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Implementation & Throughput Analysis of Perfect Difference Network (PDN) in Wired Environment

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Abstract

This paper is about Perfect Difference Network (PDN) which is an asymptotically optimal method for connecting a set of nodes into a Perfect Difference Network with diameter 2, so that any node is reachable from any other node in one or two hops.
We aim to show a simulated result of the data transmission in PDN for δ value 2 & 3 for wired network and later analysis of trace file to find the Throughput. During implementation we have tried to make disturbance in the network to better analysis of PDN implementation in wired network.

Keywords: *Perfect Difference Network*, *Perfect Difference Network*, *throughput, Wired Network, Wireless network.*

1. Introduction

Network throughput is measured as the average rate of successful message delivery over a communication channel. The data may be delivered over a link, or pass through a certain network node and is usually measured in bits per second, data packets per second or data packets per time slot. Throughput varies from wireless to wired network.

The n-node complete graph and the n-node ring represent the two extremes of network connectivity patterns. Intermediate architectures between n-node complete graph connectivity and n-node ring connectivity can be obtained in a variety of ways, providing tradeoffs in cost and performance. Network cost is affected, among other things, by the (maximum) node degree d, while indicators of network performance and network cost. Perfect difference network is one such network which is based on the concept of perfect difference sets. Fig.1. the spectrum of networks in terms of node degree.

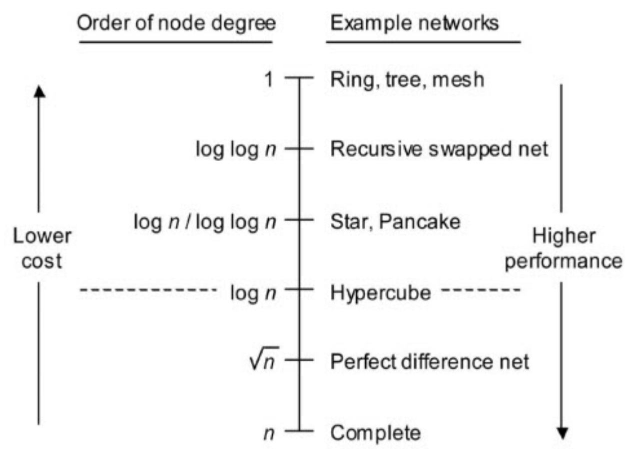

Fig 1. Various network with node degree & cost

2. Perfect Difference Set

Given that the complete graph Kn (with diameter D ¼ 1) is impractical for large n, it is quite natural to consider the best topology for D ¼ 2, the next most desirable network diameter. Based on Moore bounds, a degree-d digraph with D ¼ 2 can have no more than n ¼ d2 þ d þ 1 nodes. The corresponding upper bound n ¼ d2 þ 1 for undirected graphs is not much different. Examples of diameter-2 networks of small sizes include the Petersen and Hoffman-Singleton networks [7]. Perfect difference sets provide the mathematical tools for achieving this optimum number of nodes, in an asymptotic manner, within the framework perfect difference networks or PDNs.

TABLE 1
Perfect Difference Sets (PDS) in their Normal forms (0, 1) for δ =16.

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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

Theorem 1: A sufficient condition that there exist δ + 1 integers *s*0, *s*1, . . . , *s*δ having the property that their δ2 + δ differences *si* – *sj*, 0 ≤ *i* ≠ *j* ≤ δ, are congruent, modulo (δ2 + δ + 1), to the integers 1, 2. . . δ2 + δ in some order is that δ be a power of a prime.

Definition 1: Perfect difference set (PDS) – A set { *s*0, *s*1, . . . , *s*δ } of δ + 1 integers having the property that their δ2 + δ differences *si* – *sj*, 0 ≤ *i* ≠ *j* ≤ δ, are congruent, modulo (δ2 + δ + 1), to the integers 1, 2, . . . , δ2 + δ in some order is a *perfect difference set* of order δ. Perfect difference sets are sometimes called simple difference sets. PDS need not contain an integer outside the interval [0, δ2 + δ], because any integer outside the interval can be replaced by another integer in the interval without affecting the defining property of the PDS.

Theorem 2: Given a PDS {*s*0, *s*1, . . . , *s*δ} of order δ, the set {*as*0 + *b*, *as*1 + *b*, . . . , *as*δ + *b*}, where *a* is prime to δ2 + δ + 1, also forms a perfect difference set. By definition, any perfect difference set contains a pair of integers su and sv such that su –sv ≡ 1 mod (δ2 + δ + 1). By Theorem 2 and the observation that preceded it, subtracting su from all integers in such a PDS yields another PDS that contain 0 and 1

Definition 2: Normal PDS – A PDS {*s*0, *s*1. . . *s*δ} is reduced if it contains the integers 0 and 1. A reduced PDS is in normal form if it satisfies *si* < *si*+1 ≤ δ2 + δ, 0 ≤ *i* < δ.

Definition 3: Equivalent PDSs – Two different PDSs are equivalent iff they have the same normal form {0, 1, *s*2, *s*δ}.

Property 1: Multiplicity- For any order δ, there exist more than one PDS. Perfect Difference sets with order δ as a power of prime number and number of nodes, n= δ2 + δ + 1 are

3. Perfect Difference Networks

Consider the normal-form PDS {0, 1, *s*2. . . *s*δ} of order δ. We can construct a direct interconnection network with *n* = δ2 + δ + 1 nodes based on this PDS as follows

Definition 4: Perfect difference network (PDN) based on the PDS {0, 1, *s*2, . . . , *s*δ} – There are *n* = δ2 + δ + 1 nodes, numbered 0 to *n* ± 1. Node *i* is connected via directed links to nodes *i* ± 1 and *i* ± *si* (mod *n*), for 2 ≤ *i* ≤ δ. Because all index expressions in this paper are evaluated modulo *n*, henceforth we will delete the qualifier "mod *n*." 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 (*j*, *i*) also exists, the network corresponds to an undirected graph. Every normal-form PDS contains 1 as a member. Therefore, PDNs based on normal-form PDSs are chordal rings. In the terminology of chordal rings, the links connecting consecutive nodes *i* and *i* + 1 are *ring links*, while those that connect nonconsecutive nodes i and *i* + *si*, 2 ≤ *i* ≤ δ, are *skip links* or *chords*. The link connecting nodes *i* and *i* + *si* is referred to as the *forward skip link* of node *i* and *backward skip link* of node *i* + *si*. Similarly, the ring link between nodes *i* and *i* + 1 is a *forward (backward) ring link* for *i* (*i* + 1).

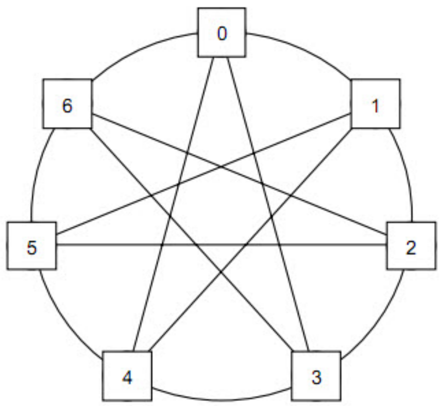

Fig. 2. PDN with *n* = 7 nodes based on the perfect difference set {0, 1, 3}.

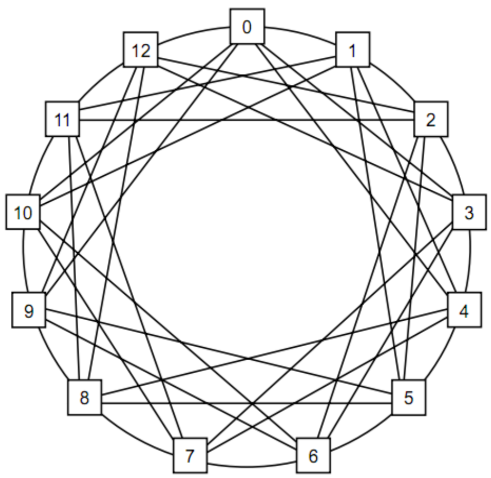

Fig. 3. PDN with *n* = 13 nodes based on the perfect difference set {0, 1, 3, 9}.

4. PDN generation and analysis from PDS

In this section we will look at the procedures for obtaining PDN from PDS for δ having values 2, 3 and 4 respectively. Then we will create a connectivity table for each node based on result of findings obtained from above step. We will also find out optimal lookup table for the PDNs by using the property that a PDN has diameter D of 2.

PDN generation for PDS.

It is given under the following headings:

Steps of implementation of PDN for δ

- Here value of δ is 2 & 3 as is evident from the given PDS.
- Number of nodes n is given by equation $n = \delta^2 + \delta + 1$.
- Go through Table 1 and note the corresponding PDS for the chosen value of δ.
- Calculate the ring links and skip links for each node by using the formulae specified in the steps for PDS to PDN conversion.
- Construct the PDN from above obtained data.
- Find out the lookup table for the PDN, keeping in mind that the diameter of the network is 2.

a. Calculations for PDN with δ = 2 and number of nodes n = 7

TABLE 2
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

b. Calculations for PDN with δ = 3 and number of nodes n = 13

TABLE 2
Node connectivity table for δ = 3

Node i	Skip Links	Ring Links	Connecting Links
0	3,4,9,10	1,12	1,3,4,9,10,12
1	4,5,10,11	0,2	0,2,4,5,10,11
2	5,6,11,12	1,3	1,3,5,6,11,12
3	0,6,7,12	2,4	0,2,4,6,7,12
4	0,1,7,8	3,5	0,1,3,5,7,8
5	1,2,8,9	4,6	1,2,4,6,8,9
6	2,3,9,10	5,7	2,3,5,7,9,10
7	3,4,10,11	6,8	3,4,6,8,10,11
8	4,5,11,12	7,9	4,5,7,9,11,12
9	0,5,6,12	8,10	0,5,6,8,10,12
10	0,1,6,7	9,11	0,1,6,7,9,11
11	1,2,7,8	10,12	1,2,7,8,10,12
12	2,3,8,9	0,11	0,2,3,8,9,11

5. Experimental Evaluation

Perfect Difference Network in Wired Network

We have implemented PDN in wired environment using the simulator NS2.It primarily shows the communication from one node to the other node. Some conditions are so arising in which the links are made down. So in this case it finds the other way which is again optimum and reaching the destination in which we find it tries to find simple 2 hop path but if more number of links are failed then at most it find 4-hop path. We have taken it for 7 nodes to implement PDN as shown in the figure below:

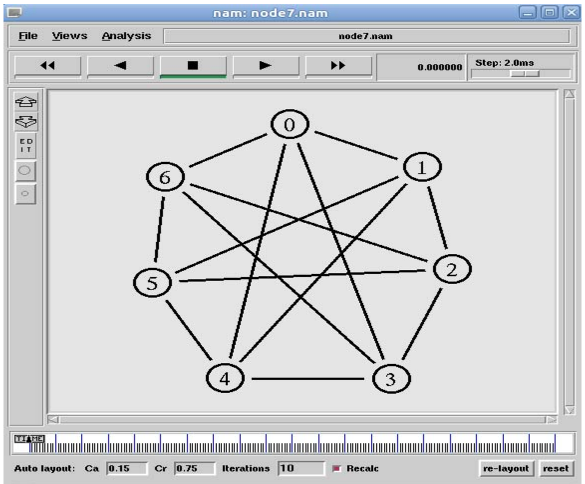

Fig. 4 PDN with 7 nodes

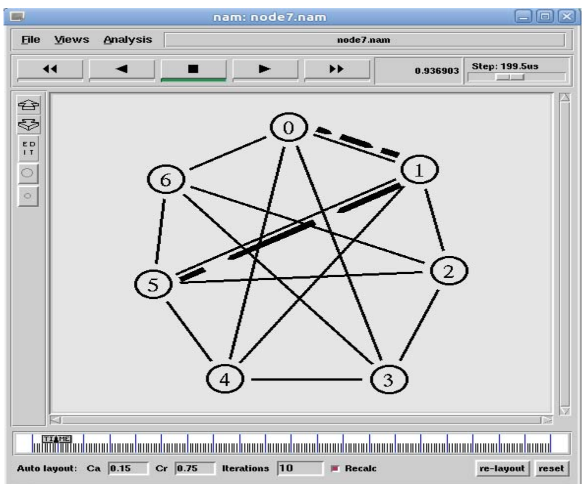

Fig. 5 Data Transmission from node 0 to node 5 via node1

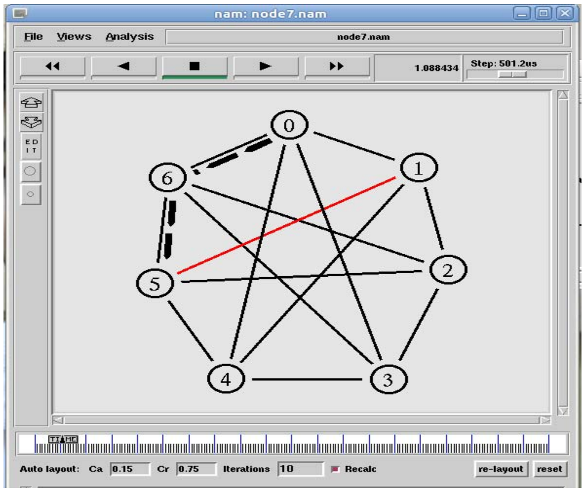

Fig. 6 Data Transmission from node 0 to node 5 via node 6

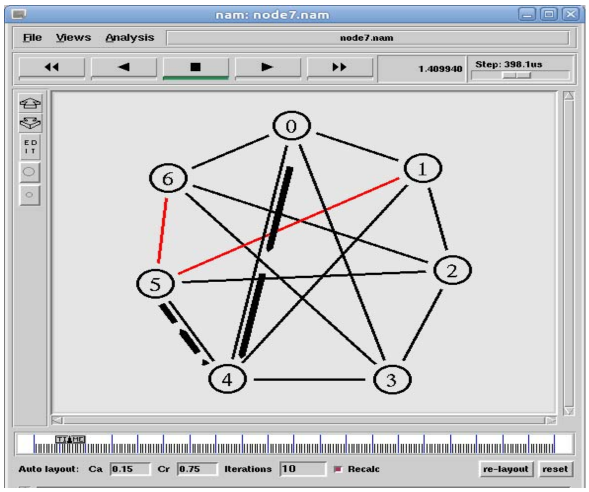

Fig. 7 Data Transmission from node 0 to node 5 via node 4

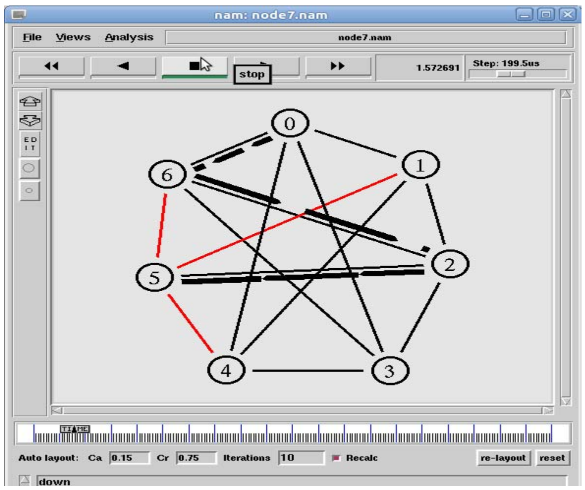

Fig. 8 Data Transmission from node 0 to node 5 via node 6 & node 2

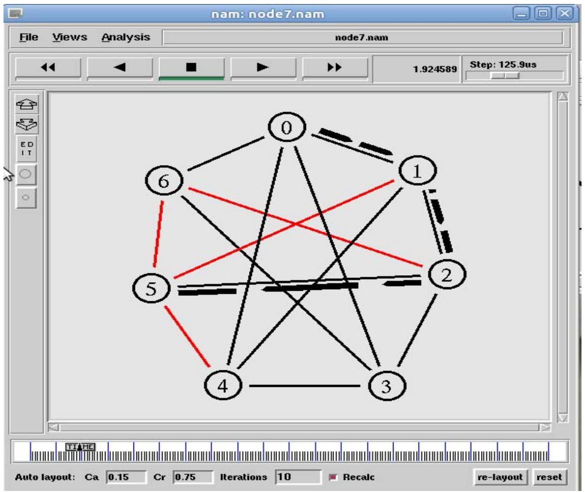

Fig. 9 Data Transmission from node 0 to node 5 via node1

This module shows the connectivity of PDN for δ=2 and n=7 nodes. And other links connected. The data is route from one end to the other end with only two hops. In case of any link failure the route is changed through other nodes. As shown in the figure below.

In the next module we shows the connectivity of PDN for δ=3 and n=13 nodes, other links connected. As shown in the figure below:

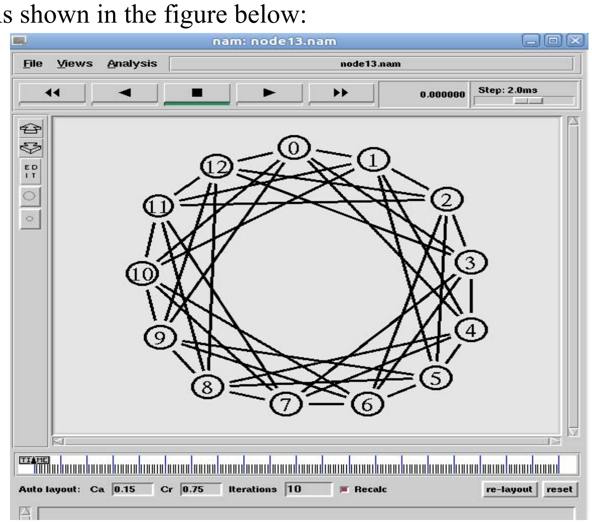

Fig. 10 PDN with 13 nodes

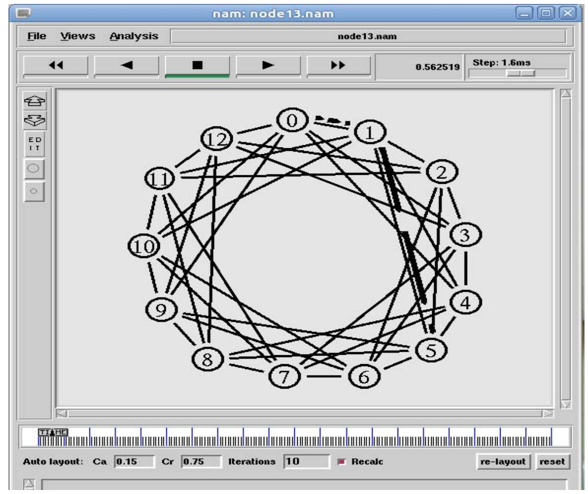

Fig. 11 Data Transmission from node 0 to node 5 via node1

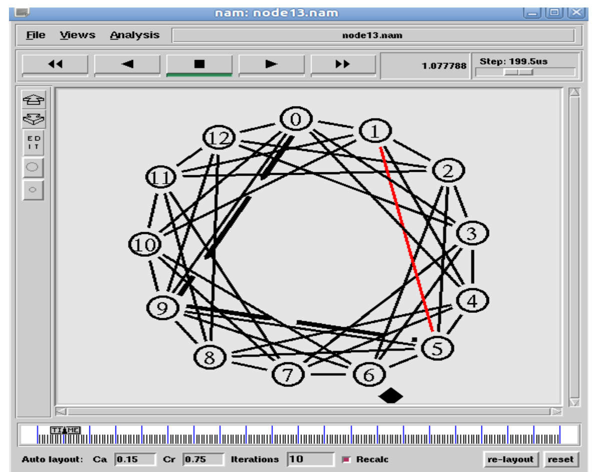

Fig. 12 Data Transmission from node 0 to node 5 via node 9

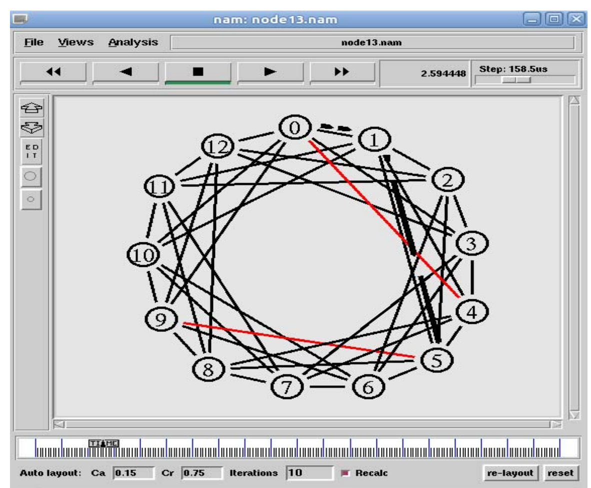

Fig. 13 Data Transmission from node 0 to node 5 via node1

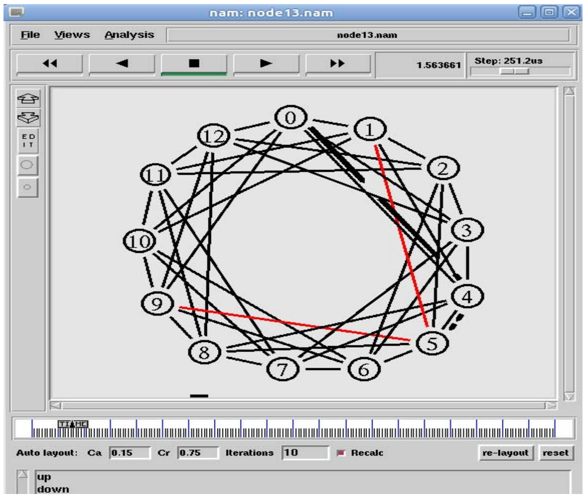

Fig. 14 Data Transmission from node 0 to node 5 via node 4

6. Simulated Results

This is the throughput calculation for two values of ‘δ’, i.e. 2 and 3.Tis is implemented in wired network as shown above.

TABLE 3
Simulation Result

Time	Node 7 δ=2	Node 13 δ=3
1	94	98
2	169	147
3	190	157
4	203	170
5	203	189
6	210	191
7	204	186
8	209	187
9	204	182
10	208	188
11	205	186
12	208	187
13	205	183
14	208	184
15	203	185
16	190	185
17	179	186
18	169	187
19	160	187
20	160	187

7. Conclusion

In the paper , the results are very different than what expected and though there are link failures during the transition of data but the throughput graph shows the steady output for both the values of ‘δ’ in wired network.

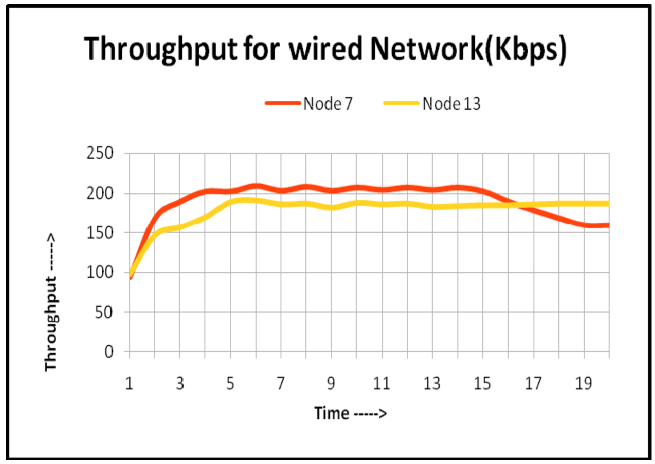

Fig. 15 Throughput analysis for node 7 and node13

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