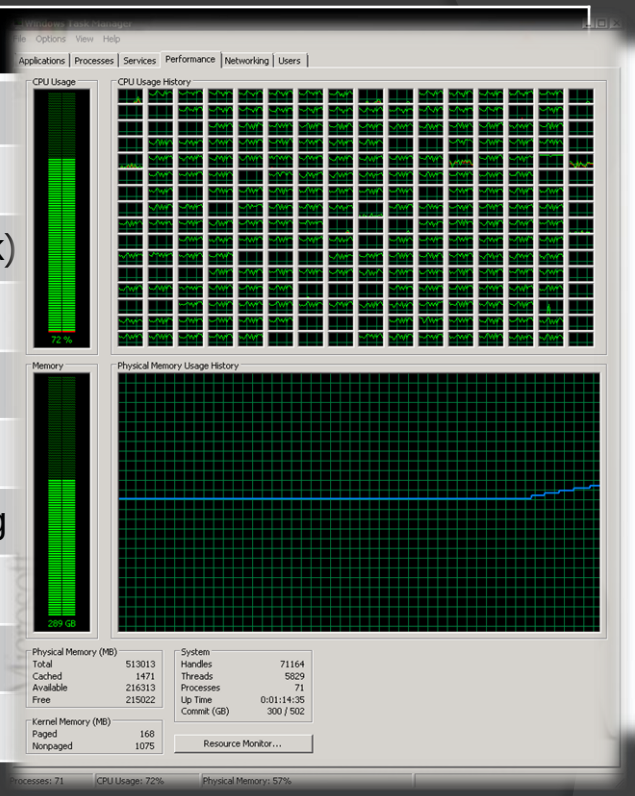
=tg= Thomas H. Grohser, bwin

How to gain performance on SQL server by making NUMA your friend

select * from =tg=

@@Version	Remark
SQL 4.21	First SQL Server ever used (1994)
SQL 6.0	First Log Shipping with failover
SQL 6.5	First SQL Server Cluster (NT4.0 + Wolfpack)
SQL 7.0	2+ billion rows / month in a single Table
SQL 2000	938 days with 100% availability
SQL 2000 IA64	First SQL Server on Itanium IA64
SQL 2005 IA64	First OLTP long distance database mirroring
SQL 2008 IA64	First Replication into mirrored databases
SQL 2008R2 IA64	First 256 CPUs & >500.000 STMT/sec
SQL 11	Can't wait to push the limits even further



Focus on SQL Server Infrastructure Architecture and Implementation
Close Relationship with Microsoft
- SQLCAT (SQL Server Customer Advisory Team)
- SCAN (SQL Server Customer Advisory Network)
- TAP (Technology Adoption Program SQL2008R2 and SQL11)

Close relationship with Hardware Vendors (Focus IA64)
Active PASS member and PASS Summit Speaker

PASS PROFESSIONAL ASSOCIATION FOR SQL SERVER
SQLCAT
intel inside ITANIUM

Agenda

- What is NUMA?
  - Why is Memory Important?
  - How does NUMA work
- How to Use It for SQL Server
  - Usage Examples
  - How to configure NUMA
  - How to avoid Context Switches
- Wrap Up
- Q&A
- Drinks and Food

What is NUMA?

- **N**one
- **U**niform
- **M**emory
- **A**ccess

- OK - but what the heck does that mean?

Why is Memory Important?

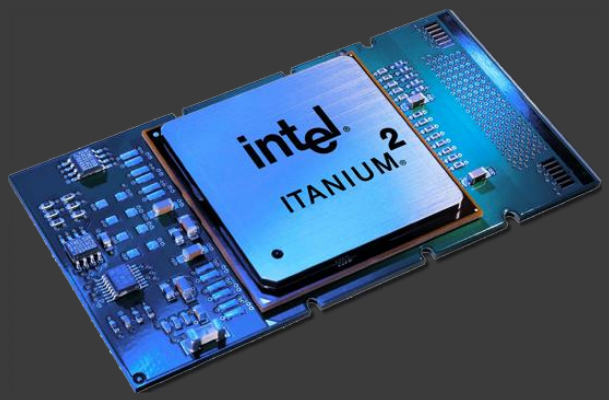
- Memory is fast
  - Disk access is measured in ms
  - Memory access in ns

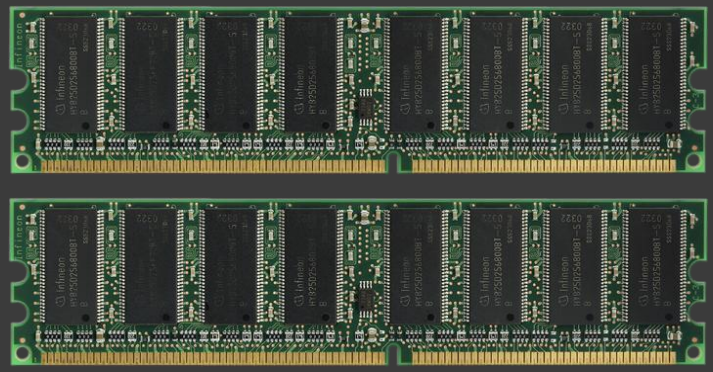
  - If snapping your finger once a second is memory access
  - Doing it every 11 days is disk access

Why is Memory Important?

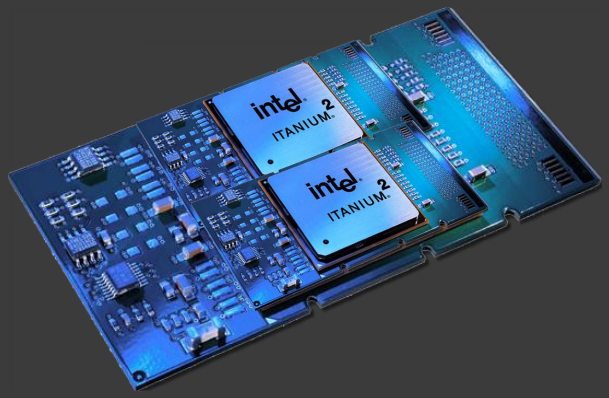
- SQL Server is a in memory database
- All Query Requests and DML statements and even all DLL statements work only on data in memory
- If data required for the operation is not in memory it is loaded from disk into memory first
- Data is written back to disk at a later time
- Only the transaction log is persisted immediately to disk

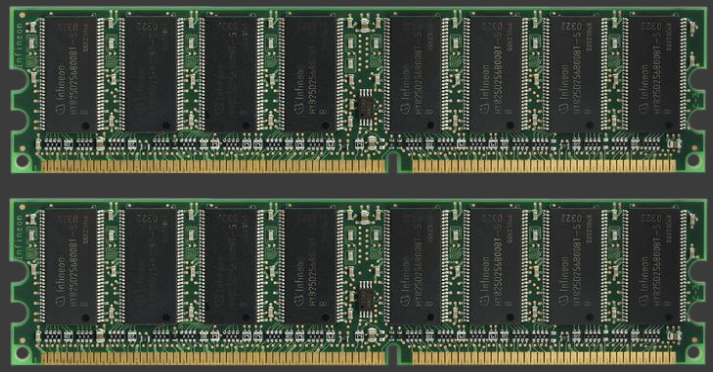
Single CPU



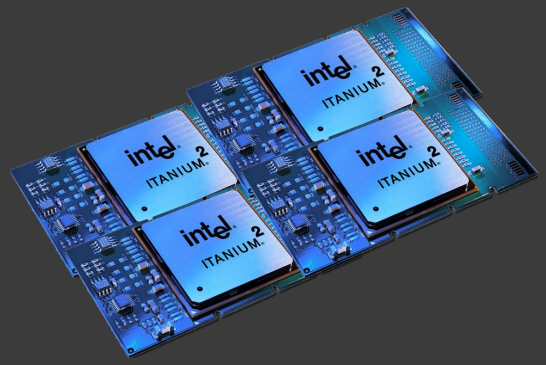


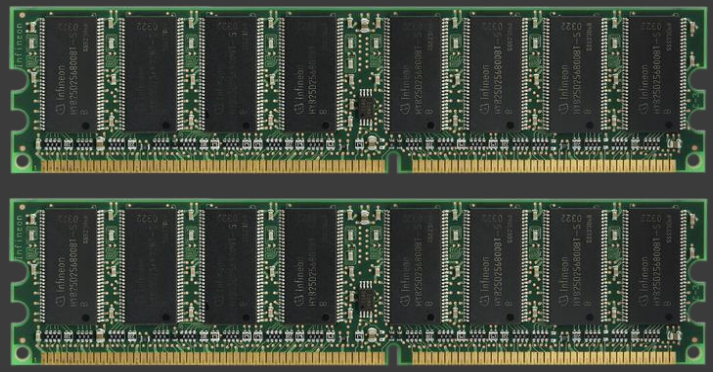
Single CPU / Dual Core



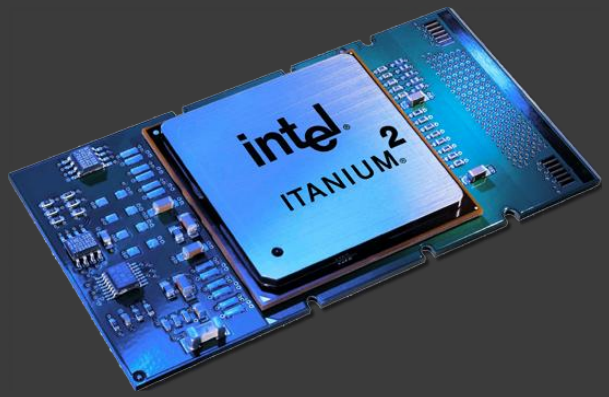


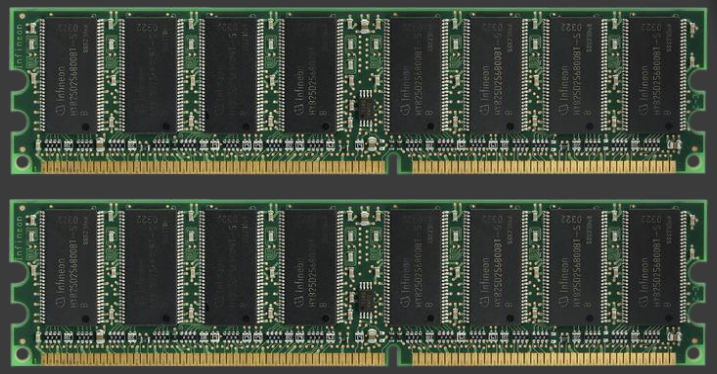
Single CPU / Multi Core

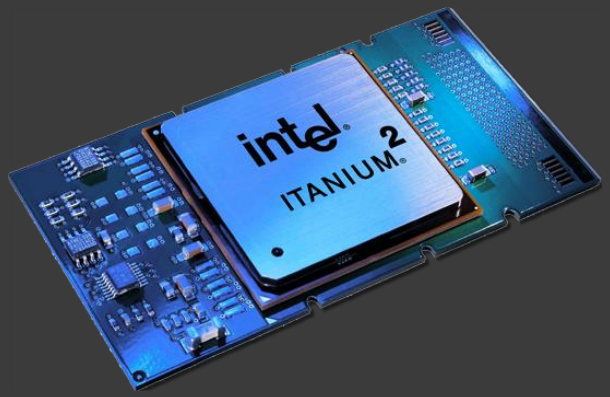




Dual CPU

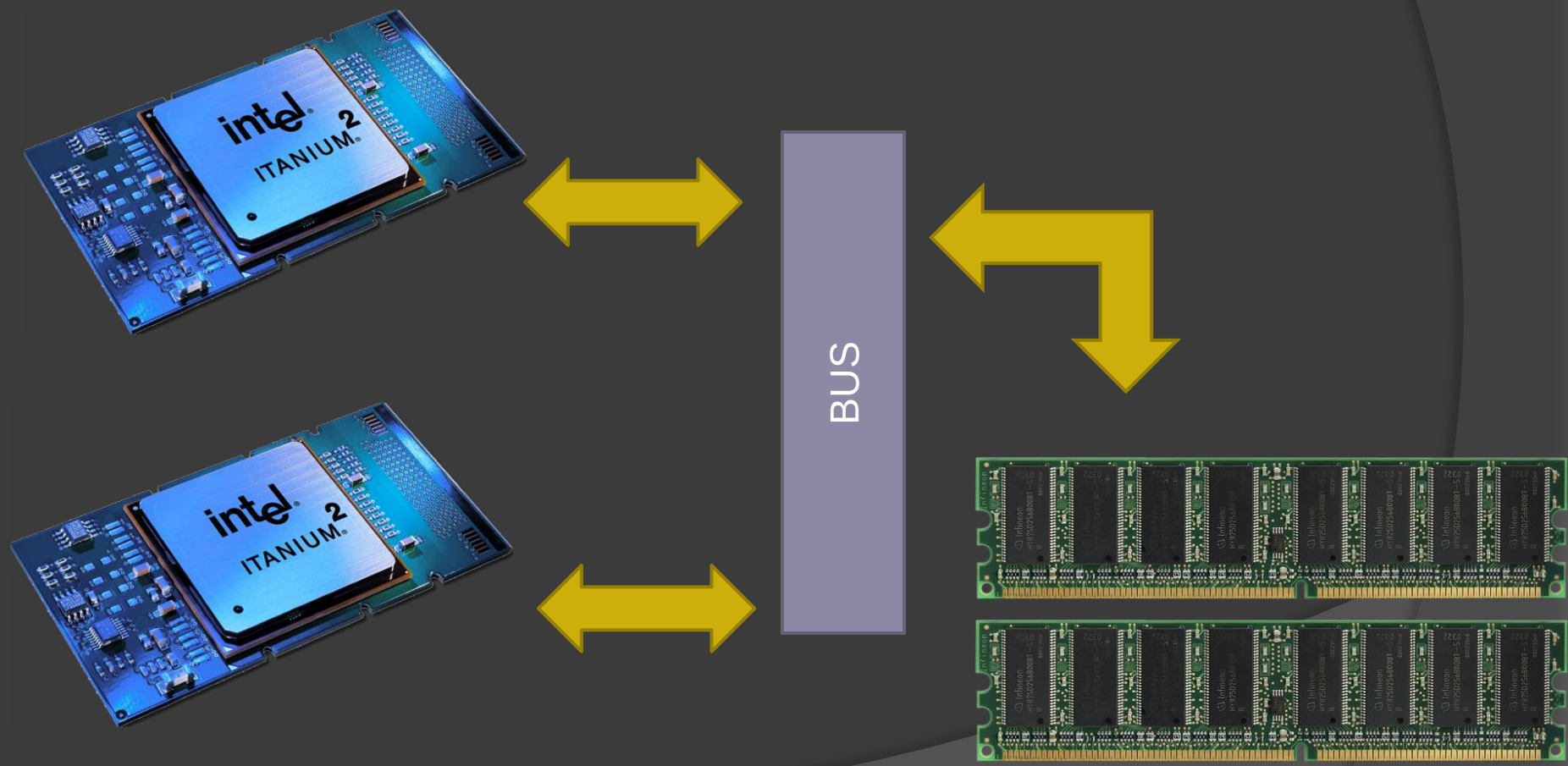




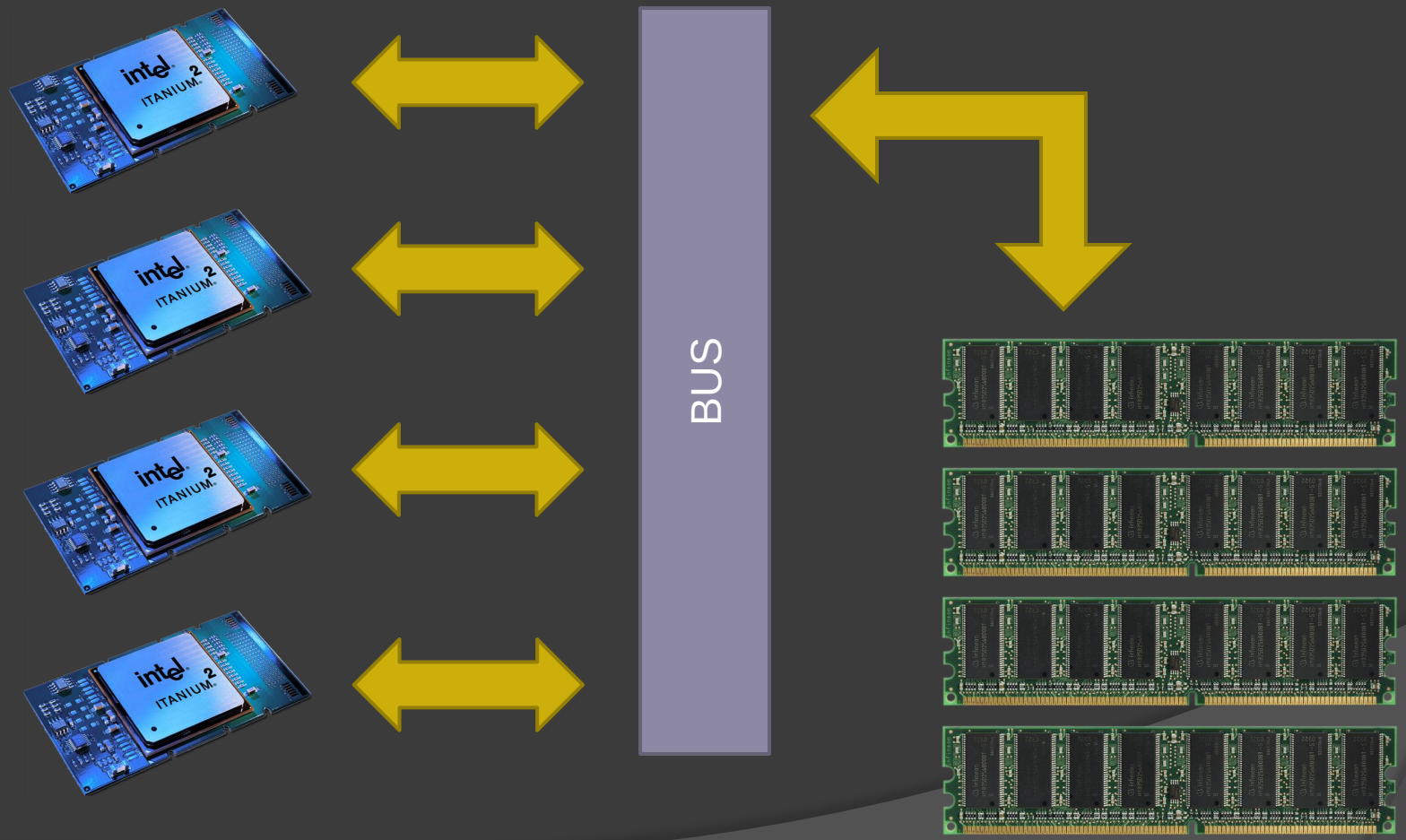


???

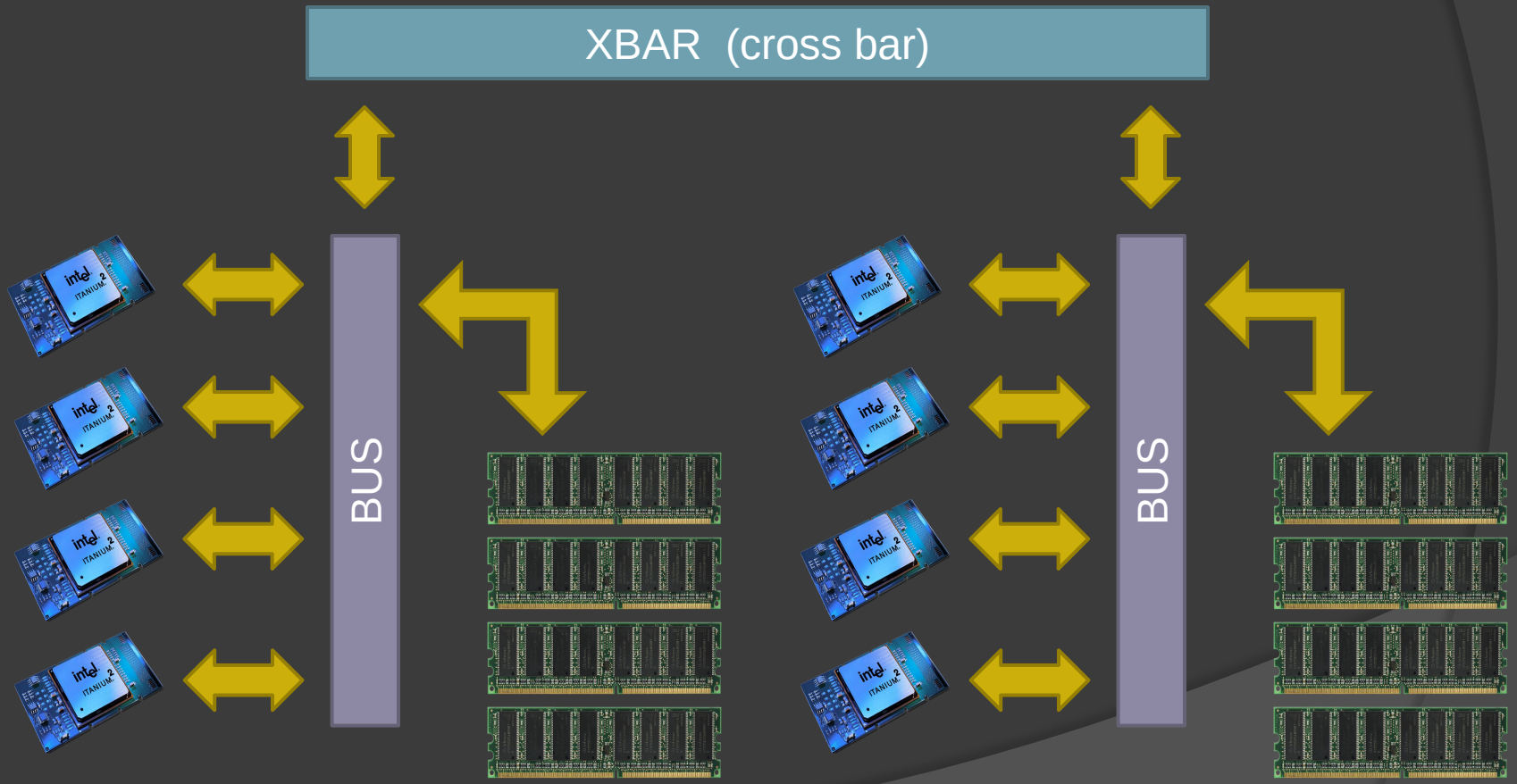
Dual CPU / Solution



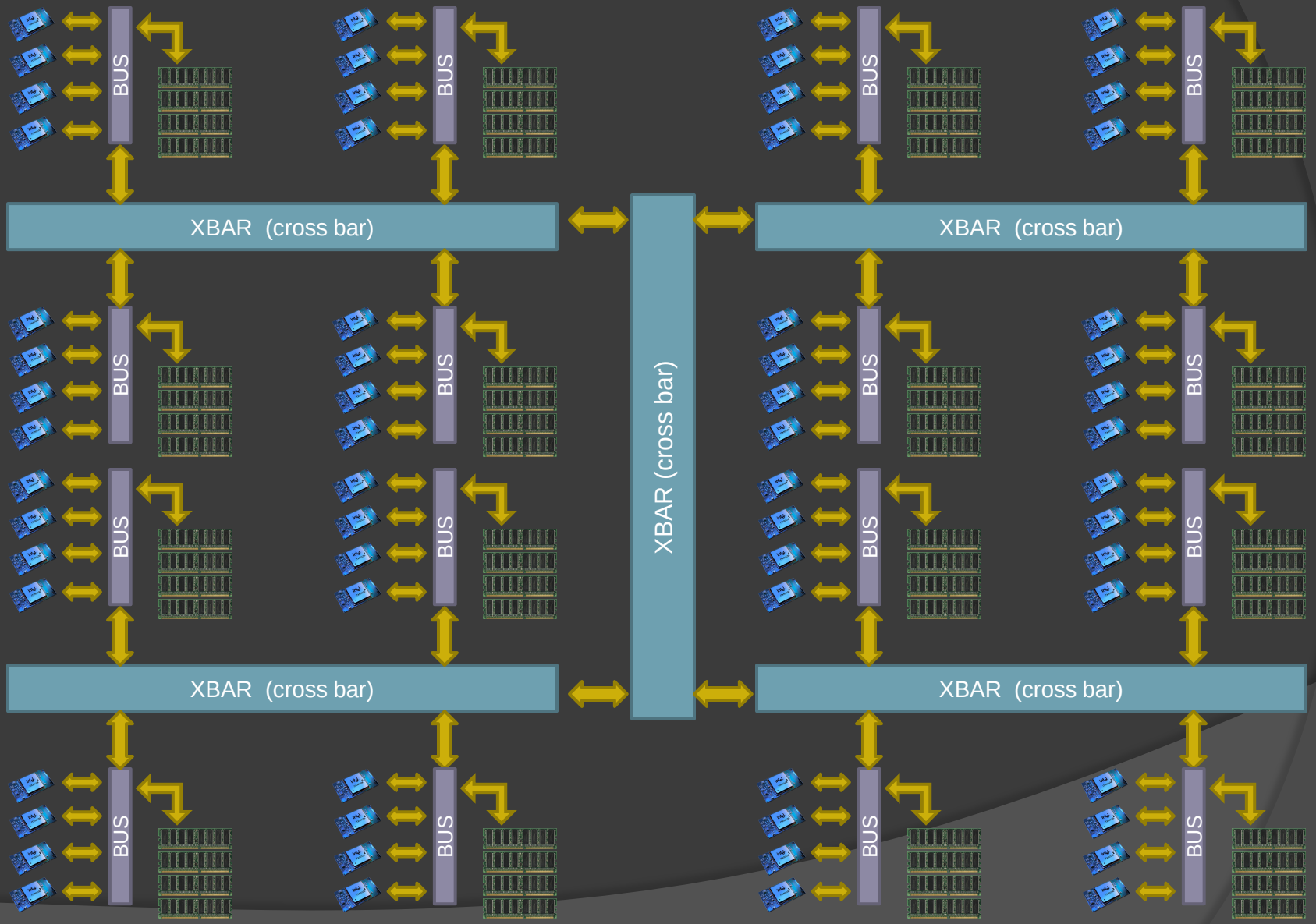
Quad CPU Solution



Octal CPU Solution



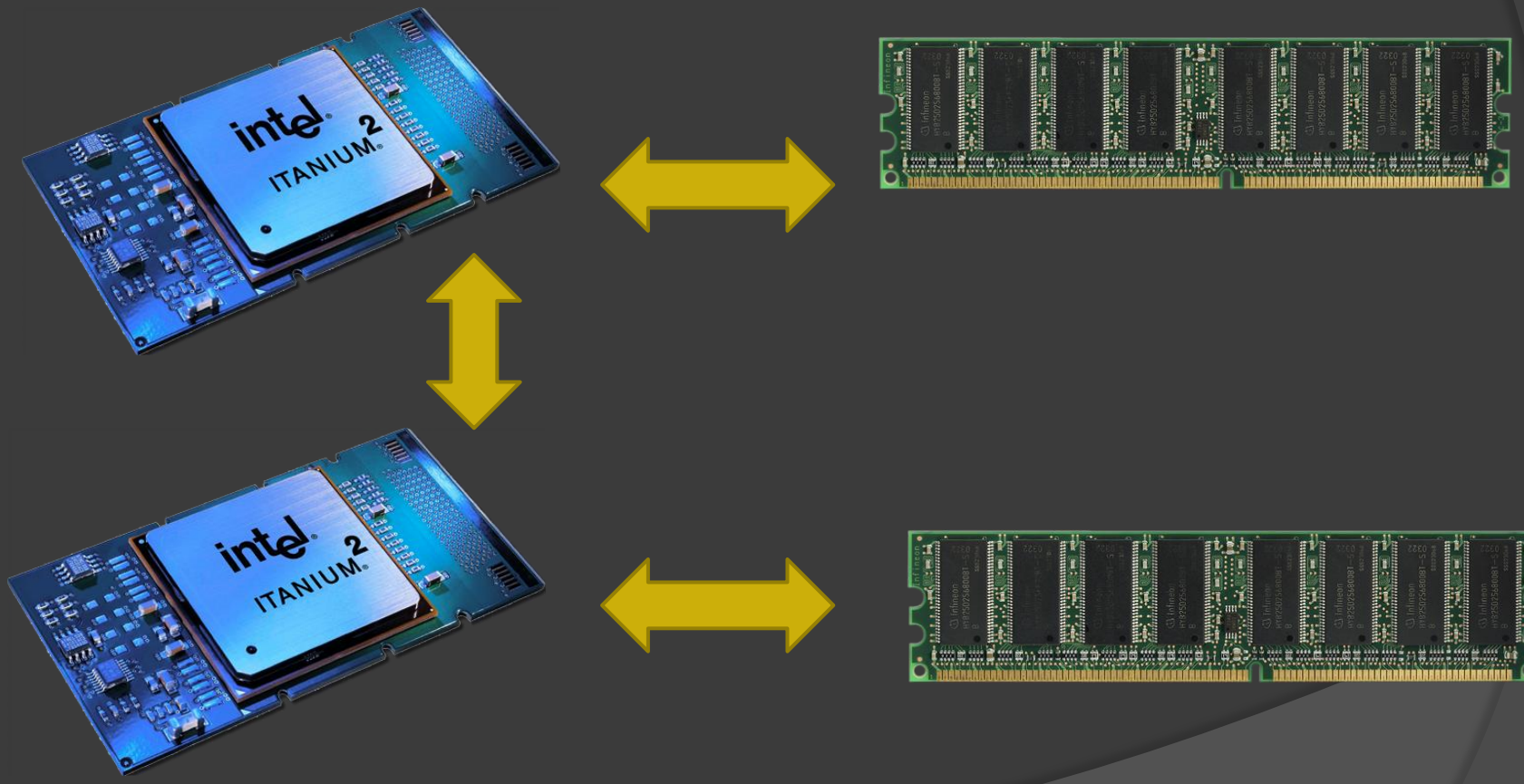
>8 CPU Solution



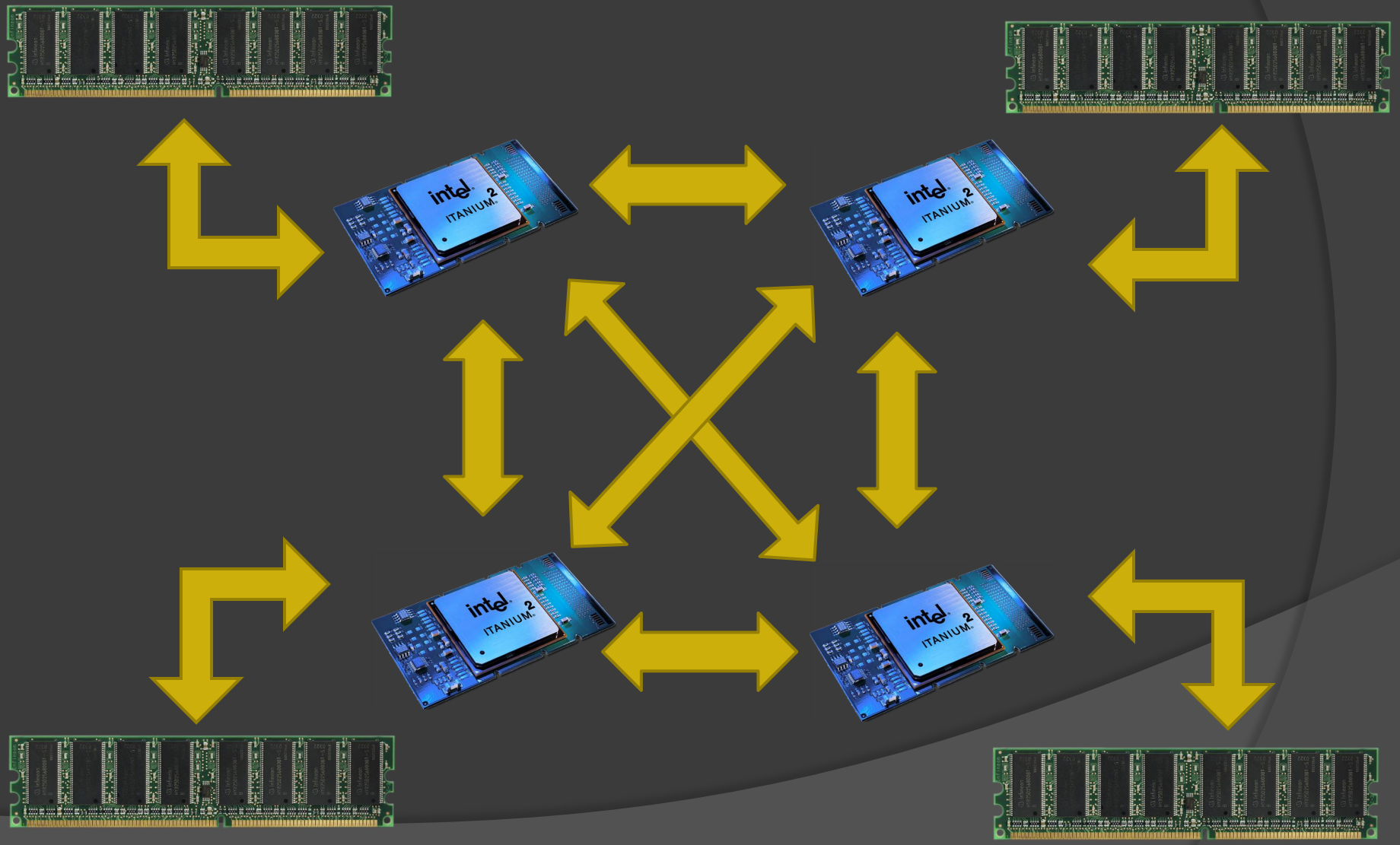
NUMA

- No longer a high end server feature
- Almost every >= 2 CPU server is now a NUMA system.

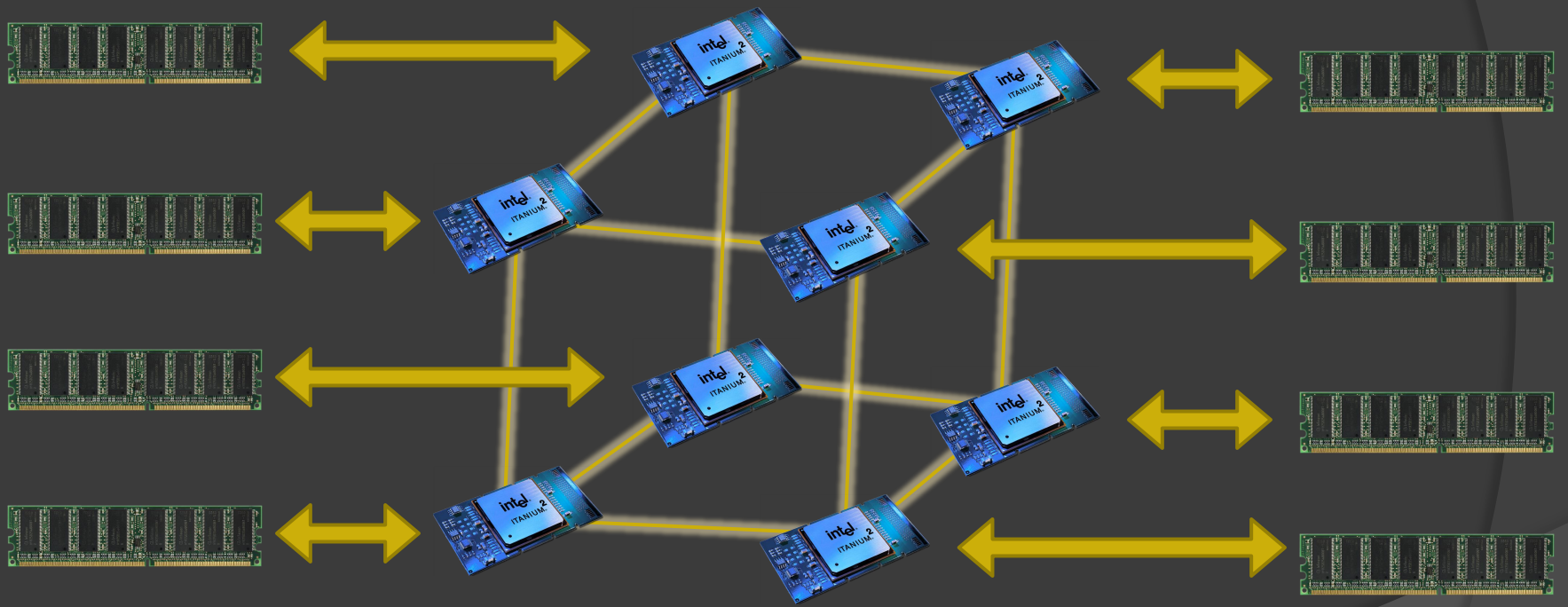
Dual CPU / Solution



Quad CPU Solution



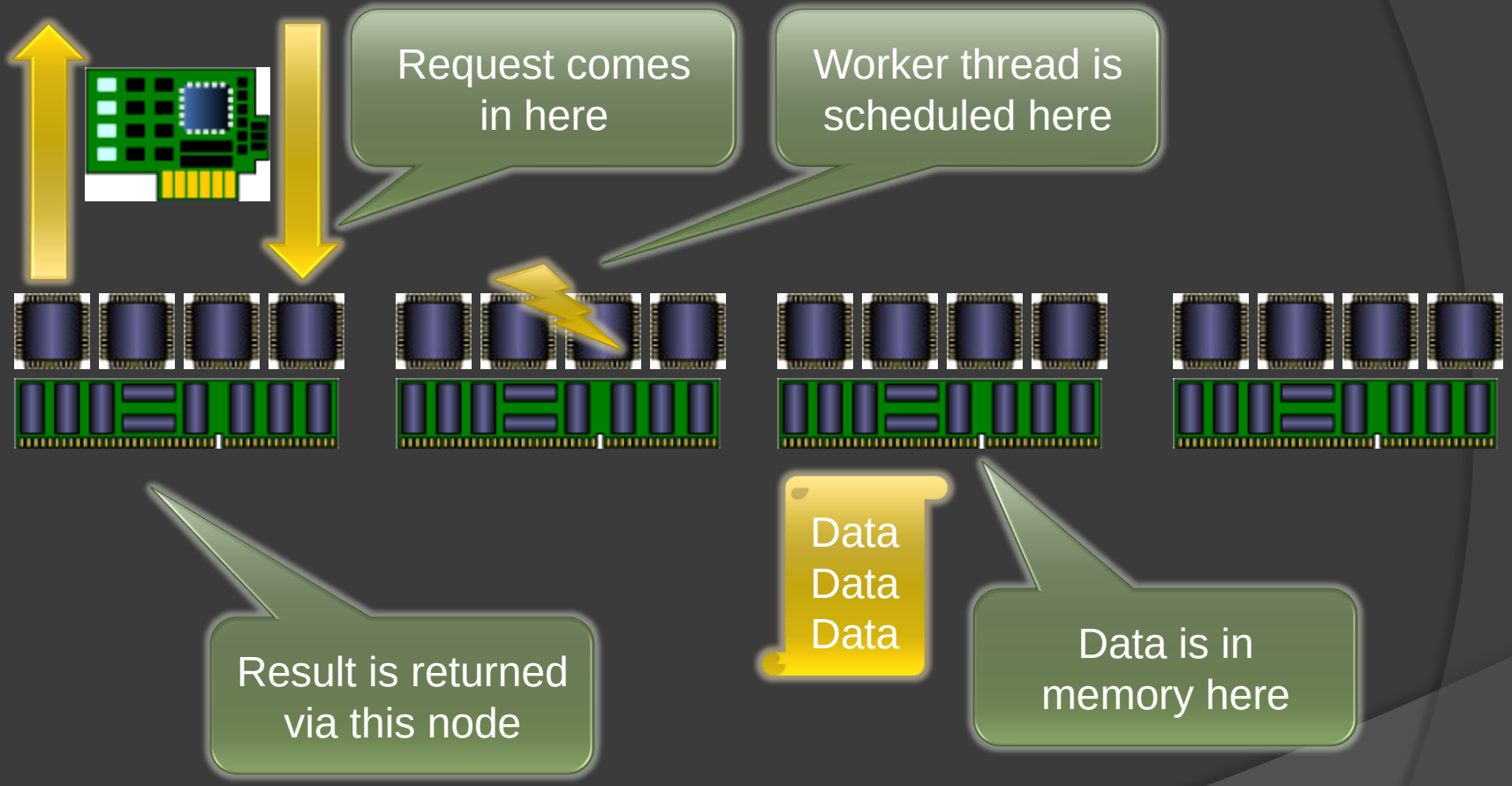
Octal CPU Solution



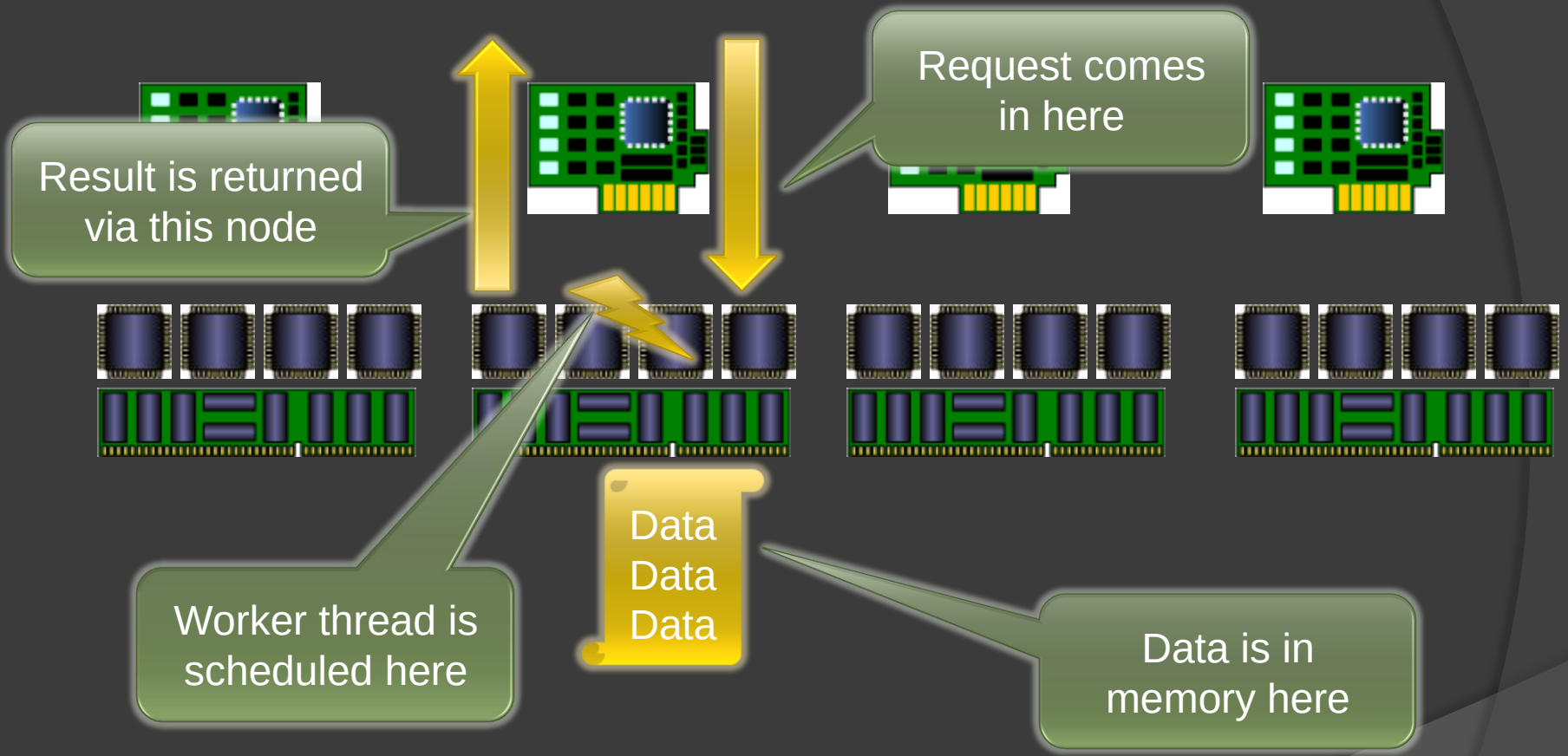
How To Use it for SQL Server

- How SQL Server uses Memory
  - Allocation from the Buffer Pool
  - Allocation from Server Memory
- How SQL Server uses Memory on a NUMA System
  - Allocation from the local Buffer Pool
  - Allocation from local NUMA Node memory

Not NUMA friendly



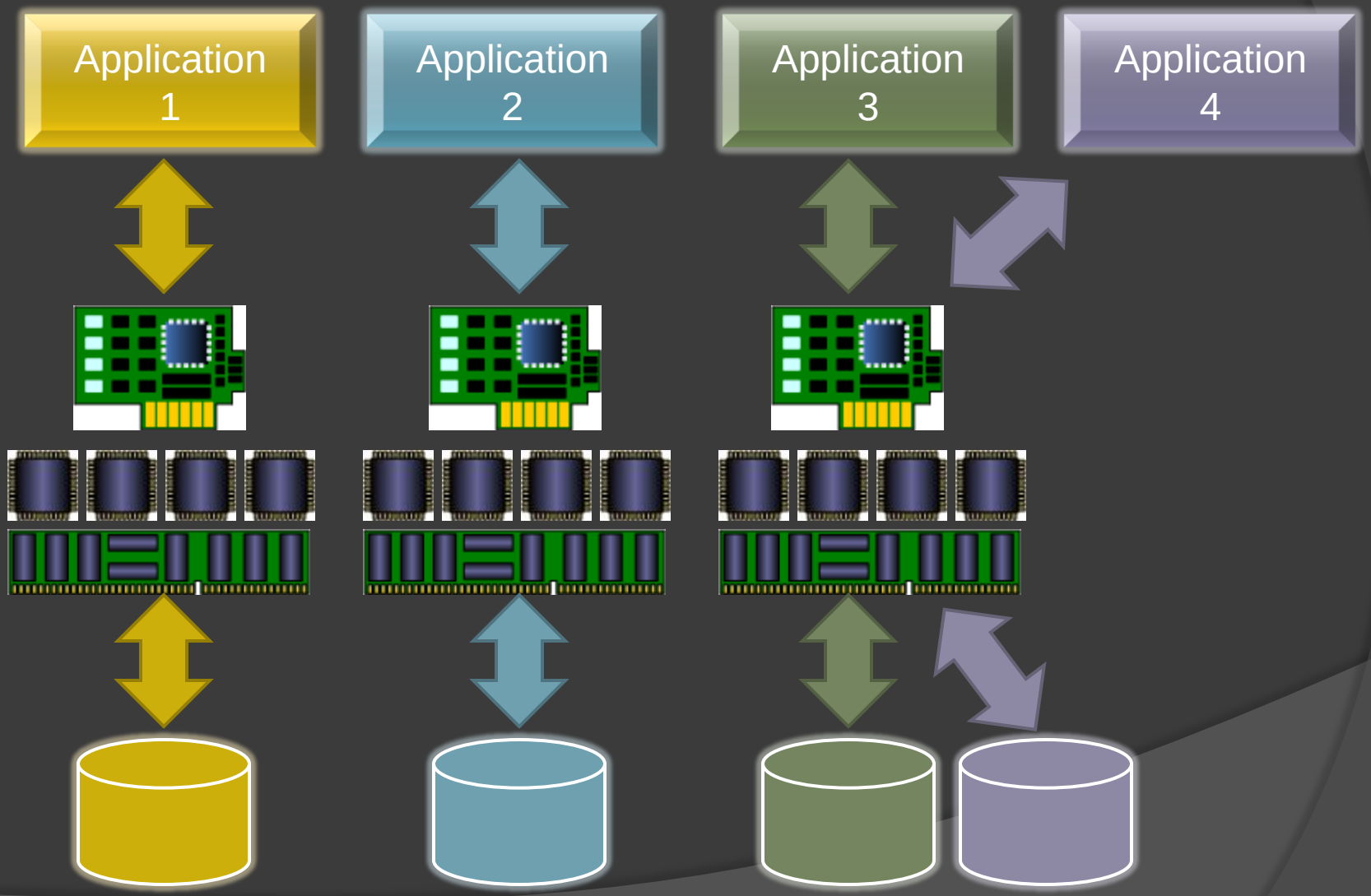
NUMA Friendly way



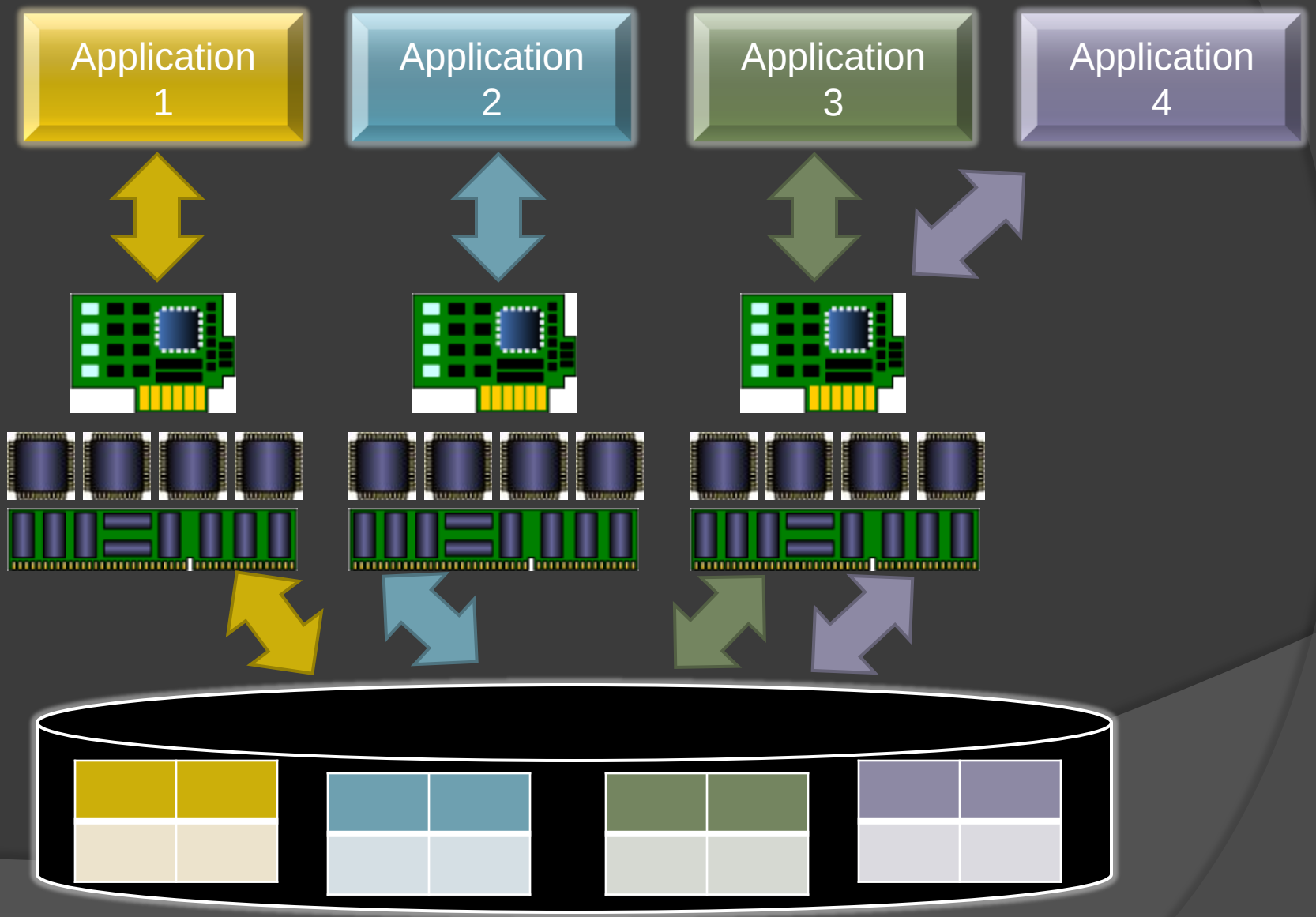
What is easy to affinitize

- Fully Transparent to the Application
  - Multiple databases on the same server used by different application
  - Same database but different applications accessing different parts of the database
- With Application Support
  - Partition the data within one application and process each partition on a separate node

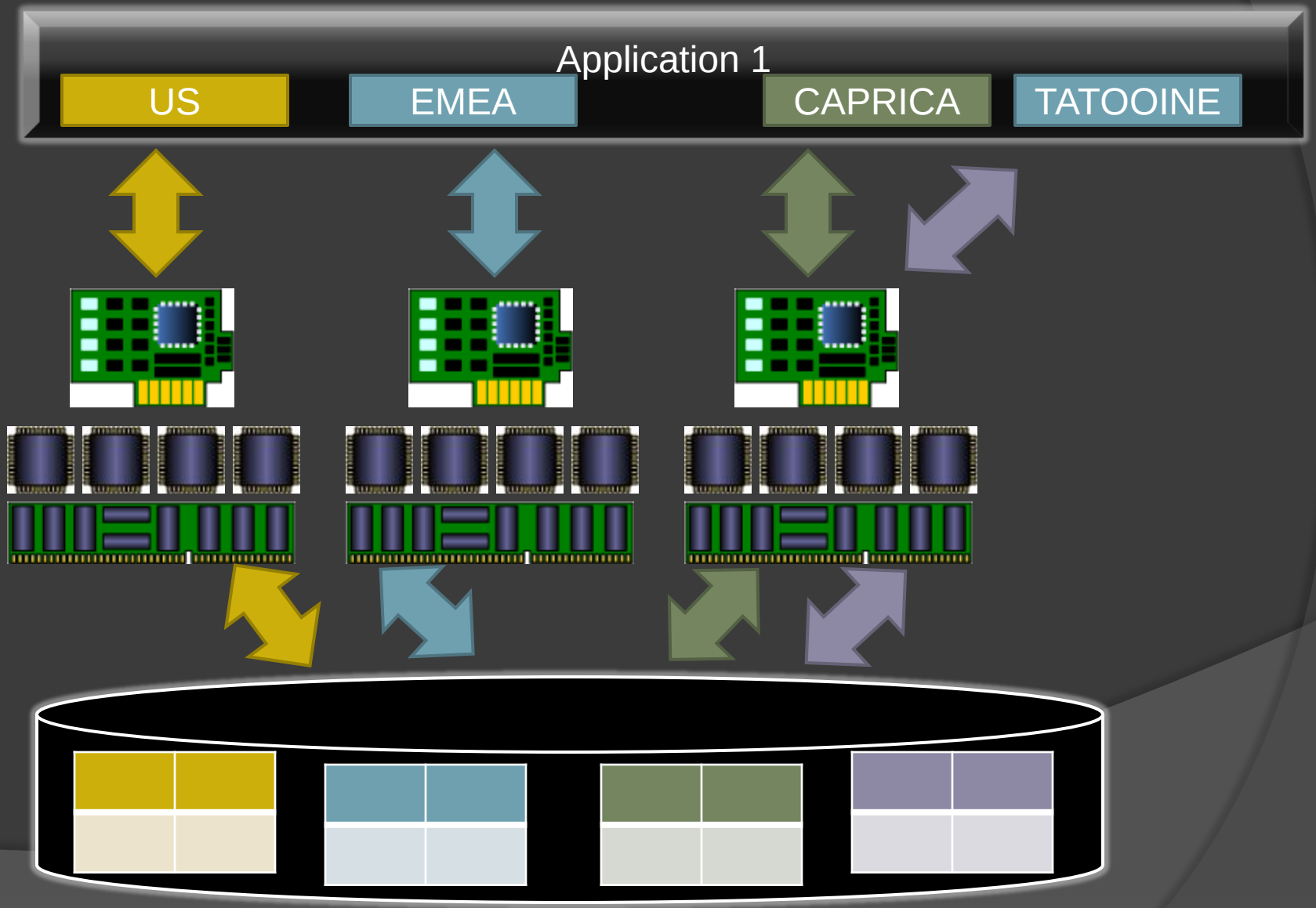
Multiple Databases and Applications



Same Database / Multiple Applications

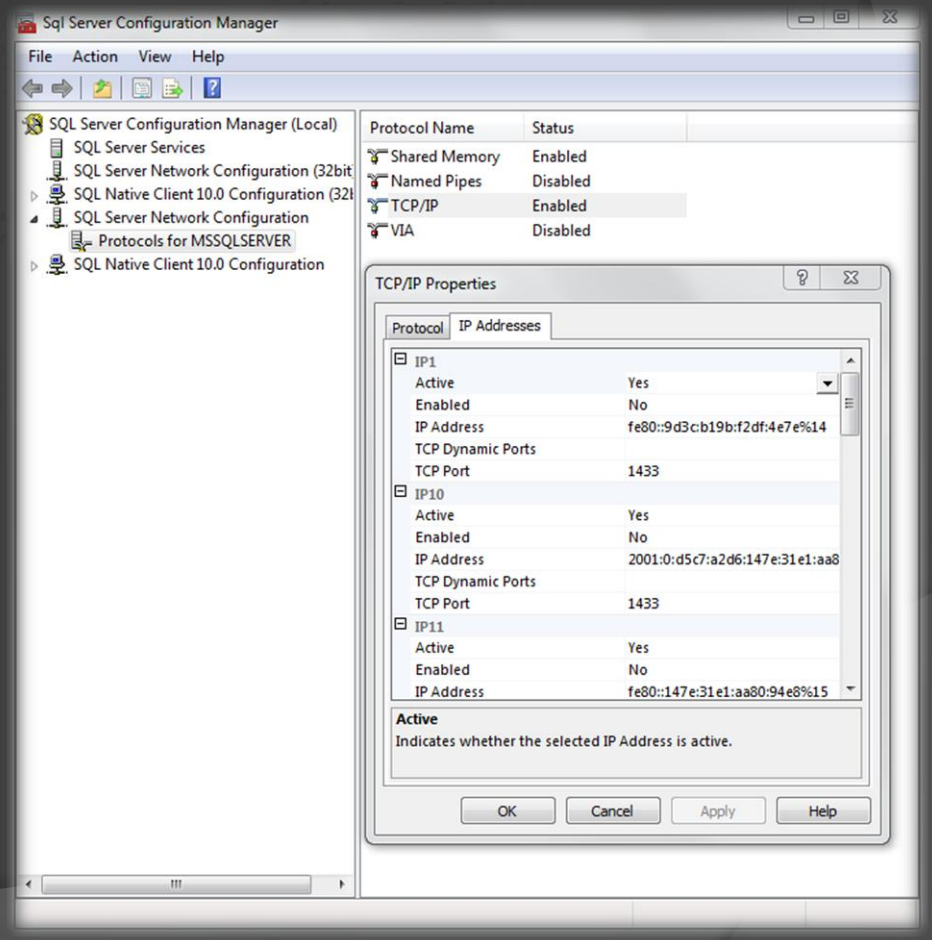


Same Database and Application



How to Affinitize

- You can map a NUMA node to an IP Address and Port



How to Affinitize

- <port number>[<affinity bit mask>]

- Single Port Examples
  - 1500[0x1] → NUMA Node 0
  - 1600[0x2] → NUMA Node 1
  - 1700[0x4] → NUMA Node 2
  - 1800[0x7] → NUMA Node 0,1,2

How to Affinitize

- You can also combine the settings
- 1500[0x1],1501[0x2],1502[0x3],1433[0xf]

  1433 uses all Nodes, while 1500 to 1502 use one node each

How to connect from an Application

string generalConnectionString =
“Server=MyServer;Database=MyDB;…”;

string node1ConnectionString =
“Server=MyServer,1500;Database=MyDB;…”

string node2ConnectionString =
“Server=MyServer,1501;Database=MyDB;…”

Good vs Bad Server design

- All I/O in one node

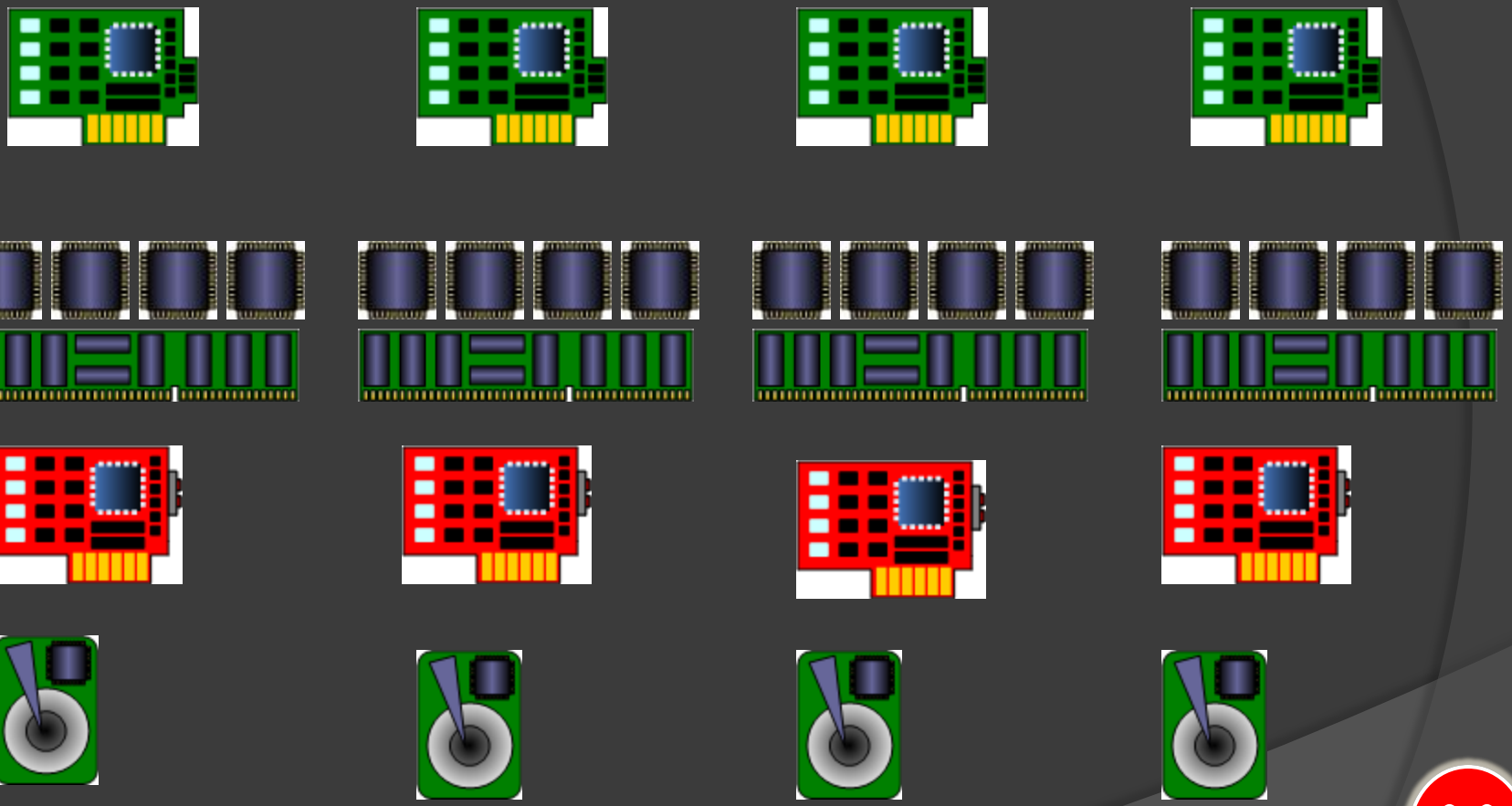
- Put OS Disks in the OS node
  - Node 0 on most systems, depends on CPU and Server manufacturer (on some system OS is in last node)

- Enable NUMA
  - Setting often called Interleaved memory On / Off
  - Tricky setting:

    On = NUMA OFF or Disabled

    Off = NUMA ON or Enabled (the good stuff)

Good vs Bad Server design



SQL Server Error log

- On a NUMA enabled system you will find the following entries in the error log

<date> <time> Server Node configuration:

node 0: CPU mask: 0x00000000000000**f0** Active CPU mask: 0x00000000000000**f0**
node 1: CPU mask: 0x00000000000000**0f** Active CPU mask: 0x00000000000000**0f**
node 2: CPU mask: 0x0000000000000f00 Active CPU mask: 0x0000000000000f00
node 3: CPU mask: 0x000000000000f000 Active CPU mask: 0x000000000000f000
node 4: CPU mask: 0x00000000000f0000 Active CPU mask: 0x00000000000f0000
node 5: CPU mask: 0x0000000000f00000 Active CPU mask: 0x0000000000f00000
node 6: CPU mask: 0x000000000f000000 Active CPU mask: 0x000000000f000000
node 7: CPU mask: 0x00000000f0000000 Active CPU mask: 0x00000000f0000000

This message provides a description of the NUMA configuration for this computer. This is an informational message only. No user action is required.

Avoiding Context Switches

```
exec sp_configure 'show advanced options', 1
reconfigure

exec sp_configure 'affinity mask', 0x0002
reconfigure
```

HEX Value is CPU mask; One bit per CPU

- Bit =1 CPU is used and a Worker Thread will not switch once started
- Bit = 0 CPU is not used
- All Bits = 0 (default) all CPU's are used but worker threads can switch from CPU to CPU
  (this costs time only good on mixed OLTP/DSS/BI systems)

Dedicating CPU's for I/O

- exec sp_configure 'affinity I/O mask', 0x0002

- If a CPU is dedicated to I/O corresponding bits in the affinity mask must be 0

Affinity Mask	0	0	1	1
Affinity I/O Mask	0	1	0	1

>32 CPUs

For the CPUs 33 to 64 there is a second pair of configuration values:

```
exec sp_configure 'affinity64 mask', 0x0000
exec sp_configure 'affinity64 I/O mask', 0x0000
```

>64 CPU's: Windows 2008 R2 and SQL Server 2008 R2

- Unisys ES7000 96 Cores Xeon
- HP Superdome 128/256 Cores Itanium
- More CPU's and cores to come in the future

ALTER SERVER CONFIGURATION

SET PROCESS AFFINITY

CPU = { AUTO | <range_spec> } |
NUMANODE = <range_spec>

>64 CPU's: Windows 2008 R2 and SQL Server 2008 R2

```
ALTER SERVER CONFIGURATION SET PROCESS
    AFFINITY CPU = AUTO

ALTER SERVER CONFIGURATION SET PROCESS
    AFFINITY CPU = 0

ALTER SERVER CONFIGURATION SET PROCESS
    AFFINITY CPU = 2 to 8

ALTER SERVER CONFIGURATION SET PROCESS
    AFFINITY CPU = 2 to 8, 12 to 100, 107

ALTER SERVER CONFIGURATION SET PROCESS
    AFFINITY  NUMANODE = 0, 2 TO 4, 7, 8
```

Side effect: Save licensing costs

- You have a lot of CPU's its very likely that one or more CPU for I/O might make sense
- Example 32 CPU's and we dedicate one per NUMA node for I/O

```
exec sp_configure 'affinity mask', 0x7777777
exec sp_configure 'affinity I/O mask', 0x8888888
```

→ Only 24 CPU licenses are required for SQL Server

Wrap Up

- NUMA has arrived or will arrive at your datacenter soon
- NUMA makes local memory access faster not remote memory access slower, without NUMA all memory access would be like remote!
- Make NUMA your friend by actively supporting it

Thank you!

Questions ?

Email: tg@grohser.com