Welcome

Final Year Project Oral Presentation

- Title: **Analysis of Fuzzy-Neuro Network Communications**
- Student: Zhang Xinhua
- Duration: January 2003 ~ June 2003
- Supervisor: A/P Peter. K. K. Loh
- Examiner: A/P Quek Hiok Chai

Project Objective

- Investigate the use of fuzzy logic in routing decisions on unstable or unreliable communication networks.
- Unify the fuzzy system for various network topologies, especially the rule base and membership functions.
- Implement the new fuzzy routing system on FPGA.
- Provide a basis for development of new, intelligent and high-performance routing techniques to enhance communications support in networks.

Tasks Finished

- Explore fuzzy neural network applied in network communications
- Design of fault-tolerant routing algorithm for Gaussian cube
- Design of fault-tolerant routing algorithm for Fibonacci-class cubes
- Proposing a new interconnection topology: Exchanged Hypercube
- Writing software simulation tools for implementation and benchmark
- Hardware implementation of two algorithms on FPGA with Handel-C

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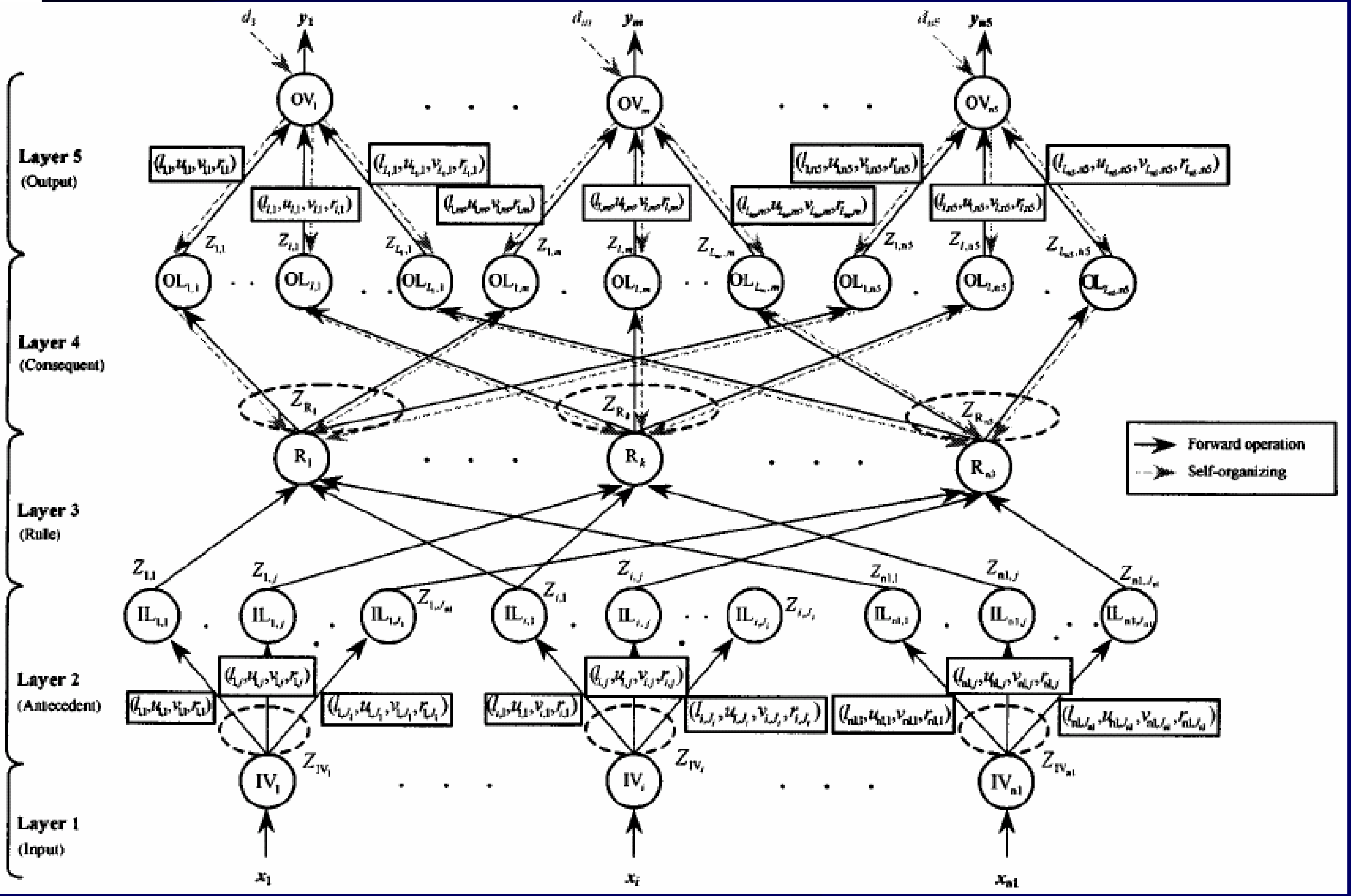
Fuzzy Neural Network

- Strengths
  - Fuzzy characteristic provides interpretable human-like IF-THEN reasoning rules.
  - Artificial neural network (ANN) supplies the learning ability to the traditional fuzzy systems by deriving fuzzy rule base and/or membership function automatically.
- Deficiencies
  - Too large rule base for real hardware implementation
  - Intractable Training time complexity: $O(\prod_{i=1}^{n} I_i \cdot \prod_{j=1}^{m} O_j \cdot T)$

Architecture of GenSoFNN



Applying FNN to Routing, Barriers

- Exponentially growing number of rules

Mamdani

$$R_i: \ IF\ x_1\ is\ A_{i1}\ and\ \ldots\ and\ x_r\ is\ A_{ir}\ THEN\ y\ is\ C_i$$

Where,

$X_j (j = 1,2,\ \ldots, r)$	input variables
y	output variable
A_{ij}	fuzzy sets for x_j
C_i	fuzzy sets for y.

TSK

$$R_i: \ IF\ x_1\ is\ A_{i1}\ and\ \ldots\ and\ x_r\ is\ A_{ir}$$
$$THEN\ y = f_i(x_1, x_2, \ldots, x_r) = b_{i0} + b_{i1}x_1 + \ldots + b_{ir}x_r$$

Where

f_i	is the linear model
$b_{ij} (j = 0,1,\ldots, r)$	are real-valued parameters

Applying FNN to Routing, Barriers

- Exponentially growing number of rules
- Too long off-line training time $O(\prod_{i=1}^{n} I_i \cdot \prod_{j=1}^{m} O_j \cdot T)$
- Difficulty in discussion of non-fuzzy metrics
- Challenges in preparing training examples
- Hard to unify membership functions and/or rule base for various topologies

Cause/Conclusion: FNN is not currently suitable for high-dimensional binary applications.

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Background of Gaussian Cube (*GC*)

- Proposed by Dr. W. J. Hsu
- Merits
  - the interconnection density and algorithmic efficiency are linked by a common parameter, the variation of which can scale routing performance according to traffic loads without changing the routing algorithm
  - such communication primitives as unicasting, multicasting, broadcasting/gathering can also be done rather efficiently
- Issue: no existing fault-tolerant routing strategy for it (node/link dilution cubes)

FT Routing algorithm for Gaussian Cube

- Significance: making GC a more fault-tolerant topology
- Chief advantages (for $GC(n, 2^{\alpha})$)
  (1) Incurs message overhead of only $O(n)$.
  (2) The computation complexity for intermediate nodes is $O(\alpha(n-\alpha)\log\alpha)$
  (3) Tolerate a large number of faults.
  (4) Guarantees a message path length not exceeding $2F$ longer than the optimal path found in a fault-free setting, provided the distribution of faults in the network satisfies some constraints.
  (5) Generates deadlock-free and livelock-free routes.

Chief Techniques Adopted (1)

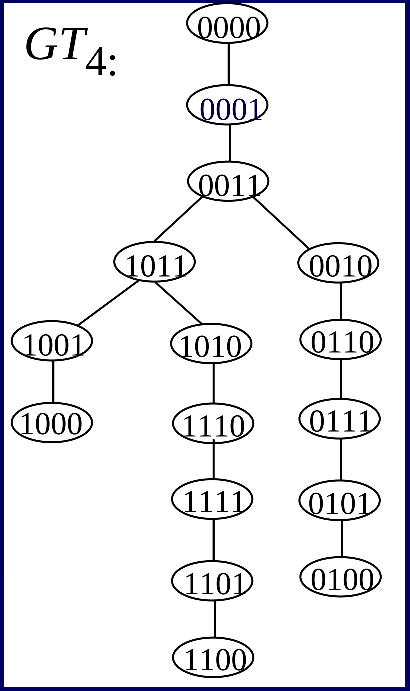
- Gaussian Tree (GT_{α} *for* $GC(n, 2^{\alpha})$)

Gaussian Tree is composed of $\langle V_n, E_n \rangle$,

where: $V_n = \{ a_{n-1}a_{n-2}\cdots a_1a_0 \mid a_i \in \{0,1\}, \text{ for } i \in [0, n-1] \}$

$$E_n = \{(a_{n-1}a_{n-2}\cdots a_c \cdots a_1a_0,\ a_{n-1}a_{n-2}\cdots \overline{a_c} \cdots a_1a_0) \mid$$

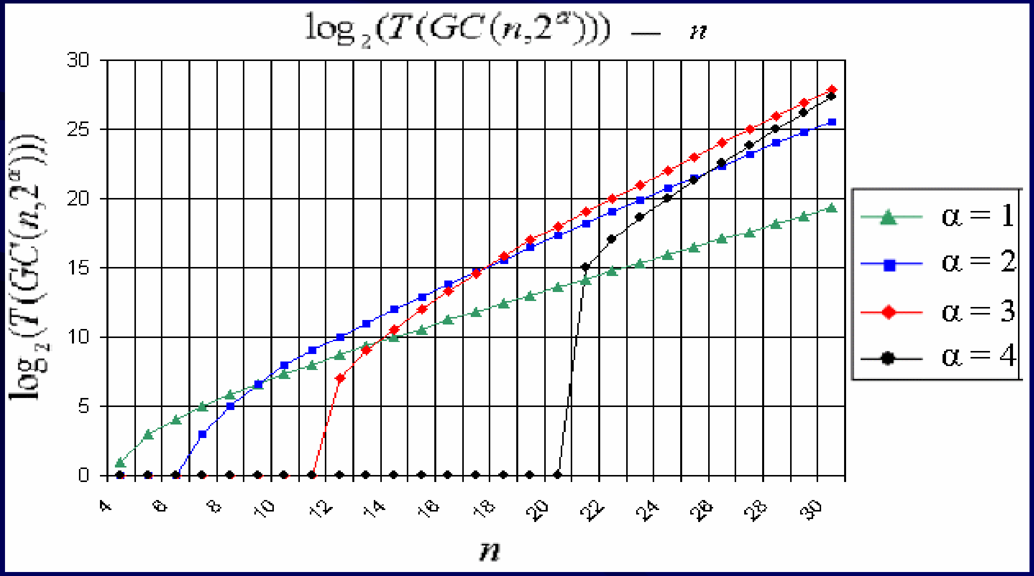
$$c=0 \text{ or } c \in [1, n-1] \text{ and } \overline{a_{c-1}a_{c-2}\cdots a_1a_0} = c \}$$



Significance: A many-to-one mapping is established between nodes in *GC* and *GT*, thus converting the original problem into routing in *GT*, which is found to be more definite and predictable.

Chief Techniques Adopted (2)

- Fault categorization
  - A, B, C - Category (partition)
  - Significance: overcome the problem of low node availability, with refined analysis of faults' location



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Background of Fibonacci Cube

- Proposed by Dr. W. J. Hsu
- Merits
  - use fewer links than the comparable hypercubes, with the scale increasing far less fast than hypercube, allowing more choices of network size
  - allow efficient emulation of other topologies such as binary tree (including its variants) and hypercube
- Issue: no existing fault-tolerant routing strategy for it (node/link dilution cubes)

Routing algorithm for Fibonacci Cube (*FC*)

- Significance: making *FC* a more fault-tolerant topology
- Chief advantages

(1) Applicable to all Fibonacci-class Cubes in a unified fashion

(2) Maximum number of faulty components tolerable is the network's node availability

(3) Generates deadlock-free and livelock-free routes

(4) Can be implemented almost entirely with simple and practical hardware requiring minimal processor control

(5) Maintains and updates at most (deg+2)*n-bit local vectors

(6) Guarantees a message path length not exceeding $n+H$ empirically and $2n+H$ theoretically.

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Exchanged Hypercube (*EH*)

- Properties and merits

(1) Reduce the number of link to 1/*n* of binary hypercube with the same number of node.

(2) Hamiltonian property, uniform node degree, low diameter, and various possibilities of decomposition.

(3) Good emulation of Gaussian Cube, binary hypercube, ring, mesh.

(4) *Extended Binomial Tree* is found as spanning tree, helping to solve broadcasting and load balancing.

(5) Deadlock/livelock free fault tolerant routing algorithm designed and the number of hops is tightly bounded.

Tasks Finished (5)

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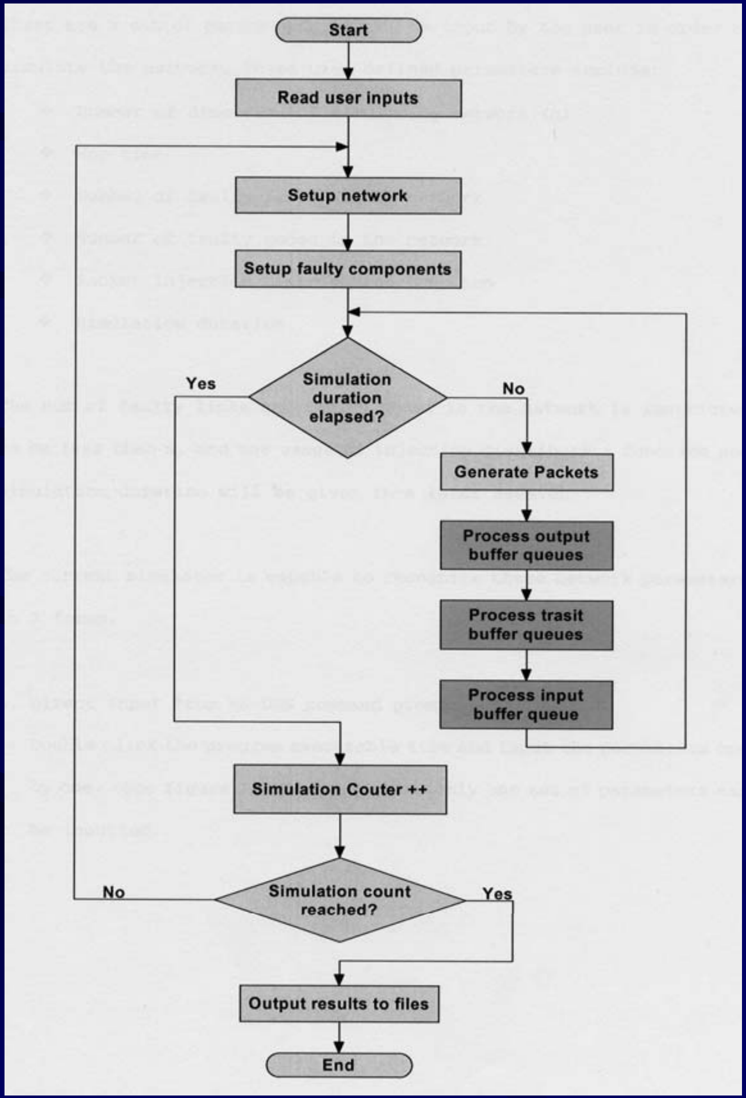
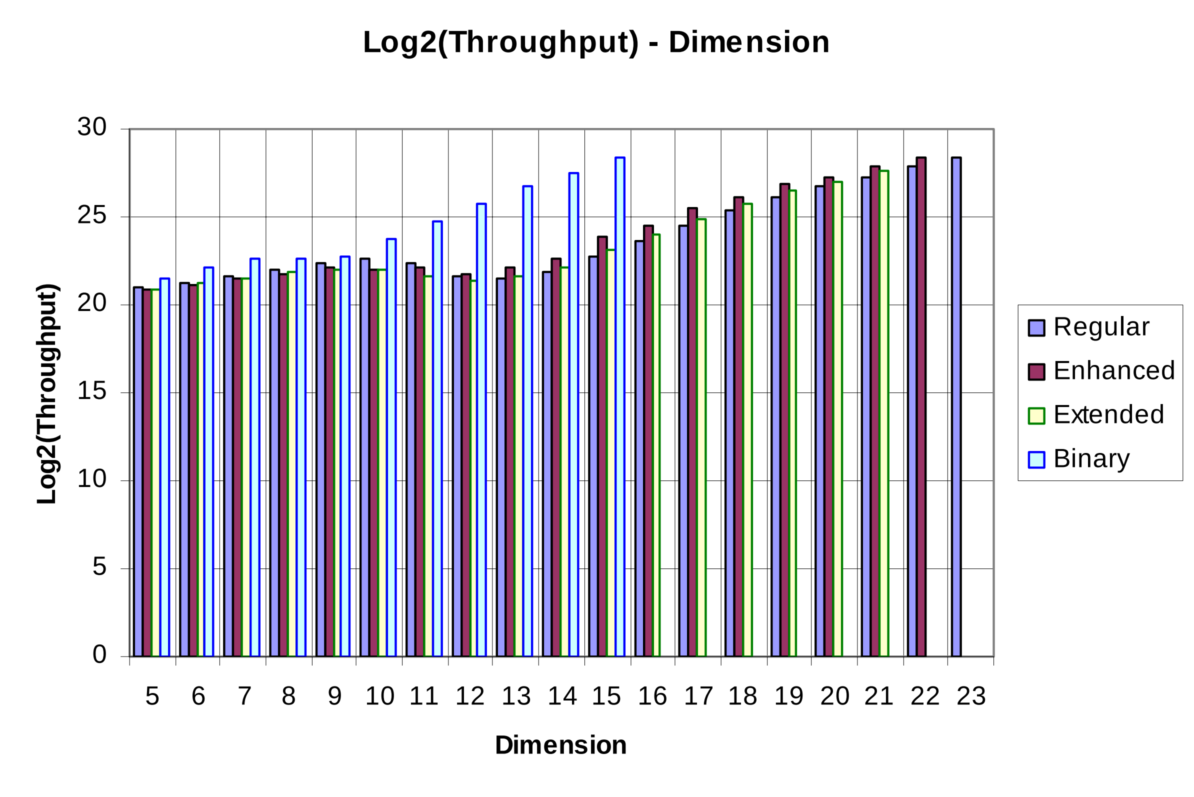
Simulator Architecture



Simulation results

- Fibonacci Cube

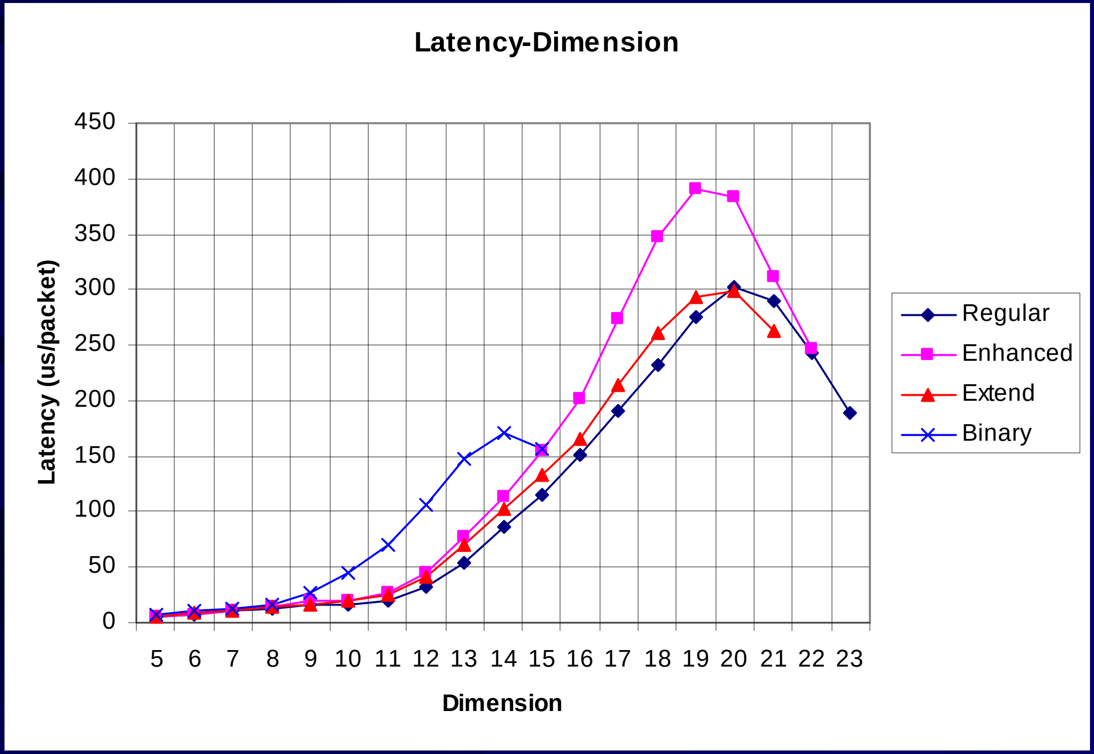
throughput (logarithm) of faulty-free Fibonacci-class Cube



Simulation results

- Fibonacci Cube

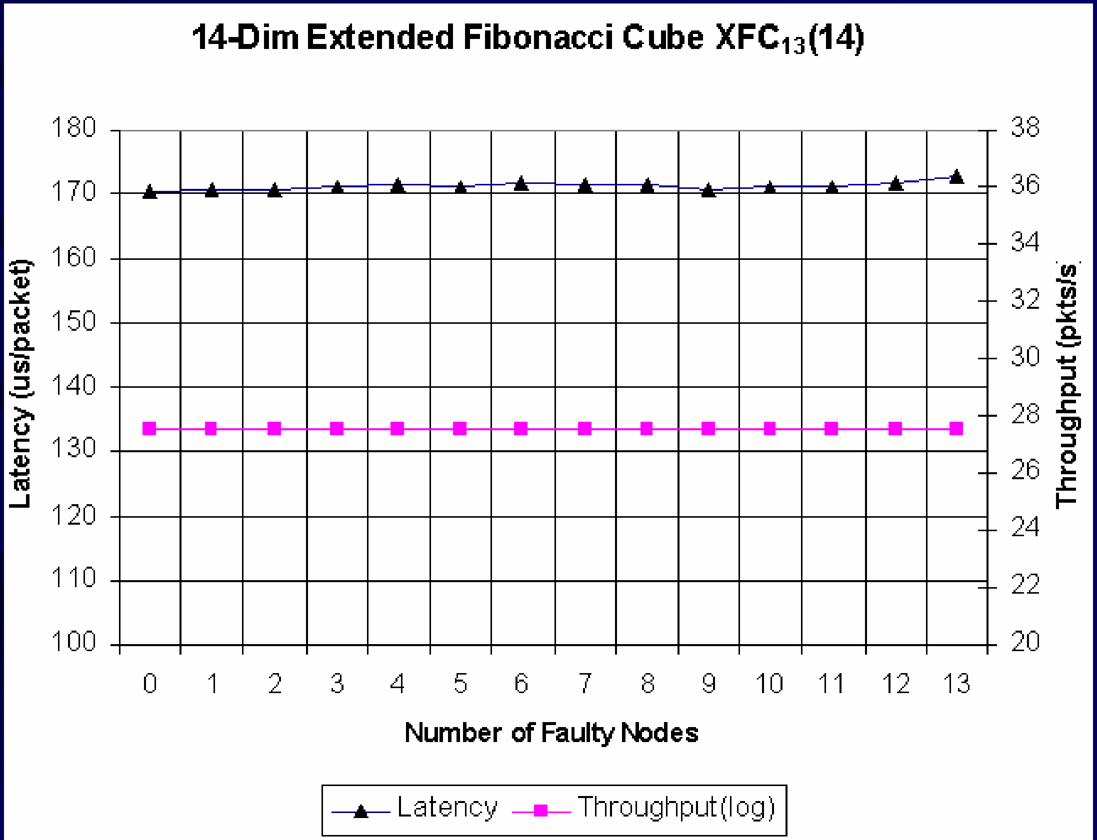
Latency of Fault-free Fibonacci-Class Cubes



Simulation results

◆ Fibonacci Cube

Throughput and Latency (logarithm) of $XFC_{13}(14)$ with respect to number of faults



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Proposal for future research

- Give theoretical proof for the fault-tolerant routing strategy of Fibonacci Cube.
- Introduce new metrics for comparison of fault-tolerant routing strategies, especially for *GC*, Fibonacci and other node/link dilution cubes.
- Improve the simulator architecture to achieve more accurate statistical results.

Question and Answer Session

Questions
are
welcomed.