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Fuzzy-Token: An Adaptive MAC Protocol for Wireless-Enabled Manycores

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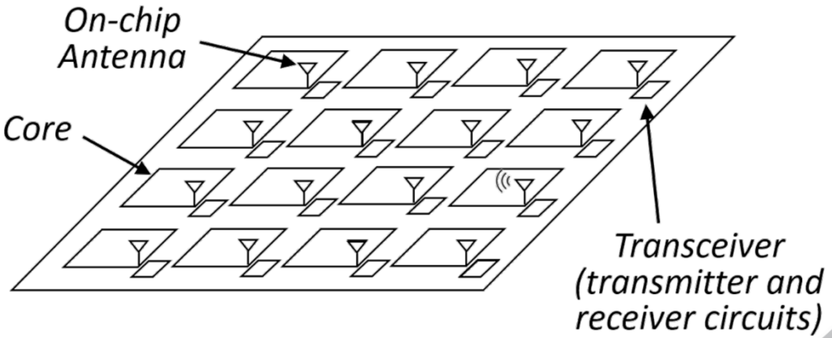
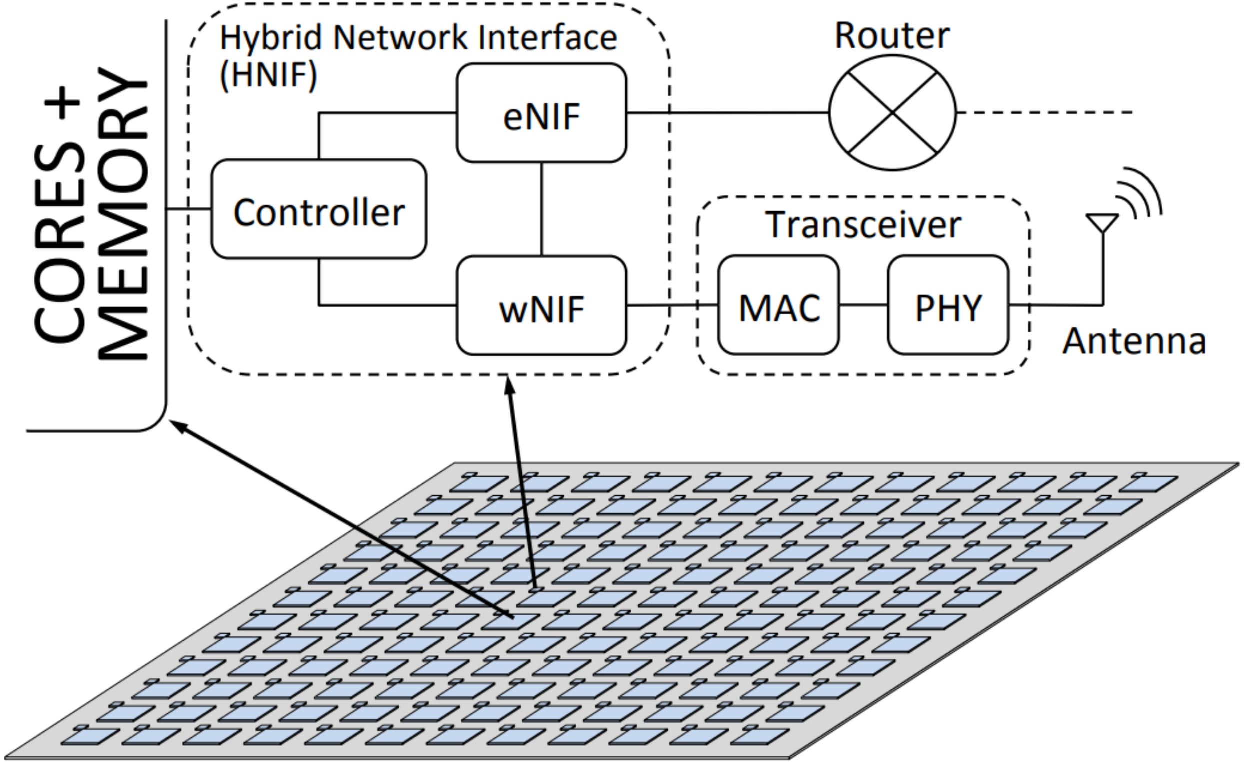
863337 (WiPLASH)

Context

- **Current trends are leading to larger manycores**
- **Wireless on-chip communication holds promise for the implementation of fast networks for these multiprocessors**
- **In complement of a wired NoC, wireless provides**
  - **Low latency**
  - **Natural broadcast capabilities**
  - **Flexibility**



Wired+Wireless Network-on-Chip



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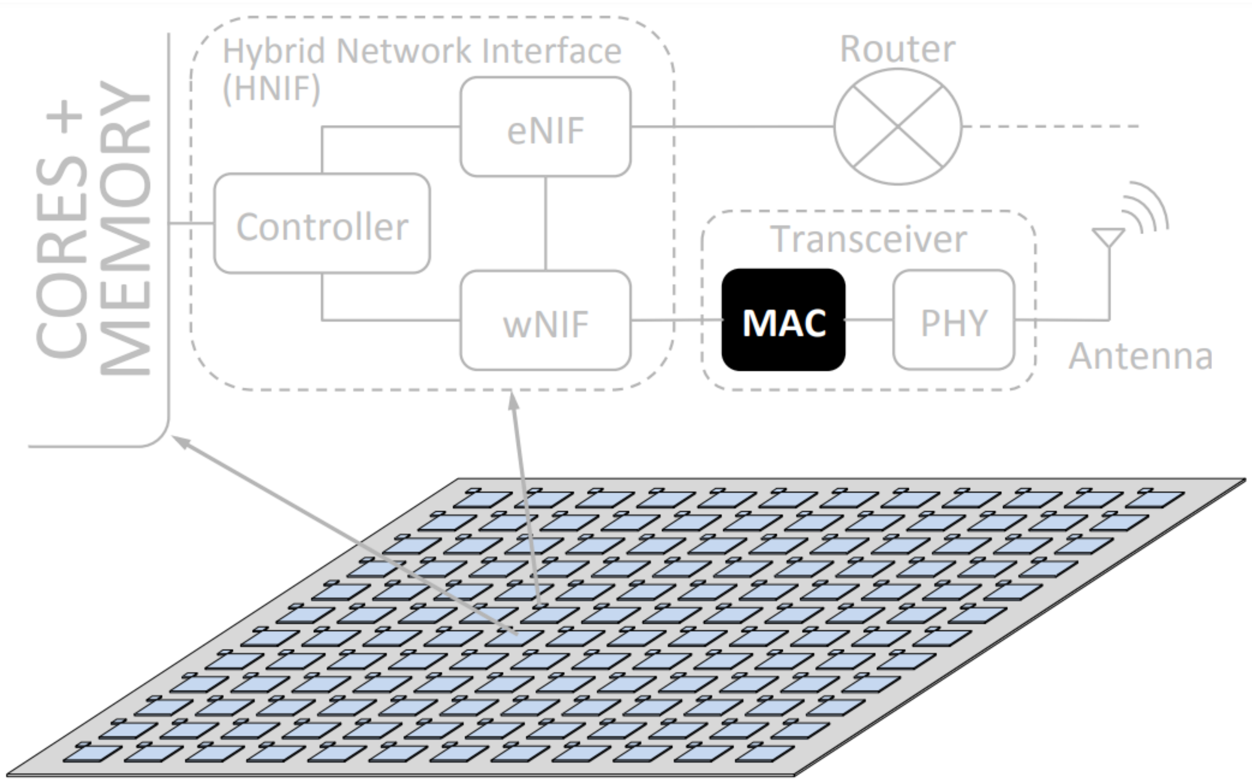


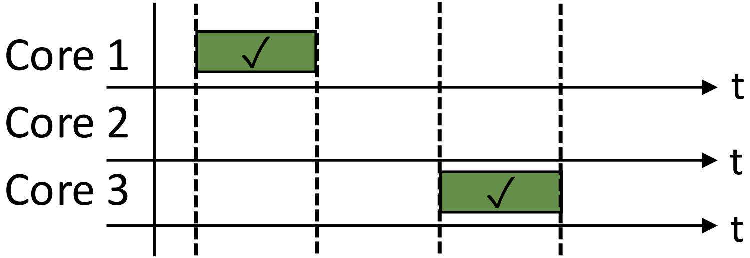
Motivation

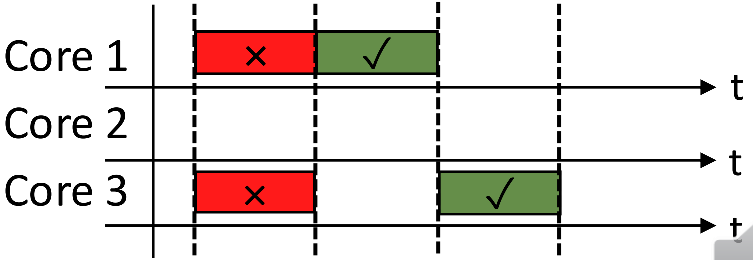
- As the core density increases, more wireless interfaces can be expected on chip
- Need for arbitration strategies (MAC protocols)
  - That provide low access latency
  - That scale with number of wireless nodes
  - That adapt to different traffic patterns
  - That are simple to implement

Medium Access Control (MAC)

- **The MAC layer defines mechanisms to ensure that all nodes can access the shared wireless medium in an organized manner**
- **Two common access methods: token passing, random access**

Token passing	**Random access**
Pass a token around a virtual ring. Only the token holder can transmit	Simultaneous accesses to the same channel collide and need to retry





Medium Access Control (MAC)

- Th… …ism… …an ac… …dium…
- Two co… …thods: token pa… …ccess

✓ No wasted cycles at high loads
× Unnecessary delays if contention is low

✓ No wasted cycles if contention is low (transmit right away)
× Lots of collisions at high loads

Token passing	Random access
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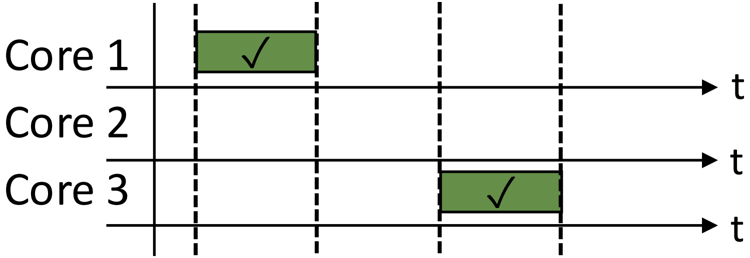
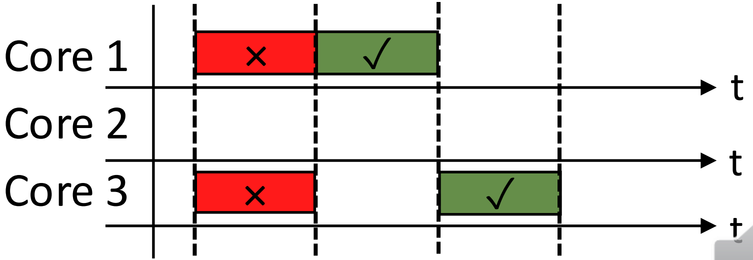




MAC Context Analysis

- Wireless on-chip scenario
  - Physically constrained – need for lightweight MAC protocol
  - Unlike off-chip scenarios, the environment is static and known beforehand
    - All nodes are synchronized
    - Collisions can always be detected
  - Protocols must scale to many cores and adapt to changes in traffic

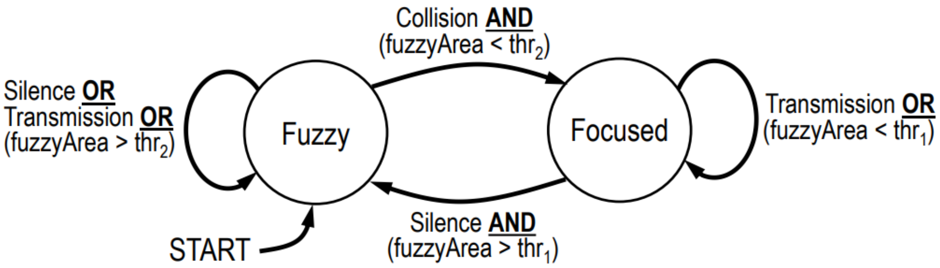
	Low load	High load	Variability
Random access	✓	✗	✗
Token passing	✗	✓	✗
???	✓	✓	✓

Contribution: *Fuzzy-Token*

- We propose *Fuzzy-Token*, a hybrid protocol based on two basic approaches: token passing, and random access
- We evaluate the performance of *Fuzzy-Token* with a synthetic traffic suite and real application traces
- We compare the obtained performance with that of a token-passing and a random-access protocol for wireless NoCs, called BRS *(Mestres et al, 2016)*

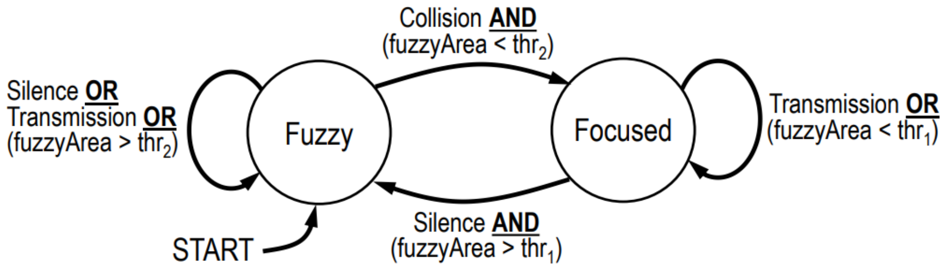
Fuzzy-Token: Main Idea (1/2)

- **2 operation modes**
  - ***Focused* → only the token holder can transmit (collision-free guarantee)**
  - ***Fuzzy* → all nodes inside *Fuzzy Area* (except token holder) that have pending packets can transmit with probability p_i**
- **Mode can change at each step**
  - **If in *focused* and token holder doesn't transmit → switch to *fuzzy***
  - **If in *fuzzy* and collision → switch to *focused***



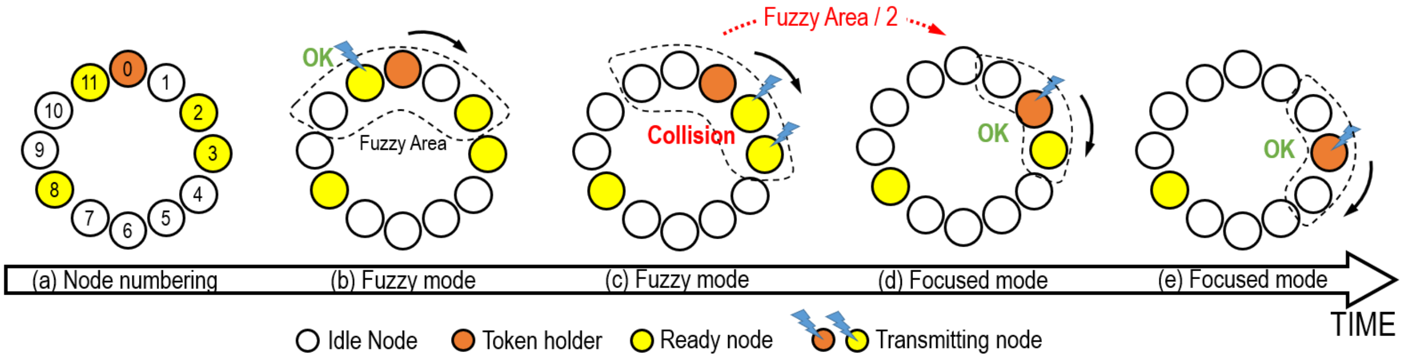
Fuzzy-Token: Main Idea (2/2)

- ***Fuzzy Area*** **size controls amount of contention at each step**
  - **Increase size (after idle step) when the load is low to give rapid access to the few nodes that want to transmit**
  - **Quickly decrease size (after collision) when load increases to minimize further collisions**



Fuzzy-Token: Example (1/2)

- **Initial state**
  - **Fuzzy Mode (all nodes inside *Fuzzy Area* except token holder may transmit)**
  - **Token holder: node 0, *Fuzzy Area* size: 5**
- ***Fuzzy Area* size updated using additive increase multiplicative decrease**
  - **Increase area size by 1 after each idle step**
  - **Decrease area size by half (round up) after a collision**



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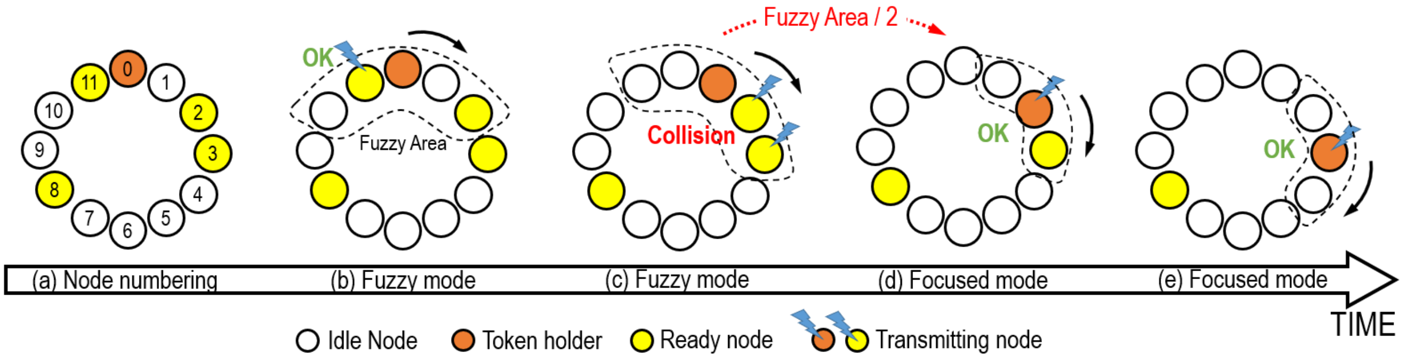

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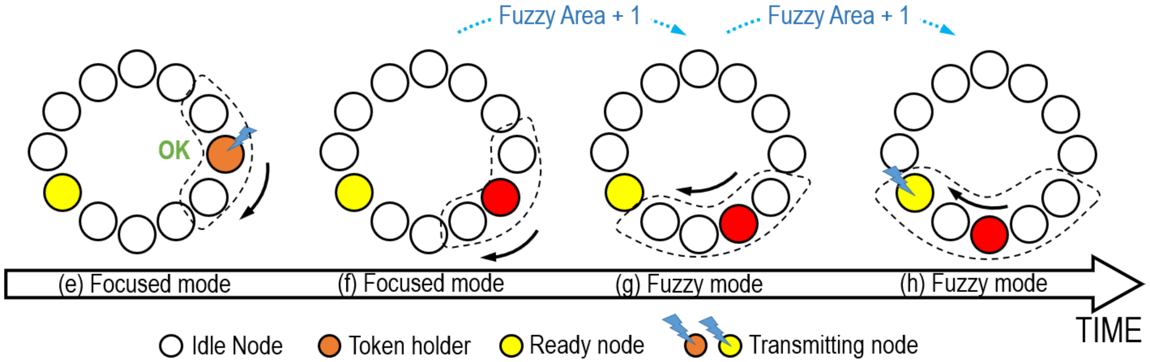
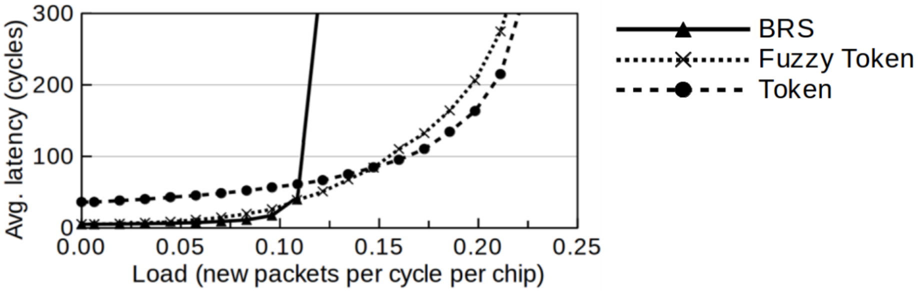


Fuzzy-Token: Evaluation (1/2)

- **Synthetic traffic latency**
  - ✓ **As good as BRS at low loads (fully open *Fuzzy Area*, transmit immediately)**
  - ✓ **Almost as good as Token at high loads (very small *Fuzzy Area*, mostly Token Holder is the only one that can transmit)**
  - ✓ **Dynamic and fast adaptation from one behavior to another as load changes**

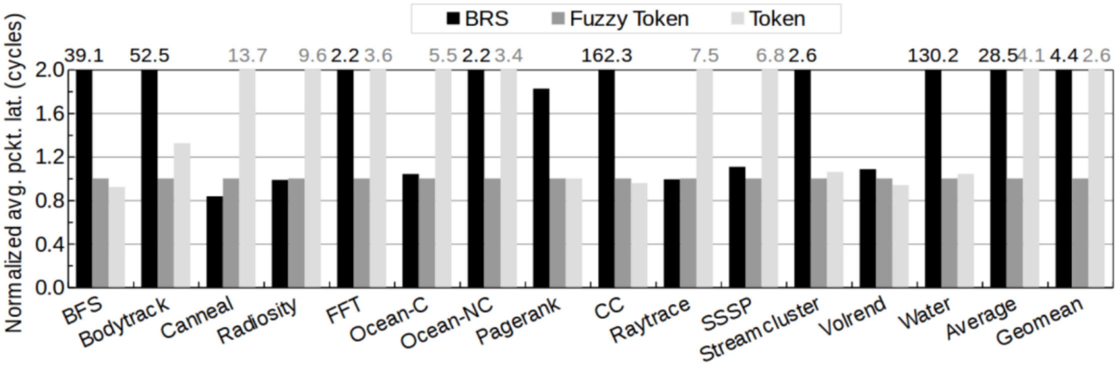


Fuzzy-Token: Evaluation (2/2)

- **Real applications**
  - **We obtain latency statistics from Multi2Sim on a 64-core chip**
  - **Benchmarks from PARSEC and CRONO suites**

  ✓ **Fuzzy-Token provides latency among the lowest of 3 protocols**

  ✓ **4.4x lower latency than BRS, and 2.6x lower than Token**



Fuzzy-Token: Also in the Paper…

- **Design decisions**
- **Related work**
- **Further analysis on…**
  - **Tail latency**
  - **Hotspot traffic**
  - **Bursty traffic**
  - **Throughput**
  - **Energy consumption**

Fuzzy-Token: Conclusions *Thank you!*

- **Hybrid approach combines pros of both token-passing and random-access protocols**
  - ✓ Low latency at low loads (random-access mode)
  - ✓ Low latency and collision-free at high loads (token-passing mode)
- **Run both random-access and token-passing methods simultaneously**
  - ✓ Token is always passed to ensure fairness among nodes
  - ✓ Protocol reacts immediately after traffic changes (mode change + *Fuzzy Area* update)
- **All transceivers see same consistent view of wireless channel**
  - ✓ All nodes are synchronized and proceed in lockstep (no need for explicit messages)
- **Evaluation with a synthetic traffic model and real application traces shows *Fuzzy-Token* achieves lowest latency than baseline protocols in many different scenarios**
  - ✓ Low/High loads
  - ✓ Hotspot/Bursty traffic