HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

Lecture 2

Bus (*Väylä*)

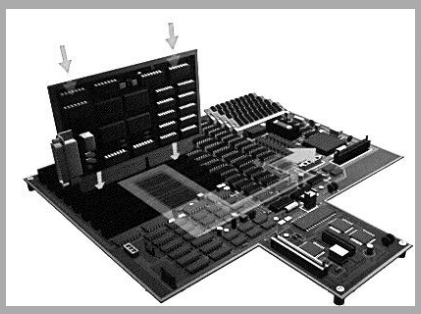
Stallings: Ch 3

What moves on Bus?

Bus characteristics

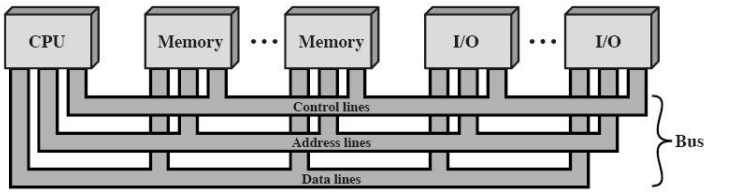
PCI-bus

PCI Express



Bus

(Sta06 Fig 3.16)



- For communication with and between devices
- Broadcast (*yleislähetys*): most common
  - Everybody hear everything
  - React to messages/signals to itself only
- Each device has its own control and status information
  - Device driver (OS) moves control data to device controller's registers
    - ~ memory address, device address, how much, direction
  - Device driver reads the status from the controller's status register
    - Ready? Operation successful? …

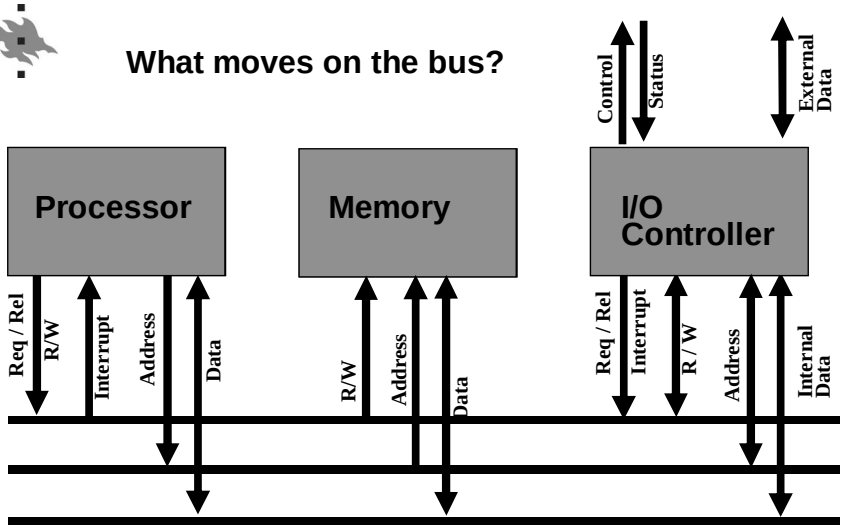
Bus structure

- Control lines (*Ohjausväylä (~ johtimet)*)
  - Control and timing information
    - Operations: like memory read, memory write, I/O read
    - Interrupt request
    - Clock
- Address lines (*Osoiteväylä*)
  - Source and destination ids
    - Memory address, device address (module, port)
    - For transfer source and destination
  - Width (number of parallel lines) determines the memory addresses space (*osoiteavaruuden koko*)
    - For example: 32 b ⇨ 4 GB

Bus structure

- Data lines (*Dataväylä*)
  - All processing information:
    - Instructions
    - Data
    - DMA –transfer contents
  - Width determines the maximum number of bits that can be transfered at the same time
    - For example 38b wide line allows 32b dataa plus 6 Hamming-coded parity bits (*tarkistusbitti)*

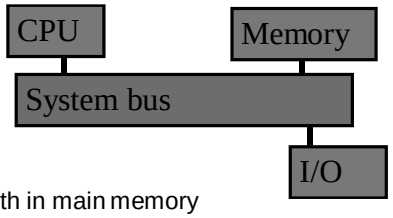
What moves on the bus?



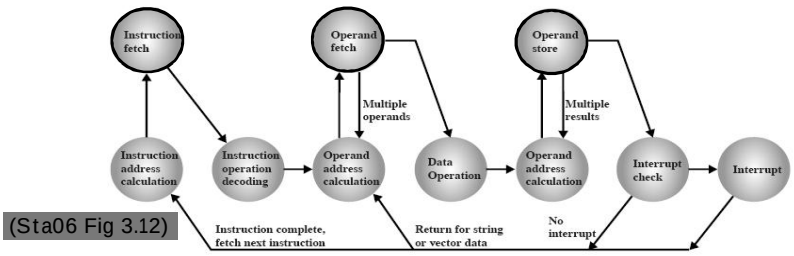
- Timing

- Memory-mapped I/O
- DMA

Bus = Bottleneck?



- von Neumann architecture
  - Instructions and the data both in main memory
  - All memory content referred using address
  - Sequentially ordered instructions executed sequentially
  - unless order changed explicitly (jumps)
- Fetch-Execute Cycle



(Sta06 Fig 3.12)

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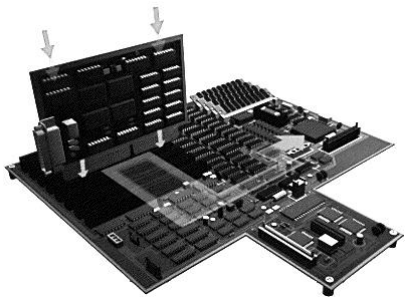
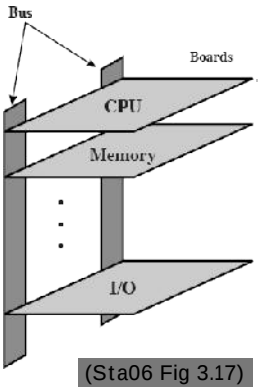


Bus characteristics

Bus characteristics

- Width
  - ~ 50 – 100 lines (*johdinta*) – mother board, cable, connectors
- Bus type
  - Dedicated, non-multiplexed (*dedikoitu*)
    - Address and data – separate lines
  - Time multiplexed (*aikavuoroteltu*)
    - Address and data share lines
    - Address valid / data valid -line
- Arbitration (*käyttövuoron varaus*)
  - Centralized
    - One bus controller, arbiter (*väyläohjain*)
  - Distributed
    - Controllers have necessary logic



(Sta06 Fig 3.17)

Bus characteristics

- Timing (*ajoitus*, tahdistus)
  - Synchronous (*tahdistettu)*
    - Regular clock cycle (*kellopulssi)* – sequence of 0s and 1s
  - Asynchronous
    - Separate signals when needed
  - Shared traffic rules

    everyone knows what is going to happen next
- Efficiency (*tehokkuus*)
  - Bandwidth (k*aistanleveys*)
    - How many bits per second

Synchronous timing

- Based on clock
  - Control line has clock pulse (cycle 1-0)
  - All devices ”hear” the same pulse
- Event takes one cycle (commonly)
  - Start at the begin of the cycle (leading edge)
  - For example, reading data takes one cycle
- All devices in the bus work at the same pace
  - Slowest determines the speed of all
  - Each device knows the speed of the others
  - ⇨ knows, when it is ready for next event
- “Do this during the next cycle”

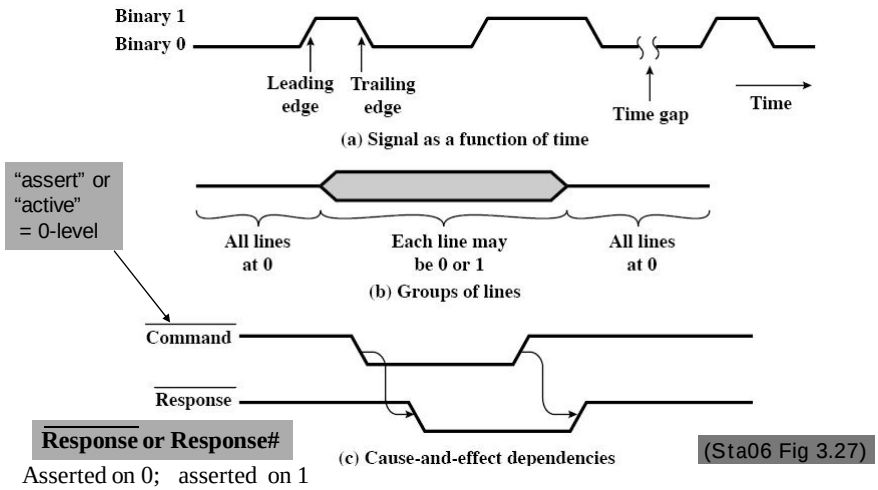
  ⇨ Device can count on the other one to do it!

Asynchronous timing

- Devices can use arbitrary speeds (variation allowed)
  - Processing time depends on the device
  - Device can determine, when the other one is ready
    - How long is the event going to last to perform?
- Synchronization using a special signal
  - Send synchronization signal, when work done and ready
    - Address and data on bus ⇨ send signal ”write”
      (for example: change ”write”-line to 1)
    - Data stored to memory ⇨ send signal ”ack”
  - Time of the next event depends on the finish of the previous
- ”Do this when you have time, inform me when ready”

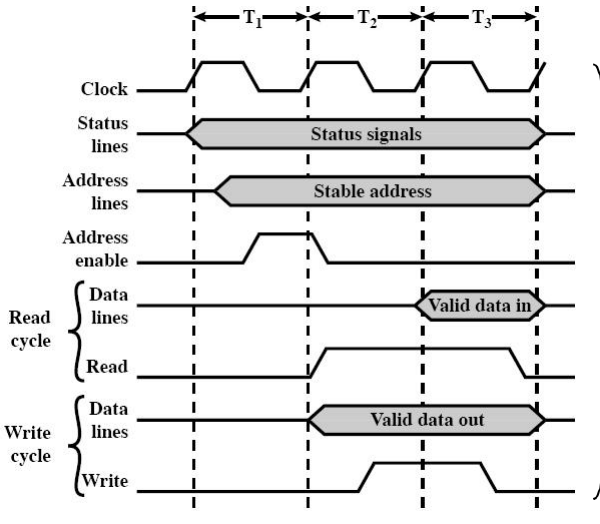
Timing diagrams (*ajoituskaavio*)

- See Appendix 3a [Sta06, Ch 3]



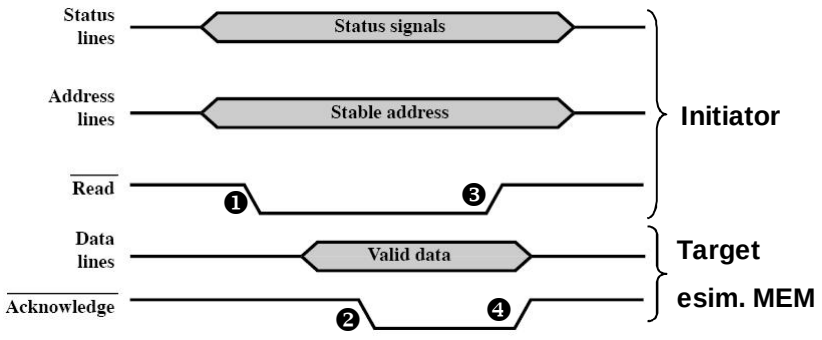
(Sta06 Fig 3.27)

Synchronous timing



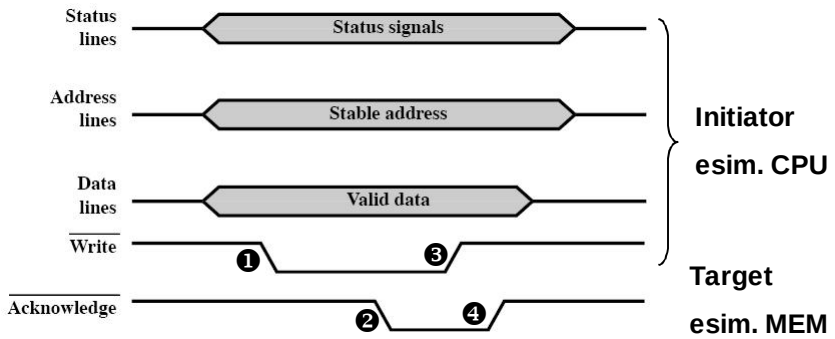
(Sta06 Fig 3.19)

Asynchronous timing - Read



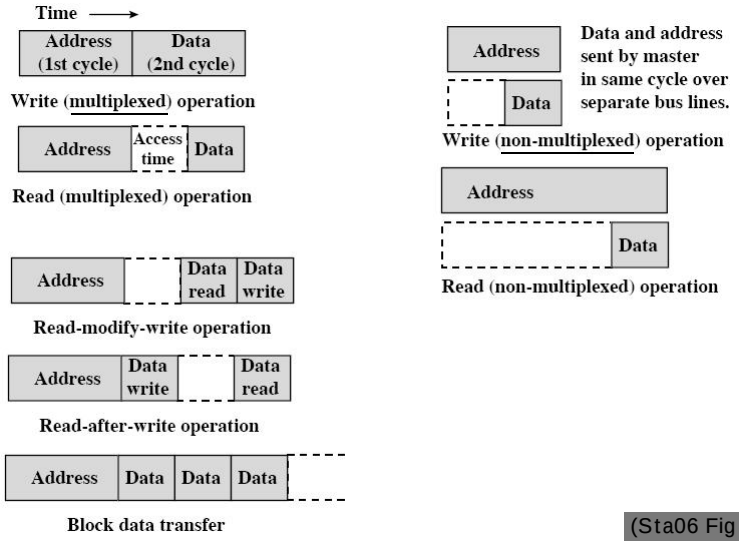
(Sta06 Fig 3.20a)

Asynchronous timing - Write



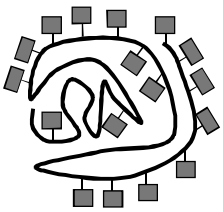
(Sta06 Fig 3.20b)

Events on bus *(väylätapahtumia)*



(Sta06 Fig 3.21)

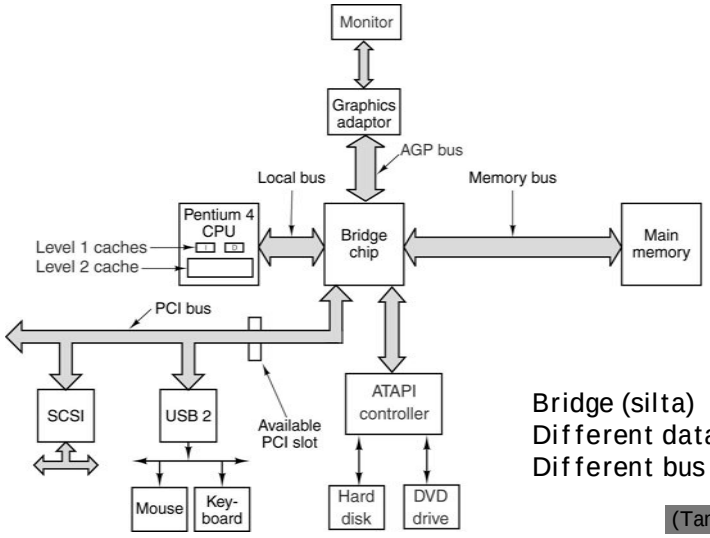
Bus configuration



- All devices on one bus?
  - All must use the same technique
  - Long bus ⇨ propagation delay (*etenemisviive)*
  - Combined data rated of the devices may exceed the capacity of the bus
  - Collisions on the arbitration, extra wait
  - Synchronous? ⇨ slowest determines the speed of all
- Bus hierarchy
  - Isolate independent traffic from each other
  - Maximize the most important transfer pace, CPU ⇔ MEM
  - I/O can manage with lower speed

Bottleneck!

Bus hierarchy, typical Pentium 4



Bridge (silta)
Different data rates
Different bus protocols

(Tan06 Fig 3-53)

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PCI-bus

[Sta06, Ch 3.5]

http://www.soe.ucsc.edu/classes/cmpe003/Spring02/motherboard.gif

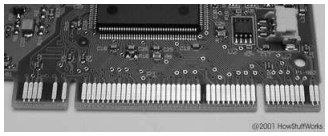
PCI: Peripheral Component Interconnect

- Time-based; 49 mandatory (+51 optional) signal lines
  - Address data: 32b mandatory (optional allows 64b)
  - Other signals: 17 mandatory (+ 19 optional)
- Centralized arbiter (*keskitetty väylän varaus*)
- Synchronous timing (*Synkroninen tahdistus*)
  - own 33 or 66 MHz clock (PCI-X: 133/156/533 Mhz)
  - Transfer rate 133, 266, 532 MB/s (PCI-X: 1 GB/s,4 GB/s)
- Events on the bus
  - read, write, read block, write block (multiplexed)
- Max 16 devices

49 mandatory signal lines (*pakollista johdinta*)

Sta06 Table 3.3

- AD[32]: address or data, multiplexed (*aikavuorottelu*)
  - + 1 parity
- C/BE[4]: bus command tai byte enable, multiplexed
  - For example: 0110/1111 = memory read/all 4 Bytes
- CLK, RST#: clock, reset
- 6 for interface control
  - FRAME#, IRDY#, TRDY#, STOP#, IDSEL, DEVSEL#
- 2 for arbitration (*väylän varaus*)
  - REQ# requires, GNT# granted
  - Dedicated lines for devices
- 2 error reporting pins (lines)
  - PERR# parity, SERR# system



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51 optional signal lines (valinnaista johdinta tai signaalia)

(ks. Sta06 Table 3.4)

- 4 lines for interrupt requests (*keskeytyspyyntö*)
  - Each device has its own dedicated line(s)
- 2 lines for cache support (on CPU or other devices)
  - snoopy cache
- 32 A/D extra lines
  - 32 mandatory + 32 optional => 64 bit address/data lines
- 4 additional lines for C/BE bus command tai byte enable
- 2 lines to negotiate 64b transfer
- 1 extra parity line
- 5 lines for testing

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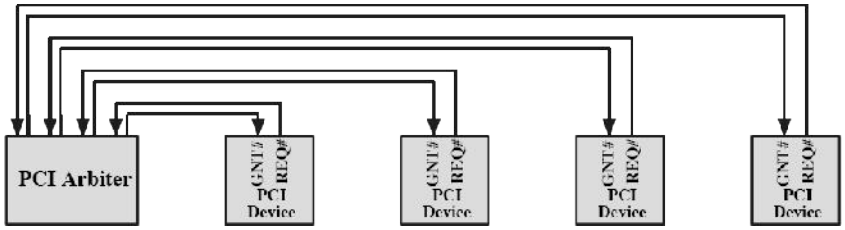
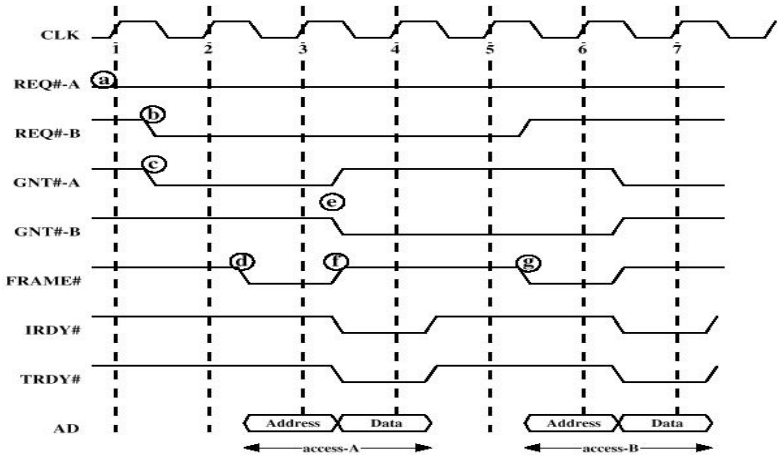
PCI: transactions

- Bus activity as transactions
  - New bus request for each new transaction
- First reservation
  - Central arbiter
  - send REQ, wait for GNT
- Then transaction
  - Initiator or master (device who reserved the bus)
  - Begin by asserting FRAME (reserve of bus)
  - Stop by releasing FRAME (indicate free bus)

(Sta06 Fig 3.24)



Bus arbitration : A and B want bus



(Sta06 Fig 3.25)

a) A wants bus

b) B wants bus

c) A granted bus knows that it has bus and bus is available

d) starts frame, requests also for next transaction

Sees that both still want it

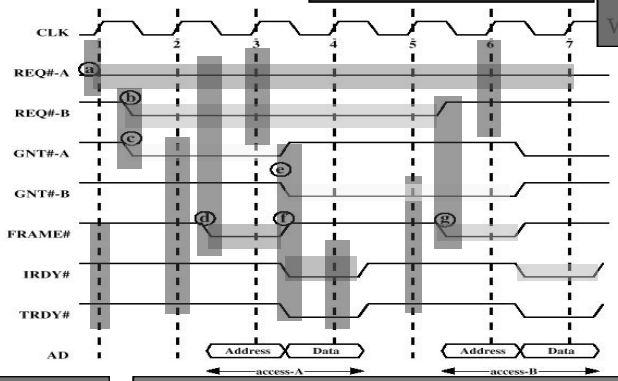
e) Grants bus to B for next trans.

f) marks last frame transfer, marks data ready

A's target reads data

g) starts frame, no more req.

Sees that only A wants it



A action

B action

Arbiter action

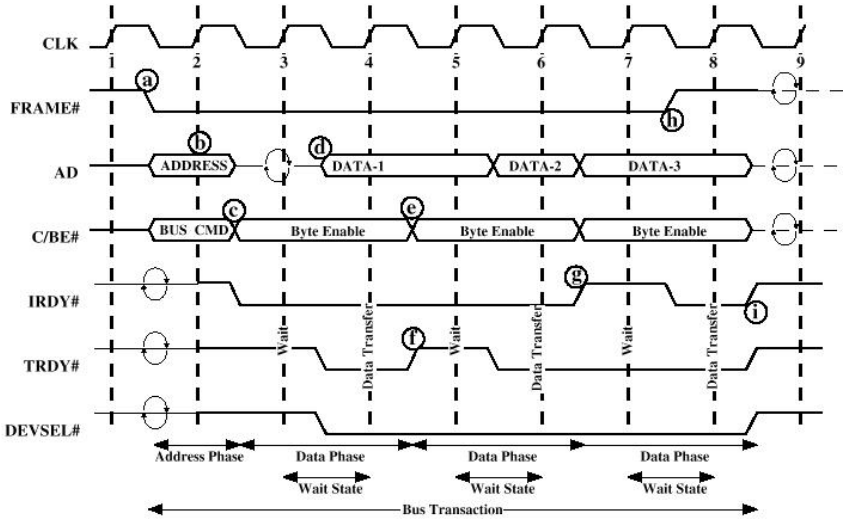
All ready for new trans

All ready for new trans, granted for B, B knows that it has bus

PCI: transactions

- Memory or I/O Read/Write [Line | Multiple]
  - Tansfer one or more words (alternatively: cache line or block)
- Memory Write and Invalidate
  - Guarantees that at least one cache line written to memory (*Takaa, että tieto siirtyy välimuistista muistiin)*
- Configuration Read/Write
  - Access to configuration parameters on the device (256B)
  - Plug-and-Play, PnP
- Interrupt Acknowledge
  - Interrupt controller collect more interrupt information from the device (to create interrupt vector for interrupt handler)
- Special Cycle
  - Broadcast (*yleislähetys)* to one or more targets
- Dual Address Cycle
  - Indication of using 64 bit address

PCI Memory Read



(Sta06 Fig 3.23)

a) start trans frame, set addr, set trans. type

b) recognise address, find data

c) select bytes, indicate ready to receive

d) ack address, set data, indicate valid data

data ready, read

e) sel next bytes

f) need more time, indicate not valid data

set & indicate data

g) not ready: hold

h) ready for last block: end frame and stop hold

Initiator CPU action

Target memory action

turnaround time

data ready, read

get ready for next

get ready for next

All ready for new transaction

All ready for new transaction

Tietokoneen rakenne

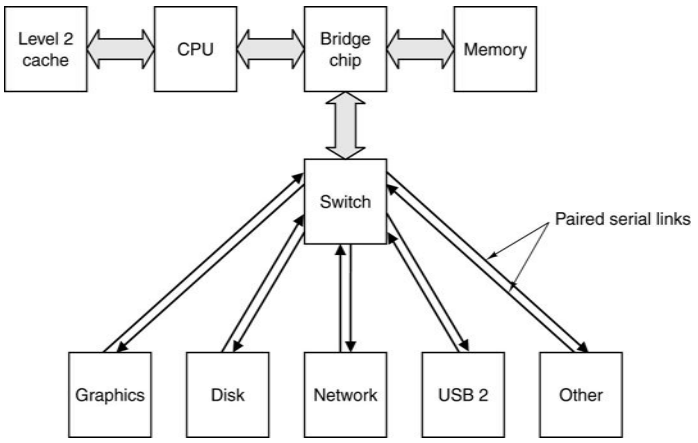
PCI Express

[Tan06, s.212]

Packet-switched PCI Express (PCIe, PCI-E)

- PCI bus is too slow for some devices
- Replaces PCI bus (and possibly other I/O-bus)
  - Already available on new computers
- Hub on motherboard acting as a crossbar switch (*kytkin*)
- Based on point-to-point connections (*kaksipisteyhteys*)
  - Full-dublex, one lane has two lines (one send, one receive)
  - One device can used one or more (2,4,8,16,32) lanes
- Data stream (serial transfer)
  - Small packets (header + payload), bits in sequence
- No reservation, no control signals.
  - Each device may send at any time, when it wishes
  - Packet header contains the control information (like target)
- Data rate on one lane 250MB/s (future 3rd gen: 1GB/s)

Typical PCI Express system



(Tan06, Fig 3-57)

PCI Express advantages

- Each packet contains error-detection code
  - CRC – cyclic redundancy check
  - More reliable than parity bit on PCI bus
- Devices can be further from each other (partitioning)
  - For example, hard disk inside the monitor covers
  - PCI allowed max 50 cm
- Expandability — PCI Express: max not determined
  - A device can be a switch
- Allows hot-swap — Plug-and-Play
  - Device can be connected /disconnected while running, PnP
- Physically smaller connectors
  - Computers and devices can be smaller

Review Questions

- Main differences between synchronous and asynchronous timing?
- Benefits of bus hierarchy?
- Main differences of PCI Express and PCI ?

- See course book for more review questions