Wireless Network-on-Chip Architectures for Multi-Core Systems

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Outlines

• Multi-core System
• Wired Network-on-chip
  o Problem of wired Network-on-chip
• Wireless Network-on-chip
  o Topology
  o Routing Protocol
  o Evaluation
Multi-core System-on-Chip

- Advanced fabrication technologies
  - Transistors
    - Reduced size
    - High speed
    - Low power consumption
  - Complex ICs (Large number of transistors)
Multi-core System-on-Chip

- System-on-Chip
  (All functional elements of a computer system)
  - Processing units
  - On-chip Memory
  - Peripherals components

http://www.maximumpc.com/article/news/ibm_gives_details_octocore_power7_processor
Multi-core System-on-Chip

- Is a sophisticated version of SoC.
- A number of replicated cores
- Work as a Multiple processing system
- Cooperate to implement complex tasks (Core level parallelism)
- Example: Intel Single Chip Cloud Computer (SCC), 48 cores

Multi-core System-on-Chip

- Applications
  - Weather forecasting
  - Bioinformatics
  - Data analysis
  - Video rendering
Network-on-Chip

- High throughput
- Low latency
- Low power consumption

http://sips.inesc-id.pt/~pfzt/?page_id=928
Wired Network-on-Chip

- Embedded cores
- Communicate via
- Switches
- Wired links (Metal interconnects)
- Fat-Tree, Mesh, Torus, and Octagon

Wired Network-on-Chip

- Characteristics
- Satisfy small number of cores system
- However, it is not suitable as systems scales up to 100 of cores.
- Data transfer between far apart cores causes
  - High latency
  - High power consumption
Wireless Network-on-Chip

- Low power consumption
- High bandwidth
- It depends on the Transmitter/ receiver theory
- Antennas
Probability of connecting \(i,j\)
\[
P(i, j) = \frac{l_{ij}^{-\alpha} f_{ij}}{\forall i \sum \forall j l_{ij}^{-\alpha} f_{ij}}
\]
- \(l_{ij}\) is the Manhattan distance.
- \(f_{ij}\) is the communication freq.
- \(\alpha\) optimized for best performance and wiring cost
Hybrid Network

- A small-world topology is used
  - Consists of a number of subnets (cluster)
  - Each cluster consists of number of cores
  - These cores are connected to central hub
    - Through wired links
- These subnets are connected together via wireless network
On-Chip Antenna

- **Metal zigzag antennas**
  o Range of GHz (UWB)
  o Bandwidth: tens of GHz

- **Carbon nanotubes (CNTs)**
  o Enhance performance up to 40 dB
  o Bandwidth: 500 GHz
  o Much higher data rate
Wireless Transceiver

Data flit to be transmitted

Transmitter Side

Antenna

Amplifier

Modulator

Serializer

Switch

Receiver Side

LNA

Demodulator

Deserializer

Data flit received

$\text{f}_c$
Routing Strategy

- **Network characteristics**
  - Hubs are connected via wired and wireless links
  - The wireless is used only if it is reduced path length
  - Any two hubs can communicate via one hop (wireless shortcuts)
- **Problem**: interference and contention
Token Passing Protocol

• One hub broadcasts messages at a given time
• All other hubs receive this message
• Only the hub that matches the destination address completes receiving
• The token is released to the next hub
• If the source has no WI, it uses wired links to the nearest hub with WI link
• If the destination has no WI, the nearest hub with WI receives the message and then routes it via a wired link
Performance Metrics

- **Throughput**

  \[
  \text{Throughput} = \frac{(\text{Number of transferred messages}) \times (\text{Message length})}{(\text{Total time})}
  \]

- **Latency**

  \[
  \text{Latency} = \text{sender overhead} + \text{transfer time} + \text{receiver overhead}
  \]

- **Power consumption**
  - For the subnets, inter-switch wires and the switch blocks.
  - For the wireless, antennas, transceiver circuits and other communication modules.
Performance Evaluation

![Diagram showing packet energy and bandwidth comparison]

- **Packet Energy (nJ)**
  - SD-MAC: 800
  - T-WiNoC: 500
  - CDMA-WiNoC: 200
  - CNT-WiNoC: 100

- **Bandwidth (Tbps)**
  - SD-MAC: 4
  - T-WiNoC: 3.5
  - CDMA-WiNoC: 3
  - CNT-WiNoC: 1
Conclusion

- Network-on-chip desired properties are high throughput, low latency, a low power
- Wired NoC not suitable for large number of cores
- Small-World network is the basic architecture for Network-on-Chip
- Hybrid Network is used instead of wired network
- Zigzag antenna is suitable for WiNoC
- Token Passing Protocol
- Efficient scaling is possible for future
Question