Performance Analysis and Implementation of Perfect Difference Network Using NS-2

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Abstract - PDN is an asymptotically optimal method for connecting a set of nodes into a Perfect Difference Network (PDN) with diameter 2, so that any node is reachable from any other node in one or two hops atmost. It is mainly based on the mathematical notion "the Perfect Difference Sets" given by "Singer". Perfect difference network is a robust, high-performance interconnection network for parallel and distributed computation. PDNs have a diameter of 2 and a node degree of approximately 2, which place them close to complete networks in terms of routing performance and much lower with respect to implementation cost. The rich connectivity and small diameters of PDNs and related networks make them good candidates for wireless/optical network technologies.

Keywords : PDN, PDS, NAM.

I. INTRODUCTION

1.1 Perfect Difference Sets

Set in mathematics is a collection of entities called elements of the set, that may be real object or conceptual entities. Set theory has a wide applicability in not just the field of mathematics but also in many other fields. Perfect Difference Set is an extension to it,[3].

Perfect Difference Sets were first discussed by Singer in 1938. Perfect Difference Set is a specialized set of $\delta+1$ non negative integer data $\{s_0, s_1,\ldots\ldots, s_\delta\}$ that can be uniquely expressed in the form s_i-s_j, where $i\neq j$, i,j=0,1,…… Ex: {1, 2 ,4}(mod 7), {1, 2, 5, 7}(mod 13), etc….

A necessary condition for a difference sets to exist is that n be of the form $\delta^2+\delta+1$ and the sufficient condition is that δ be a prime power.

Table 1.1: Perfect Difference Sets upto order 16

δ	n	Example PDS of order δ in normal form
2	7	0, 1, 3
3	13	0, 1, 3, 9
4	21	0, 1, 4, 14, 16
5	31	0, 1, 3, 8, 12, 18
7	57	0, 1, 3 , 13, 32, 36, 43, 52
8	73	0, 1, 3, 7, 15, 31, 36, 54, 63
9	91	0, 1, 3, 9, 27, 49, 56, 61, 77, 81
11	133	0, 1, 3, 12, 20, 34, 38, 81, 88, 94, 104, 109
13	183	0, 1, 3, 16, 23, 28, 42, 76, 82, 86, 119, 137, 154, 175
16	273	0, 1, 3, 7, 15, 31, 63, 90, 116, 127, 136, 181, 194, 204, 233, 238,255

1.2 Perfect Difference Network

Perfect Difference Network (PDN) based on the PDS $\{0,1,s_2,\ldots,s_\delta\}$ There are n= $\delta^2+\delta+1$ nodes, numbered 0 to n-1. Node i is connected via directed links to nodes i±1 and $i\neq s_j$ (mod n), for $2 \leq j \leq \delta$. The preceding connectivity leads to a chordal ring of in and out-degree d=2δ and diameter D=2. Because, for each link from node i to node j, the reverse link from node j to node i also exists, the network can be drawn as an undirected graph. Normal-form PDS contains 1 as a member. Therefore, PDNs based on normal PDNs are special types of chordal rings. In the terminology of chordal rings, the links connecting consecutive nodes i and i+1 are rings, the links connecting consecutive nodes i and i+1 are ring links, while those that connect non consecu.1tive nodes i and $i+s_j$, $2 \leq j \leq \delta$, are skip links or chords [1].

1.3 Motivation

Networks evolved from the simplest ring, linear to a far better mesh, star to more complex and stronger hypercube, pancake and complete network architectures. All these networks served their best in their ages, then why the newer architectures should be introduced the answer is communication needs of applications and technological capabilities. PDN was introduced as an approach to design a network that not only stands big in the performance list but also rules out the limitations inherent in each of the architectures at a lesser cost. PDN is thus a step ahead in the same path of achieving the goal of better network services [2].

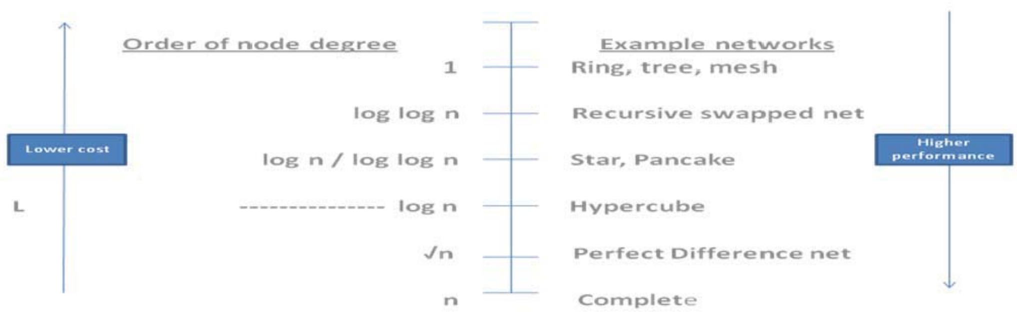

Figure 1: The spectrum of network in terms of node degree. The hypercube, with its excellent performance and logarithmic Diameter, is often used as a reference point for comparison.

II. LITERATURE REVIEW

Interconnection Network has been studied before many a time by many Mathematicians, Computer Designers and Computer Scientists intensively for it is applicable to both parallel and distributed computer systems. [1] As a result today we have an array of good, better and best interconnection networks competing in the market for providing connection. Bus, Ring, Star, Hypercube, Pancake, Complete are some of the example from the long array and more are being added every day. PDN is a new name added to the array. The work started way before 1980's and still the work is in process to make it a better network. The following paragraphs states some pieces of work done on PDN formerly by researcher an asymptotically optimal method for connecting a set of nodes into a perfect difference network (PDN) with diameter 2, so that any node is reachable from any other node in one or two hops. PDNs offer optimal performance and fault tolerance relative to their complexity or implementation cost. The network architecture in its basic and bipartite forms and shows how the related multidimensional PDNs can be derived. [2]

The paper "Perfect Difference Network for Network-on-Chip Architecture," [6] states that System-on Chips (SoCs) are designed as a tightly interconnected set of cores, where all components share the same system clock. There is a need to treat SoCs as Network-on-Chip where the interconnections are designed using an adaptation of the protocol stack. Network-on-Chip (NoC) is a new paradigm for designing core based system on chip, where various Intellectual Property (IP) resource nodes are connected to the router-based square network of switches using resource network interface. NoC supports high degree of reusability and is scalable. Energy consumption of a VLSI system became one of the most important factors to optimize in most of the designs due to factors such as the expanding market for mobile products, the increasing cooling cost, etc. Though the technology in computer network is well developed, a direct adaptation of network protocols to NoCs is impossible, due to different communication requirements, cost considerations and architectural constraints. The design goals for NoCs can be described as platform based design, separation between communication and computing resources and minimization in energy. The paper summarizes the concept of Perfect Difference Network to minimize the communication energy by proposing the energy model for NoC architecture for Inter-tile geometry in comparison with PDN Circular geometry.

III. SIMULATION ENVIRONMENT

3.1 Simulations

In communication and computer network research, network simulation is a technique where a program models the behaviour of a network either by calculating the interaction between the different network entities (hosts/routers, data links, packets, etc.) using mathematical formulas, or actually capturing and playing back observations from a production network. Simulation is broadly classified into two types, namely, continuous simulation and discrete event simulation.

3.2 What is NS-2

NS is an Object Oriented Discrete Event Simulator Simulator maintains list of events and executes one event after another Single thread of control: no locking or race condition. Back end is C++ event scheduler, Protocols mostly & fast to run, more control. Front end is OTCL Creating scenarios, extensions to C++ protocols & fast to write and change.

IV. ANALYSIS AND IMPLEMENTATION OF PERFECT DIFFERENCE NETWORK

4.1 Perfect difference network

Perfect Difference Network (PDN) based on the PDS $\{0,1,s_2,\ldots..,s_\delta\}$ There are $n= \delta^2+ \delta +1$ nodes, numbered 0 to n-1. Node i is connected via directed links to nodes $i\pm1$ and $i\neq s_j$ (mod n), for $2 \leq j \leq \delta$. given that all index expressions in this paper are evaluated modulo n, henceforth, we will delete the qualifier "mod n" in our presentation. The preceding connectivity leads to a chordal ring of in and out-degree $d=2\ \delta$ and Diameter D=2 (this is justified later). Because, for each link from node i to node j, the reverse link from node j to node i also exists, the Network can be drawn as an undirected graph[1].

Every normal-form PDS contains 1 as a member. Therefore, PDNs based on normal PDNs are special types of chordal rings. In the terminology of chordal rings, the links connecting consecutive nodes i and i+1 are rings, the links connecting consecutive nodes i and i+1 are ring links, while those that connect non-consecutive nodes i and $i+s_j$, $2 \leq j \leq \delta$, are skip links or chords.

4.2 Steps for Developing PDN from PDS

i. Take the value of δ and calculate the value of $n= \delta^2+ \delta +1$

ii. Note the PDS for the above value of δ from the PDS table specified above.

iii. For constructing PDN follow the steps for node connectivity.

iv. Connection among the nodes is obtained as follows:

v. For any node i connections is as follows $i\pm1$ and $i \pm sj$ (mod n) where $j>= \delta$

Then we get the corresponding Perfect Difference Network for value of δ and corresponding no of nodes**.**

4.3 PDN Generation

4.3.1 Example of PDN Generation for δ=2 based on the PDS {0, 1, 3}

First go through the initial value of δ=2 and see how a Perfect Difference Network would be as follows:
Go as per the steps prescribed below:

4.3.1.1 Steps of implementation for δ=2 based on the PDS{0,1,3}

i. As specified in the steps above we will take the value of δ =2
ii. Calculate the no of nodes as $n=\delta^2+\delta+1$
iii. Obtain the no of nodes = 7
iv. Go through the PDS table and note the corresponding PDS as {0,1,3}
v. Calculate the each node connectivity by using the formula specified in the
vi. steps for PDS to PDN conversion.
vii. Construct a routing table for each node connectivity.
viii. Construct the Perfect Difference Network which will be as follows.

4.3.1.2 Calculations for node n=7 and δ=2

For the purpose of calculations take the notice of PDS for δ =2 which is {0,1,3}
Which are $s_0=0, s_1=1$ and $s_2=3$ Here consider the formula as i±1 and i±sj(mod n) where j<= δ
So here we have j=2 since we have δ=2 so $s_2=3$ which we will be used for calculation purpose.

For node i=0: 0+1=1, 0-1=6, 0+3=3, 0-3=4

For node i=1: 1+1=2, 1-1=0, 1+3=4, 1-3=5

For node i=2: 2+1=3, 2-1=1, 2+3=4, 2-3=6

For node i=3: 3+1=4, 3-1=2, 3+3=6, 3-3=0

For node i=4: 4+1=5, 4-1=3, 4+3=0, 4-3=0

For node i=5: 5+1=6, 5-1=4, 5+3=1, 5-3=2

For node i=6: 6+1=0, 6-1=5, 6+3=2, 6-3=3

After the above calculations the table will be as follows as depicted below:

4.3.1.3 Node connectivity for δ=2 and n=7 for PDS {0, 1, 3}

Table 4.1: Node connectivity table for δ =2

Node i	skip links	ring links	Connecting links
0	3,4	1,6	1,3,4,6
1	4,5	0,2	0,2,4,5
2	5,6	1,3	1,3,5,6
3	0,6	2,4	0,2,4,6
4	0,1	3,5	0,1,3,5
5	1,2	4,6	1,2,4,6
6	2,3	0,5	0,2,3,5

4.3.1.4 Perfect Difference Network for δ= 2 and n=7 for PDS {0, 1, 3}

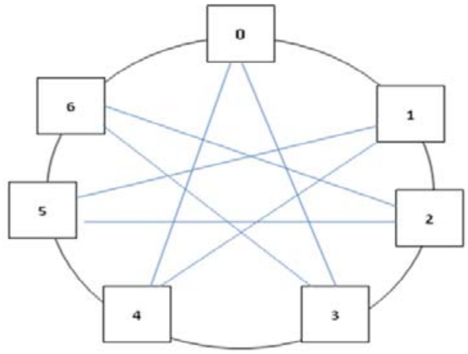

Fig.2: PDN with n = 7 nodes based on the Perfect Difference Set {0, 1, 3}

V. Algorithmic Steps

Each module viz #1, #2… was well defined in terms of requirements, efforts and time required to build even before the work was started. The steps are as follows:

- As the first module of the program the NODE Generator takes δ and the mathematical formula $\delta^2 + \delta + 1$ as requirements and gives the corresponding value of n as output.
- The second module of program is entering the PDS set for the previously calculated value of n.
- The third module using the result of the former module converts the sets into the corresponding nodes and find out the node connectivity for each node.
- The fourth module is about taking δ, n, corresponding PDS and connectivity table as an input preparing a tcl script for showing the data transition in the PDN. This script is stored with an extension .tcl in the memory.
- The tcl script is then compiled and the corresponding output displaying the data transition or traffic in the PDN in NAM i.e. Network Animator is produced. This is the Fifth module. The result is then analyzed using the Latency and Throughput graph .

VI. TESTING & SCREENSHOTS FOR PDN

1. Now after clicking the play button we will see the data flow from n-0 to n-5 when there is no traffic. By clicking on the link we can able to see the bandwidth of the topology.

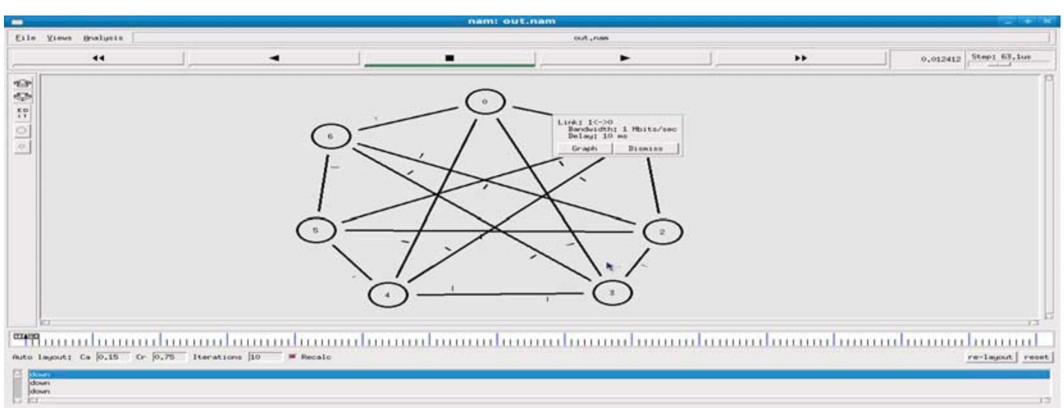

Fig.3 : PDN of 7 Nodes

2. When there is traffic in the network and we want to send data packets from node-0 to node-5 then the flow of packet will be as shown in below:

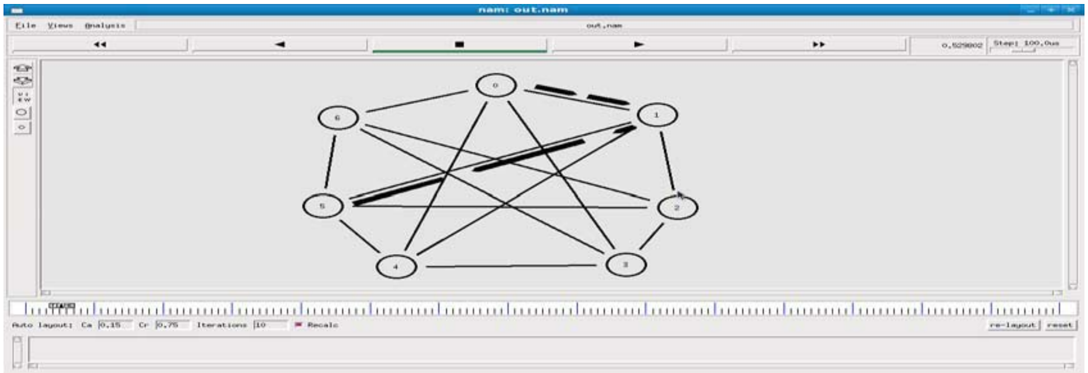

Fig. 4 : Flow of Data Packet from node=0 to node-5

3. If there is any link failure, say link 1-5 become fail then it is indicated by the red line and the packets will flow through another path according to the routing table which will show the shortest path from node-0 to node-5 as shown below:

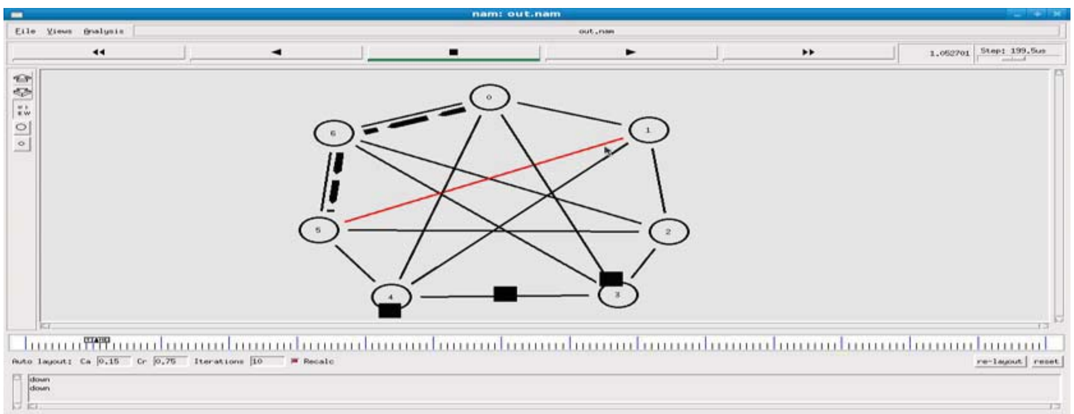

Fig.5 : Link Failure between nodes 0-5

4. In all the above screenshots it has been seen that the packets were going through only one hope in the PDN Network. Now the screenshot given below shows that in PDN the packets may follow at most two hops to send data from source to destination here the packets are flow from node-0 to node-5 and from node-1 to node-6 by at most two hops.

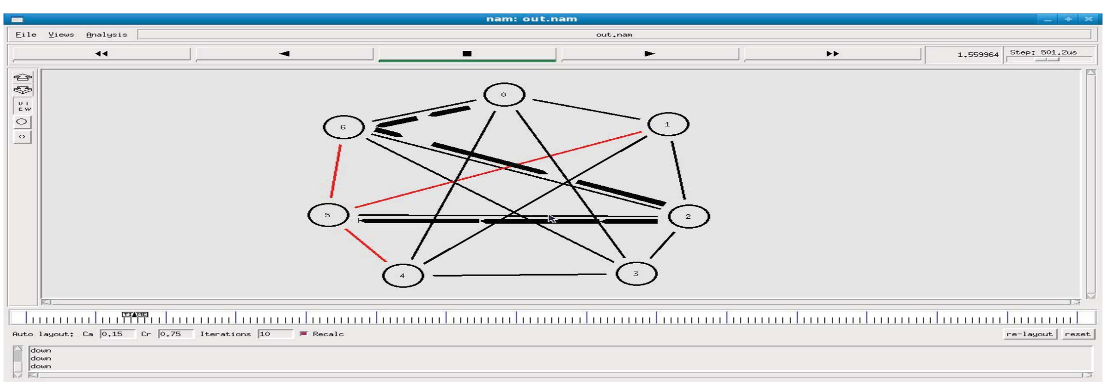

Fig. 6 : Transmission of Packet in more than two hops at Extreme condition

VII. CONCLUSION

We have analyzed and simulated the Perfect Difference Networks and the mathematical underpinnings that make it desirable as robust, high-performance interconnection networks. PDN is an approach to design a network that not only stands big in the performance list but also rules out the limitations inherent in each of the architectures at a lesser cost.

In our project we have implemented the Perfect Difference Network for wired networks. We have implemented the wired Perfect Difference Network for δ=2,3,4,5,7,8,9,11,13, and 16, where number of nodes can be calculated by the formula, n= δ^2+ δ +1. For simulation of network we have used NS-2 as it is open source. NS-2 is a discrete event simulator and it provides one to one correspondence between a class in compiled hierarchy and the one in interpreted hierarchy. We have tested the network for two different transport layer protocols viz., TCP and UDP. Again we have studied the network parameters like throughput and latency for the same Perfect Difference Network for various values of δ where we found that the throughput for the network using TCP is more than that for the network using UDP. And latency is found to be constant corresponding to specified path for both the designed networks using either TCP or UDP, as we have observed the latency at different time intervals and ultimately no congestion is found there. In terms of scalability we can conclude that the Perfect Difference Network is not so scalable as compared to mesh topology.

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