Maximization of Per Node Throughputfor2HR-Manets under Limited Buffer Constraint

B. BasaveswaraRao, SK. MeeraSharief, K. GangadharaRao, K Chandan

Abstract: ***This paper proposes an analytical framework on the lines of Jia Liu et al for maximization of per node throughput under limited buffer constraint of two hop relay (2HR) MANETs. To achieve maximization of per node throughput through partial derivative method with necessary and sufficient conditions (NSC) based search algorithm for finding the optimal values of network control parameter, buffer size at source node and buffer size at relay node. The per node throughput is evaluated through NSC search algorithm for different values of packet generating probability, area of the MANET and node density. The numerical results illustrate the effects of different network parameters on throughput performance.***

Keywords: 2HR, Source Buffer, Relay Buffer, Node Density, Throughput.

I. INTRODUCTION

The technological developments in Internet and wireless communications have increased exponentially over last two decades.Due to mobility of devices there is a necessity to investigate theMobile Ad Hoc Network,which is being a infrastructure less, wireless network without centralized administration. In such type of networks the mobility of nodes depends on the different parameters such as mode of mobility of users, mechanism of forwarding packets and node density. The real time applications of MANETs are military, disaster relief, rescue applications and border communication during war time etc.

The commercialization of MANET can be achieved by two fold 1. With thorough understanding of node mobility, routing mechanism, congestion control, security mechanisms etc., through real timeapplications. 2. To achieve the customized MANETs with better QOS metrics.One of the major research problem in MANETs is the packet dropping which would be directly or indirectly effecting the important QOS metrics of MANETs there is always a possibility to create some buffer space at individual node so that the packet would not get dropped, instead they get stored in buffer space.

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In the real time usage of MANETs, the existence of finite buffer at each node is quintessential characteristic for their basic existence would be the main contribution for optimizing QOS parameters. The quantification of QOS metrics in the context of infinite buffer size is not appropriate and there would not be any accuracy in doing so.

From the last two decades several researchershave derived the QOS metrics for finding parameters in MANETs using queuing models. SaadTalib has developed queuing approach to model the MANET performance using two queuing mechanisms as Drop Tail and REM for different queuing parameters and observed the REM performed well in each observation for infinite buffer. Ahyoung Lee and Iikyeun Ra have developed a queuing network model for multimedia communication using adoptive-gossip algorithm for maximizing the achievable throughput for infinite buffer. Michael J.Neely and EytanModianohave drawn exact expressions for network capacity and also fundamental rate delay curve.All the researchers aforementioned have assumed infinite buffer which never had any considerable bearing on optimizationofQoS Parameters because of the implicit assumption thatthe dropping probability is zero.Jia Liu and Yang Xu have performed the modeling for MANETs under general limited buffer constraints and resource allocation for throughput optimization using b/b/1/k Bernoulli process and theoretically modeled. Jia Liu and Yang Xuhavedeveloped a general theoretical framework and determined the end to end delay using basic probabilities of two hop relay network.Hiroki Takakura and Ruo Ando have studied throughput optimization for 2HR MANET under the general buffer constraint and derived the exact expressions for per node throughput. B.BasaveswaraRao and SK.MeeraSharief have compared the routing protocols of MANET and found the optimal protocol in terms of performance and also investigated the impact of mobility patterns on different routing protocols in MANETs with and without buffer schemes and discussed the observations in both the schemes.

All the above mentioned research contributions are related to MANET QOS measures like dropping probability for both with and without buffers. But these contributions have never focused on optimizing the routing control parameter, buffer sizefor throughput maximization involved in packet transmission process, under different network areas for new packet arrivals or relay packet arrivals. This objective of throughput

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maximization is to identify the MANET efficiency.

There is a need to achieve maximize the throughput with buffer optimization and routing control.To fill this gap and to achieve this objective the analytical study is proposed on the line of[9, 10].

The main objectives and contributions of this paper are as follows:

- To derive a better procedure than earlier contributions of [9,10] optimal values for the routing control parameter, source and relay buffer values.
- In this direction a specific set of necessary and sufficient conditions are derived through partial derivative method.
- To provide a search algorithm for finding the optimal values for maximization of per node throughput.
- The numerical illustration is presented for supporting this process and drawn conclusions.

The remaining part of thispaper is organized as follows. Section 2 is discussed about the related work with limited buffer in MANETs by taking different performance metrics withan intent towards buffer and service optimization. Section 3 clearly discusses about the preliminaries of the system and the respective parameter definitions and derivations. Methodology, Exact expressions and derivations for enhancement of buffer, routing control parameter andmaximization of throughputusing a novelistic algorithm and different derivations are presentedin section 4.In section 5numerical illustrationsof the network setting parameters and initial values are provided. Results and discussions are presented.These were illustrated and examined deeply in section 6.Finally the conclusions and future scope of the work are presented in section 7.

II. RELATED WORK

A significant amount of research work has been published earlier in the area of performance analysis of MANETs through analytical and simulation studies. Some of the research works mentioned below related to the queuing model based performance metrics with buffer and without buffer at each node of the MANET.

F.R.B. [1] Cruz et al have developed a multi objective approach for the buffer allocation and throughput tradeoff problem for single server queuing model for Generalized Expansion Method through Multi Objective Genetic Algorithm and found the optimal solutions. A.Lee and I.Ra [2] have proposeda queuing network model based on adoptive-gossip algorithm with loss probabilityfor reducing the routing load. Mouna A and Mounir F et al [3] have improved the performance of delay tolerant mobile networks using mobile relay nodes under general buffer constraint and conducted tests for different mobility models as network settings.Yujian Fang [4]etal have reported practical performance of MANETs in single server queuing theory for buffer size, packet life time, throughput, packet loss ratio, and packet delay in a theoretical framework.

Jia Liu and Min Sheng [5]et al revealed the relationship between the throughput capacity and relay-buffer blocking probability under general buffer constraints with 2HR-α Scheme.Yin Chen [6] has derived the expressions for throughput capacity of A-MANETs and developed a theoretical framework for exact capacity evaluation for other MANET scenarios.Jia Liu and Min Sheng [7]et alhave studied a novel theoretical framework with two hop relay mobile ad hoc networks for end to end delay modeling. Wu wang and Bin yang [8] et al have studied packet delivery delay performance in three-dimensional mobile ad hoc networks using an algorithm and derived the closed-form expressions. Jia Liu and Ruo Ando [9] et al have created a theoretical framework to calculate the inherent buffer occupancy behaviors in Bernoulli process model.Jia Liu and Yang Xu [10] et al have modeled a 2 Hop Relay with routing control parameter for packet delivery in MANET under general limited buffer constraints and explored the ideas to implement in an experimentalsetup.B.BasaveswaraRao and SkMeeraSharief[11] et al have performed a comparison between the routing protocols and identified the best performing protocol using a limited buffer at a random value through simulation. SK M Sharief and B BasaveswaraRao[12]et alhave identified the impact between the routing protocols using buffer considering the buffer value asrandomly and without buffer through simulation for different network parameters.

Ad hoc nodes should be deployed compactly to maintain a elevated extent of interaction between mobile nodes because of their limited transmission power, and many ad hoc route discovery protocols have been implemented based on simple flooding method from occasion to occasion broadcasting routing packets in all the other nodes to provide the shortest-path routing techniques and achieve a far above the ground extent of availability to set up secure routes in an optimistic way.

This paper proposes a queuing network model with B/B/1/K that maintains at each node a limited buffer B, the packet generating at each node is Bernoulli process with packet generating probability rate λ and service generating rate μ [9, 10], number of nodes in the network are "n" and area is m x m which is equally partitioned with an m^2 number of cells.

III. PRELIMINARIES

This section presents the brief idea about the notations and definitions used to derive the maximum throughput exact equations by [9,10] for limited buffer MANETs. The required definitions and notations are explained below.

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A. Notations:

m: Area of the torus network

n: Number of mobile nodes in the torus network

B: Size of the total buffer at each node

B_s: Size of the buffer at Source Node

B_r:Size of the buffer at Relay Node

P_{sd}:Probability that a node gets the chance to transmit the packet fromsource to destination

P_{sr}:Probability that a node gets the chance to transmit the packet fromsource to relay

P_{rd}:Probability that a node gets the chance to transmit the packet fromrelay to destination

λ_s:Packet generating Probability rate at source node

μ_s:Packet transmission Probability rate at source node

α: Routing control mechanism parameter

$\pi_s(0)$:Initial probability that the packets occupying at the source buffer

$\pi_r(i)$: The probability that there are i packets occupying in the relay buffer

B. Network Model Assumptions:

The widely used network model is adopted from [6, 9, 10].The torus network area is evenly partitioned with non-overlapping cells of m x m area contains n mobile nodes randomly move in the network area following a uniform type mobility model. By using this mobility model, the location identity of node is motionless with stationary distribution uniform on the network area on theother hand routes of different nodes are independent and identically distributed. The time slotted, supports only one transmission between two nodes within the radio transmission range. The concurrent transmission of packets in different cells will not interfere with each other. There also exists more than one node in a cell. Each node in cell becomes the transmitter with equal likelihood. The maximum number of nodes in a cell is not more than three, i.e. source node, destination node and relay node. The minimum number of nodes in a cell may be zero. It means a cell may or may not contain a node.

C. *Traffic Model:*

Bernoulli process model is used for packet generating process at each node with a rate of λ_s and during a time slot the total amount of data that can be transmitted from a transmitter to its corresponding receiver is fixed and normalized to one packet. Unicast traffic flow model is used as the traffic model in this paper [10] which is n unicast traffic flows exist in the network. In the network each node is the source of one traffic flow and meanwhile the destination of another traffic flow.

D. Buffer Model:

As illustrated in fig 1, consider that node maintains a total buffer space of B packets, which is allocated to the source buffer of size B_s and relay buffer of size B_r .i.e.,

$$B=B_s+B_r \qquad (1)$$

The source buffer is for storing the packets of its own flow and works as queuing mechanism in an order of first in first out (FIFO) source queue.while the relay buffer is for storing packets of all other n-2 flows and works as n-2 FIFO virtual relay queues.

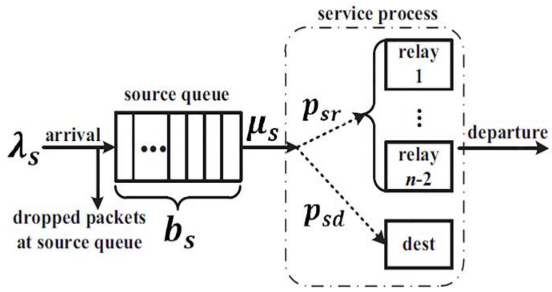

Fig1:B/B/1/B_sQueuing Model for Source Buffer

E. 2HR-Routing Scheme

To support the efficient operation of a MANET under the general buffer constraint, introduced a new routing scheme and control parameter into the 2HR scheme for packet delivery and routing from the source node to destination node without loss of generality. Here a tagged flow is focused as source node to destination node as S and D respectively.Once S gets access to wireless channel at the beginning of the time slot in the torus network area of size mxm in the total nodes n.It executes the 2HR Scheme as follows.

i. If D is within the cell of S, S executes the source to destination operation.

ii. If D is not within the cell of S, S randomly selects one of the node R as relay within its cell as its receiver, it executes source to relay operation with a two way probability, and continued relay to destination operation with another way of probability.

F. *Basic Probabilities :*

Let P_{sd},$P_{sr}$and P_{rd}[9, 10] denote the basic probabilities that a node gets the chance to transmit packet from the source to destination (S-D) , source to relay (S-R) and finally relay to destination (R-D) operations respectively and these basic probabilities are as follows

$$P_{sd}=\frac{m^2}{n}-\frac{m^2-1}{n-1}+\frac{m^2-1}{n(n-1)}\left(1-\frac{1}{m^2}\right)^{n-1} \qquad (2)$$

$$P_{sr}=\alpha\left\{\frac{m^2-1}{n-1}-\frac{m^2}{n-1}\left(1-\frac{1}{m^2}\right)^{n}-\left(1-\frac{1}{m^2}\right)^{n-1}\right\} \qquad (3)$$

$$P_{rd}=(1-\alpha)\left\{\frac{m^2-1}{n-1}-\frac{m^2}{n-1}\left(1-\frac{1}{m^2}\right)^{n}-\left(1-\frac{1}{m^2}\right)^{n-1}\right\} \qquad (4)$$

G. Buffer occupancy process analysis

a. *Source buffer :*

The buffer at source node can be defined as, in every time slot a new packet is generated with probability of $\lambda_s$and a service opportunity arises with probability of μ_s can be determined as

$$\mu_s=P_{sd}+P_{sr} \qquad (5)$$

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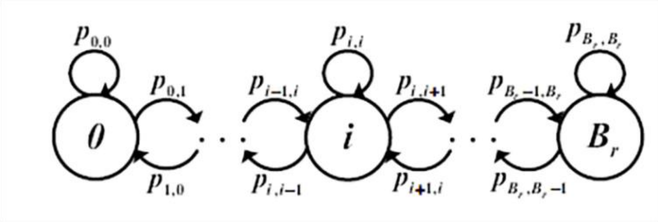

Fig:2 Birth Death Chain Processes of State Machines

Thus, the occupancy process of source buffer can be modeled by a B/B/1/$B_s$queue.Let π_s (i) denote the probability that there are i packets occupying the source buffer in the stationary state then the stationary occupancy state distribution(OSD) of the source buffer $\prod_s = \{ \pi_s(0), \pi_s(1), \ldots, \pi_s(B_s)\}$ is given by

$$\pi_s(i) = \begin{cases} \dfrac{\mu_s - \lambda_s}{\mu_s - \lambda_s.\theta^{Bs}}, i = 0 \\ \dfrac{\mu_s - \lambda_s}{\mu_s - \lambda_s.\theta^{Bs}} \dfrac{1}{1-\mu_s} \theta^i, 1 \le i \le B_s \end{cases} \quad (6)$$

$$where, \theta = \frac{\lambda_s(1-\mu_s)}{\mu_s(1-\lambda_s)}$$

b. *Relay Buffer:*

The analysis of occupancy process of relay buffer in Source S can be determined as π_r (i).Let π_r (i) may denote the probability that there are i packets occupying the relay buffer in the OSD determined as

$$\pi_r(i) = \frac{C_i(1-\pi_s(0))^i \beta^i}{\sum_{k=0}^{B_r} C_k(1-\pi_s(0))^k \beta^k},$$

$$0 \le i \le B_s \quad (7)$$

$$where\ \beta = \frac{\alpha}{1-\alpha} \text{ and } C_i = \binom{n-3+i}{i}.$$

From the above notations and basic definitions the following section is to improve the procedure for contributions of [9,10] the buffer size at source node, relay node, routing control parameterare optimized for maximization of per node throughput for various given values of m, n, and λ_s.

IV. IMPROVED DERIVATION FOR MAXIMIZATION OF THROUGHPUT(T*)

The main objective of this paper is toimprove the maximization of per node throughput of a limited buffer MANETs with 2HR schemecompared to earlier contributions of [9,10]. To achieve this objective the contributions [9, 10] have been considered and also adopt the exact derivation of per node throughput, to find the optimum values of α*, B_s*, B_r* for given values of λ_s,m and n.The per node throughput (T) is derived in [9, 10] as follows.

$$T = P_{sd}(1-\pi_s(0)) + P_{sr}(1-\pi_s(0)(1-\pi_r(B_r))), \quad (8)$$

The authors[9,10] achieve maximization of per node throughput (T*) through optimization of α, B_s, and B_r withpartial derivative method after thengolden search algorithm is used forfinding the corresponding α*, **B_s*andB_r***.

This section intends to find optimal values for α*, B_s* and B_r* to maximize T* using partial derivative method andalso to derive necessary and sufficient conditions.For this partial derivative method is used to arrive at necessary and sufficient conditions, these conditions are used as a basis to develop novel criteria based search algorithm.

If one observes the equation (8),there is a condition to be identified that the values of π_s(0) and π_r(B_r) are minimized then T is maximized. So for minimization of π_s(0)and π_r(B_r), thepartial derivative of equations (6) and (7) and equals to zero then derive the necessary and sufficient conditions withsecond order partial derivative which is positive . From these suitable necessary and sufficient conditions an algorithm is proposed for finding α*, B_s* and B_r* which is as follows.

A. *Derivations Of The Necessary And Sufficient Conditions For The Existence Of A* And B_s*:*

Let π_s(0) denote the initial probability that the packets occupying the source buffer is given in (6) then first partial derivative and second partial derivatives are given below:

$$\pi_s(o)\cdot(\mu_s - \lambda_s.\theta^{Bs}) = (\mu_s - \lambda_s)$$

$$\frac{\partial\ \pi_s(o)}{\partial B_s}(\mu_s - \lambda_s.\theta^{Bs}) + \pi_s(o)\cdot(0 - \lambda_s.\theta^{Bs}\cdot\log\theta) = 0$$

$$\frac{\partial\ \pi_s(o)}{\partial B_s} = \frac{\pi_s(o)\cdot(0 + \lambda_s.\theta^{Bs}\cdot\log\theta)}{(\mu_s - \lambda_s.\theta^{Bs})}$$

$$\frac{\partial\ \pi_s(o)}{\partial B_s} = \frac{(\mu_s - \lambda_s)\cdot(\lambda_s.\theta^{Bs}\cdot\log\theta)}{(\mu_s - \lambda_s.\theta^{Bs})^2} \quad (9)$$

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$$\frac{\partial \pi_s(o)}{\partial B_s}(\mu_s-\lambda_s.\theta^{Bs})+\pi_s(o)\cdot(0-\lambda_s.\theta^{Bs}\cdot\log\theta)=0$$

$$\frac{\partial^2\pi_s(o)}{\partial B_s^2}(\mu_s-\lambda_s.\theta^{Bs})+\frac{\partial \pi_s(o)}{\partial B_s}\cdot(0-\lambda_s.\theta^{Bs}\cdot\log\theta)+\frac{\partial \pi_s(o)}{\partial B_s}\cdot(0-\lambda_s.\theta^{Bs}\cdot\log\theta)+\pi_s(o)\cdot(0-\lambda_s.\theta^{Bs}\cdot(\log\theta)^2)=0$$

$$\frac{\partial^2\pi_s(o)}{\partial B_s^2}(\mu_s-\lambda_s.\theta^{Bs})-2\frac{(\mu_s-\lambda_s)\cdot\lambda_s\cdot\theta^{Bs}\log\theta}{(\mu_s-\lambda_s.\theta^{Bs})^2}\cdot(\lambda_s.\theta^{Bs}\cdot\log\theta)-\frac{(\mu_s-\lambda_s)}{(\mu_s-\lambda_s.\theta^{Bs})}\cdot(\lambda_s.\theta^{Bs}\cdot(\log\theta)^2)=0$$

$$\frac{\partial^2\pi_s(o)}{\partial B_s^2}(\mu_s-\lambda_s.\theta^{Bs})=2\frac{(\mu_s-\lambda_s)\cdot(\lambda_s\cdot\theta^{Bs}\log\theta)^2}{(\mu_s-\lambda_s.\theta^{Bs})^2}+\frac{(\mu_s-\lambda_s)}{(\mu_s-\lambda_s.\theta^{Bs})}\cdot(\lambda_s.\theta^{Bs}\cdot(\log\theta)^2)$$

$$\frac{\partial^2\pi_s(o)}{\partial B_s^2}(\mu_s-\lambda_s.\theta^{Bs})=\frac{(\mu_s-\lambda_s)\cdot\lambda_s\cdot\theta^{Bs}(\log\theta)^2}{(\mu_s-\lambda_s.\theta^{Bs})}\left(\frac{2\lambda_s.\theta^{Bs}}{(\mu_s-\lambda_s.\theta^{Bs})}+1\right)$$

$$\frac{\partial^2\pi_s(o)}{\partial B_s^2}=\frac{(\mu_s-\lambda_s)\cdot\lambda_s\cdot\theta^{Bs}(\log\theta)^2}{(\mu_s-\lambda_s.\theta^{Bs})^2}\left(\frac{2\lambda_s.\theta^{Bs}}{(\mu_s-\lambda_s.\theta^{Bs})}+1\right) \qquad (10)$$

From the equations (9) and (10) to minimize$\pi_s(0)$ there must be a second derivative which is positive and first derivative beingzero. To observe (9) and (10) the necessary and sufficient conditions are drawn for minimize $\pi_s(0)$ i.e.

$$\frac{\partial \pi_s(o)}{\partial B_s}=0 \text{ and } \frac{\partial^2\pi_s(o)}{\partial B_s^2}>0 \ iff \ \mu_s<\lambda_s \qquad (11)$$

$$(\theta)^{Bs}>0 \qquad (12)$$

The maximum per node throughput will be occurred when the probability of transmission packets at source is always greater than the probability of packet generated at source that routing control parameter α yields optimal value. This condition $\theta^{Bs}>0$ will exist only which $B_s$value holds $\theta^{Bs}>0$ that $B_s$value must be a optimal value of throughput maximization where $\mu_s>\lambda_s$.

B. Derivations of The Necessary And Sufficient Conditions For The Existence Of B_r*:

Let $\pi_r(B_r)$ denote the probability that the packets occupying the relay buffer is given in (7) then first order partial derivative and second order partial derivatives are as given below:

$$\pi_r(i)=\frac{C_i(1-\pi_s(0))^i\beta^i}{\sum_{k=0}^{B_r}C_k(1-\pi_s(0))^k\beta^k},$$

$$\pi_r(B_r)=\frac{C_{B_r}(1-\pi_s(0))^{B_r}\beta^{B_r}}{\sum_{k=0}^{B_r}C_k(1-\pi_s(0))^k\beta^k}$$

$$\pi_r(B_r)=\frac{\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^{B_r}\beta^{B_r}}{\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k}=\frac{A}{B}$$

$$\frac{\partial\pi_r(B_r)}{\partial B_r}=\frac{A'B-B'A}{B^2}$$

$$A'=\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'((1-\pi_s(0))\beta)^{B_r}+\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)((1-\pi_s(0))\beta)^{B_r}\log((1-\pi_s(0))\beta)$$

$$=((1-\pi_s(0))\beta)^{B_r}\left(\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'+\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)\right)$$

$$B'=0+\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'((1-\pi_s(0))\beta)^{B_r}+\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)((1-\pi_s(0))\beta)^{B_r}\log((1-\pi_s(0))\beta)$$

$$=((1-\pi_s(0))\beta)^{B_r}\left(\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'+\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)\right)$$

$$\frac{\partial\pi_r(B_r)}{\partial B_r}=\frac{((1-\pi_s(0))\beta)^{B_r}\left(\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'+\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)\right)\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k-\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)(1-\pi_s(0))^{B_r}\beta^{B_r}\right)}{\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k\right)^2}$$

$$\frac{\partial\pi_r(B_r)}{\partial B_r}=0$$

i.e.,

$$\frac{((1-\pi_s(0))\beta)^{B_r}\left(\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'+\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)\right)\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k-\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)(1-\pi_s(0))^{B_r}\beta^{B_r}\right)}{\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k\right)^2}=0$$

$$\frac{\pi_r'(B_r)}{\partial B_r}=\frac{((1-\pi_s(0))\beta)^{B_r}\left(\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'+\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)\right)\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k-\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)(1-\pi_s(0))^{B_r}\beta^{B_r}\right)}{\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k\right)^2}$$

$$\pi_r'(B_r)\cdot\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k\right)^2=((1-\pi_s(0))\beta)^{B_r}\left(\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'+\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)\right)\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k-\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)(1-\pi_s(0))^{B_r}\beta^{B_r}\right)$$

$$\pi_r''(B_r)\cdot\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k\right)^2+\pi_r'(B_r)\cdot2\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^{B_r}\beta^{B_r}\right)\bullet\left(\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'.(1-\pi_s(0))^{B_r}\beta^{B_r}+\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)(1-\pi_s(0))^{B_r}\beta^{B_r}\right)$$

$$=\log(1-\pi_s(0))\beta)((1-\pi_s(0))\beta)^{B_r}\left(\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'+\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)\right)\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k-\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)(1-\pi_s(0))^{B_r}\beta^{B_r}\right)$$
$$+((1-\pi_s(0))\beta)^{B_r}\left(\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'+\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)\right)\left(\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'.(1-\pi_s(0))^{B_r}\beta^{B_r}+\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k\log((1-\pi_s(0))\beta)(1-\pi_s(0))^{B_r}\beta^{B_r}\right)$$
$$-\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'(1-\pi_s(0))^{B_r}\beta^{B_r}-\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)(1-\pi_s(0))^{B_r}\beta^{B_r}$$

$$\pi_r''(B_r)\cdot\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k\right)^2$$
$$=\log(1-\pi_s(0))\beta)((1-\pi_s(0))\beta)^{B_r}\left(\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'+\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)\right)\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k-\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)(1-\pi_s(0))^{B_r}\beta^{B_r}\right)$$
$$+((1-\pi_s(0))\beta)^{B_r}\left(\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'+\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)\right)\left(\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'.(1-\pi_s(0))^{B_r}\beta^{B_r}+\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k\log((1-\pi_s(0))\beta)(1-\pi_s(0))^{B_r}\beta^{B_r}\right)$$
$$-\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'(1-\pi_s(0))^{B_r}\beta^{B_r}-\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)(1-\pi_s(0))^{B_r}\beta^{B_r}$$
$$-\pi_r'(B_r)\cdot2\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^{B_r}\beta^{B_r}\right)\bullet\left(\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'.(1-\pi_s(0))^{B_r}\beta^{B_r}+\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)(1-\pi_s(0))^{B_r}\beta^{B_r}\right)$$

$$\pi_r''(B_r)\cdot\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k\right)^2$$
$$=\log(1-\pi_s(0))\beta)((1-\pi_s(0))\beta)^{B_r}\left(\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'+\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)\right)\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k-\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)(1-\pi_s(0))^{B_r}\beta^{B_r}\right)$$
$$+((1-\pi_s(0))\beta)^{B_r}\left(\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'+\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)\right)\left(\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'.(1-\pi_s(0))^{B_r}\beta^{B_r}+\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k\log((1-\pi_s(0))\beta)(1-\pi_s(0))^{B_r}\beta^{B_r}\right)$$
$$-\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'(1-\pi_s(0))^{B_r}\beta^{B_r}-\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)(1-\pi_s(0))^{B_r}\beta^{B_r}$$
$$-\frac{((1-\pi_s(0))\beta)^{B_r}\left(\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'+\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)\right)\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k-\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)(1-\pi_s(0))^{B_r}\beta^{B_r}\right)}{\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k\right)^2}\cdot2\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^{B_r}\beta^{B_r}\right)\bullet$$
$$\left(\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'.(1-\pi_s(0))^{B_r}\beta^{B_r}+\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)(1-\pi_s(0))^{B_r}\beta^{B_r}\right)$$

$$\pi_r''(B_r)=\frac{\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k\right)^2\left(\begin{array}{l}\log(1-\pi_s(0))\beta)((1-\pi_s(0))\beta)^{B_r}\left(\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'+\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)\right)\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k-\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)(1-\pi_s(0))^{B_r}\beta^{B_r}\right)\\+((1-\pi_s(0))\beta)^{B_r}\left(\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'+\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)\right)\left(\begin{array}{l}\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'.(1-\pi_s(0))^{B_r}\beta^{B_r}\\+\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k\log((1-\pi_s(0))\beta)(1-\pi_s(0))^{B_r}\beta^{B_r}\end{array}\right)\\-\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'(1-\pi_s(0))^{B_r}\beta^{B_r}-\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)(1-\pi_s(0))^{B_r}\beta^{B_r}\end{array}\right)\\-((1-\pi_s(0))\beta)^{B_r}\left(\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'+\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)\right)\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k-\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)(1-\pi_s(0))^{B_r}\beta^{B_r}\right)\cdot2\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^{B_r}\beta^{B_r}\right)\bullet\\\left(\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'.(1-\pi_s(0))^{B_r}\beta^{B_r}+\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)(1-\pi_s(0))^{B_r}\beta^{B_r}\right)}{\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k\right)^4}$$

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From the equations of $\frac{\partial \pi_r(B_r)}{\partial B_r}=0$ and $\frac{\partial^2 \pi_r(B_r)}{\partial B_r^2}=0$ to minimize$\pi_r(B_r)$ there must be a second derivative which is positive and the corresponding first derivative beingzero. To observe these equationsthe necessary and sufficient conditions are drawn to minimize $\pi_r(B_r)$ i.e.

$$\frac{\partial \pi_r(B_r)}{\partial B_r}=0 \text{ and } \frac{\partial^2 \pi_r(B_r)}{\partial B_r^2}>0$$

The second order derivative always positive because the numerator terms contains with power of 2 and logarithmic terms and hence the numerator is always positive. The denominator term contains with power of 4 so the denominator is also positive. The following four necessary and sufficient conditions are satisfied when the first derivative is equal to zero.

CONDITION 1:

$$i.e.,\left(\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k-\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)(1-\pi_s(0))^{B_r}\beta^{B_r})\right)=0$$

$$\sum_{k=0}^{B_r}\frac{(n-3+B_r)!}{(n-3)!B_r!}(1-\pi_s(0))^k\beta^k=\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)(1-\pi_s(0))^{B_r}\beta^{B_r})$$

CONDITION 2:

$$\left(\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'+\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)\right)=0$$

$$\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)'=-\left(\frac{(n-3+B_r)!}{(n-3)!B_r!}\right)\log((1-\pi_s(0))\beta)$$

CONDITION 3:

$$((1-\pi_s(0)))^{B_r}=0$$

$$\left(1-\left(\frac{\mu_s-\lambda_s}{\mu_s-\lambda_s(\theta)^{B_s}}\right)\right)^{B_r}=0$$

$$\left(\frac{\mu_s-\lambda_s(\theta)^{B_s}-\mu_s+\lambda_s}{\mu_s-\lambda_s(\theta)^{B_s}}\right)^{B_r}=0$$

$$=\left(\frac{\lambda_s-\lambda_s(\theta)^{B_s}}{\mu_s-\lambda_s(\theta)^{B_s}}\right)^{B_r}=0$$

$$\left(\lambda_s-\lambda_s(\theta)^{B_s}\right)^{B_r}=0$$

$$\left(\lambda_s(1-(\theta))^{B_s}\right)^{B_r}=0$$

$$\left((1-(\theta))^{B_s}\right)^{B_r}=0$$

CONDITION 4:

$$(\beta)^{B_r}=0$$

$$\left(\frac{\alpha}{1-\alpha}\right)^{B_r}=0$$

$$(\alpha)^{B_r}=0$$

From the above four conditions only the fourth condition is suitable for finding the B_r*value which B_r value satisfies the fourth condition is B_r*.

C. Discussion on Necessary and Sufficient Conditions:

From the above A and B sections the following three necessary and sufficient conditions are derived for per node throughput maximization.

1.$\mu_s>\lambda_s$

2.$(\theta)^{Bs}>0$

3.$(\alpha)^{Br}>0$

To finding the optimal control parameter α*, it is a necessary and sufficient condition $\lambda_s<\mu_s$for different network parameters m,n, μ_s is varied as for corresponding P_{sd} and P_{sr} values. So for obtaining maximum throughput node the α* value be identified as per the $\lambda_s<\mu_s$.

The second condition $(\theta)^{Bs}>0$,where θ can be written as

$$\theta=\frac{\lambda_s(1-\mu_s)}{\mu_s(1-\lambda_s)}$$

$$\theta=\frac{\lambda_s}{(1-\lambda_s)}\cdot\frac{(1-\mu_s)}{\mu_s}$$

$$\theta=\frac{\left(\frac{\lambda_s}{(1-\lambda_s)}\right)}{\left(\frac{\mu_s}{(1-\mu_s)}\right)}$$

$$\theta=\frac{(\textit{The ratio of generating probability})}{(\textit{The ratio of transmission probability})}$$

The whole power of ratio of ratios ofgenerating probability and transmission probability to the source buffer must be greater than zero is the optimal value of B_s*.

The third condition $(\alpha)^{Br}>0$,where α is the control parameter is the deciding factor for the total number of relay nodes and route discovery. The whole power of control parameter to the relay buffer must be greater than zero is the optimal value of B_r*.

Based on these existing necessary and sufficient conditions the following Necessary and Sufficient Conditions (NSC)

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Search algorithm is proposed for finding T*.

The following algorithm is to find the values of α*, B_s^*, B_r*, T*for given m,n,$\lambda_s$as follows:

D. The proposed NSC Search Algorithm for Finding α*, B_s*, B_r*, T* for given m, n, andλ_s

Input: {m, n, λ_s,and Tolerance ϵ }

Output: {α*, B_s*,B_r*, T*}

1. Initialization: set α=0.01, B_s=1,B_r=1, θ_c=0, α_c=0, ϵ=0.000001;

$$P_{sd}=\frac{m^2}{n}-\frac{m^2-1}{n-1}+\frac{m^2-1}{n(n-1)}\left(1-\frac{1}{m^2}\right)^{n-1}$$

$$P_{sr}=\alpha\left\{\frac{m^2-1}{n-1}-\frac{m^2}{n-1}\left(1-\frac{1}{m^2}\right)^{n}-\left(1-\frac{1}{m^2}\right)^{n-1}\right\}$$

$\mu_s=p_{sd}+p_{sr}$

$$\theta_1=\left(\frac{\lambda_s(1-\mu_s)}{\mu_s(1-\lambda_s)}\right)^{B_s}$$

2. While ($\mu_s \le \lambda_s$) { for finding α* }

$$P_{sr}=\alpha\left\{\frac{m^2-1}{n-1}-\frac{m^2}{n-1}\left(1-\frac{1}{m^2}\right)^{n}-\left(1-\frac{1}{m^2}\right)^{n-1}\right\}$$

$\mu_s=p_{sd}+ p_{sr}$

α=α+0.01 then goto step2

3. End while α*=α;

4. While (ϵ!= (θ_c - θ_1)){ for finding B_s*}

$B_s=B_s+1$

$$\theta_c=\left(\frac{\lambda_s(1-\mu_s)}{\mu_s(1-\lambda_s)}\right)^{B_s}$$

$\theta_1=\theta_c$

5. Goto step4

6. End whileB_s*=B_s

7. $\alpha_1=(\alpha)^{Br}$

8. While (ϵ != (α_c - α_1)){ for finding B_r*for given α*}

$B_r=B_r+1$

$$\alpha_c=(\alpha)^{B_r}$$

$\alpha_1=\alpha_c$

9. Goto step8

10. End whileB_r*=B_r

11. {For finding T*forCorrespondingB_s*, B_r* and α* of μ_s}

$$\pi_s(0)=\frac{\mu_s-\lambda_s}{\mu_s-\lambda_s.\theta^{Bs*}}$$

$$\pi_r(B_r*)=\frac{C_{B_r}(1-\pi_s(0))^{B_r*}\beta^{B_r*}}{\sum_{k=0}^{B_r*}C_k(1-\pi_s(0))^k\beta^k}$$

$$P_{sr}=\alpha*\left\{\frac{m^2-1}{n-1}-\frac{m^2}{n-1}\left(1-\frac{1}{m^2}\right)^{n}-\left(1-\frac{1}{m^2}\right)^{n-1}\right\}$$

12. T*=$P_{sd}(1-\pi_s(0))+P_{sr}(1-\pi_s(0))(1-\pi_r(B_r*))$;

13. Return α*, B_s*, B_r*and T*;

In the above algorithm the values for α* andB_s* are calculated with two necessary and sufficient conditions of $\mu_s>\lambda_s$ and$\theta^{Bs}>0$ correspondingly. The α convergent to α* upto the valueof λ_s is less thanμ_s i.e. the source to relay transmission probability control parameter is α* for given λ_s value. The B_s convergent to B_s* up to $\theta^{Bs}>0$.The α* value can be used to calculate the B_r* value by applying the condition $(\alpha)^{Br}>0$. The T* value calculated by using α*, B_s* and B_r* values. The following numerical illustration explores this algorithm for various values of network parameters m and n.

V. NUMERICAL ILLUSTRATION

Based on proposed algorithm for finding maximize the per node throughput forgiven$\lambda_s$the numerical results are presented to illustrate the impact of $\lambda_s$for different types of network area parameters m, n.

The numerical illustration of Throughput maximization T* for different values of packet generating rate (λ_s) varies from 0.05 to 0.25 with an interval of 0.05 because the control parameter 'α' value is varied from 0 to 1 as the corresponding values of the service opportunity probability μ_s, as a range from 0 to maximum of 0.3 such that the packet generating rate is fixed as per the service probability. Network parameters are varied in area is 4,5,6,7,8 square meters and total number of nodes in the network are32, 50, 72, 98, 128 respectively where the NSC search algorithm finds the corresponding control parameter α* of the torus network, the optimized source buffer size B_s* , and the optimized relay buffer size B_r* by using these values the maximization of per node throughput T* is derived.The following results and discussions section explain the different network parameters with packet generating rate probability and also presents the dynamic behavior of optimized routing control parameter, source and relay buffer

VI. RESULTS AND DISCUSSIONS

The packet generating probability is key factor to be observed for the different cases as discussed in theabove section.

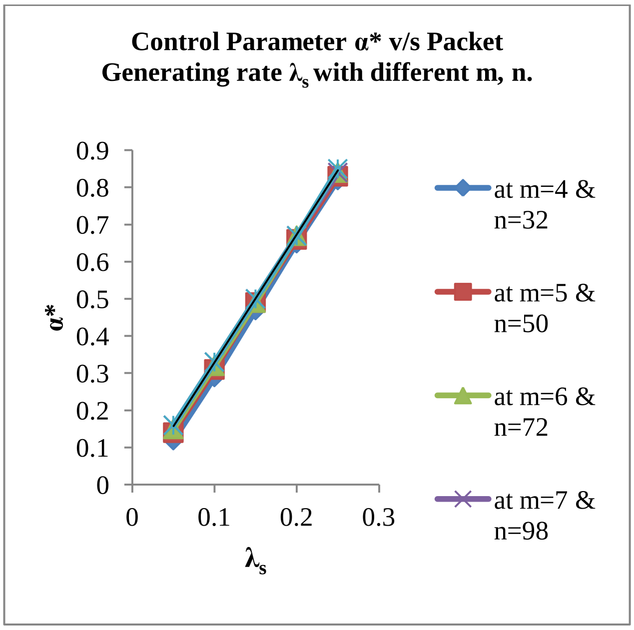

Fig VI.I-Effect of α for different m,n*

To observe the above graph there is no significant difference in α* for different network parameters m, n, when λ_s increases.

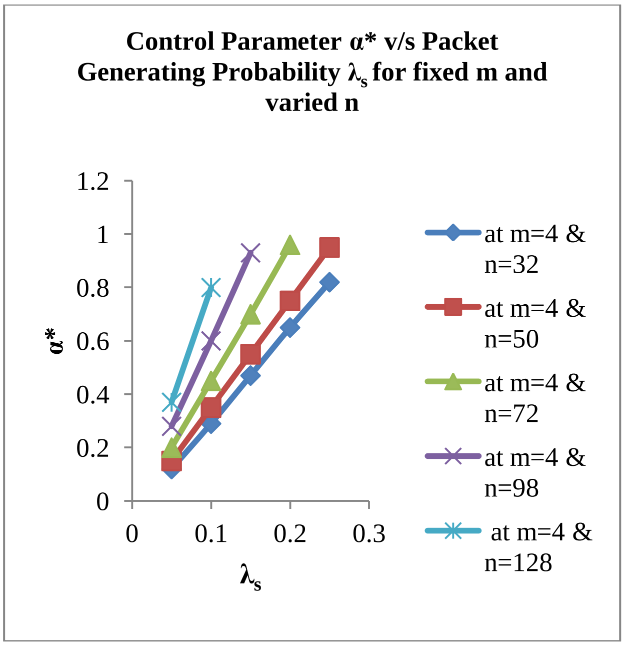

Fig VI.II-Effect of α for fixed area and various node density*

The above graph α* increasing when λ_s increases, for the values of n=72, 98, 128 theα* values are greater than one, so the corresponding $\lambda_s$values doesn't satisfy the condition of α*≤1.

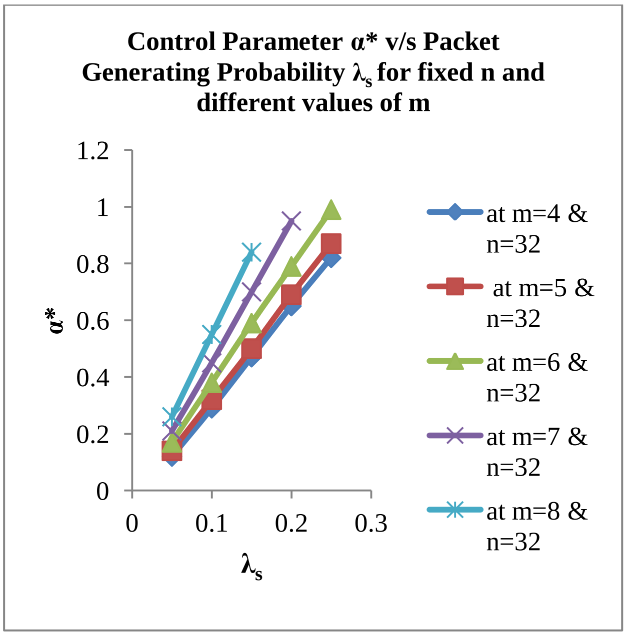

Fig VI.III-Effect of α for fixed nodes and different area*

The above graph α* increasing when λ_s increases, for the values of m =7, 8, theα* values are greater than one, so the corresponding $\lambda_s$values doesn't satisfy the condition of $\alpha^* \leq 1$.

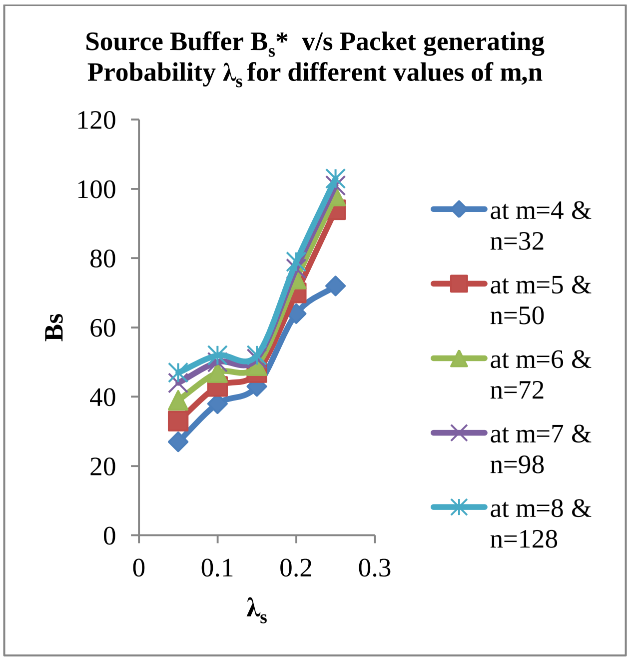

Fig VI.IV-Effect of B_s for different m,n.*

If the packet generating rate increases then the size of the source buffer $B_s$also slowly increases uptoλ_s=0.15 after then it will steeply increasefor all the values of m, n.

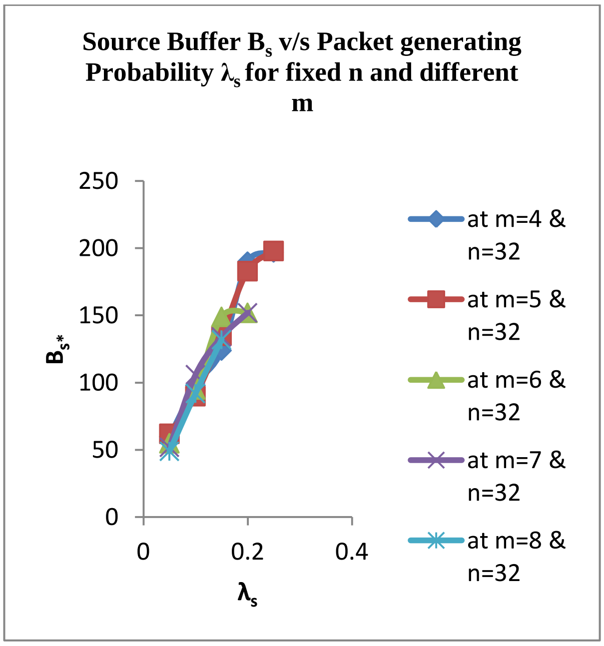

Fig VI.V-Effect of B_s for fixed nodes and different area.*

When λ_s increases the B_s also increases and then stabilizes for all values of m and fixed value of n.

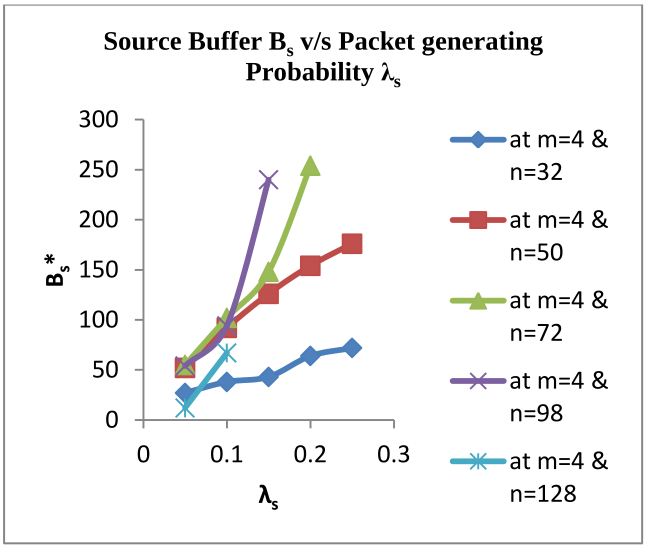

Fig VI.VI- Effect of B_s for fixed nodes and different area*

When λ_s increases thenB_s also increases for all values of n and fixed value of m.The demand for the increased size of the source buffer is there when the number of nodes areincreasing within the same torus network area.

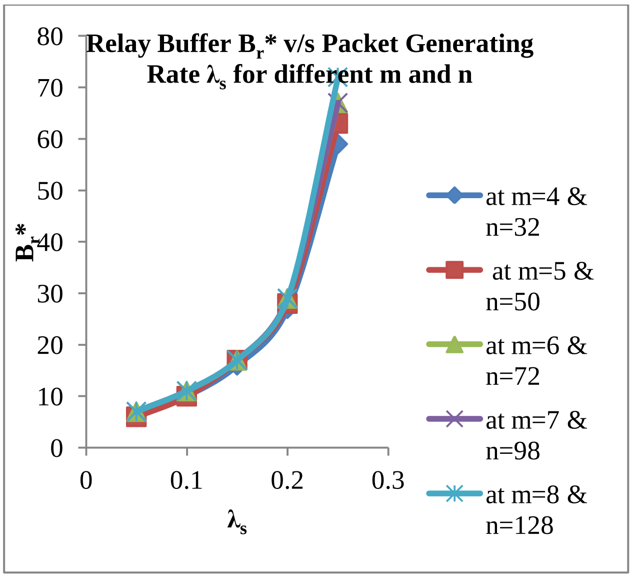

*Fig VI.VII- Effect of B_r * for different m, n*

If the packet generating rate λ_s increases then gradually the size of the relay buffer B_r increases correspondingly for all the values of m and n.

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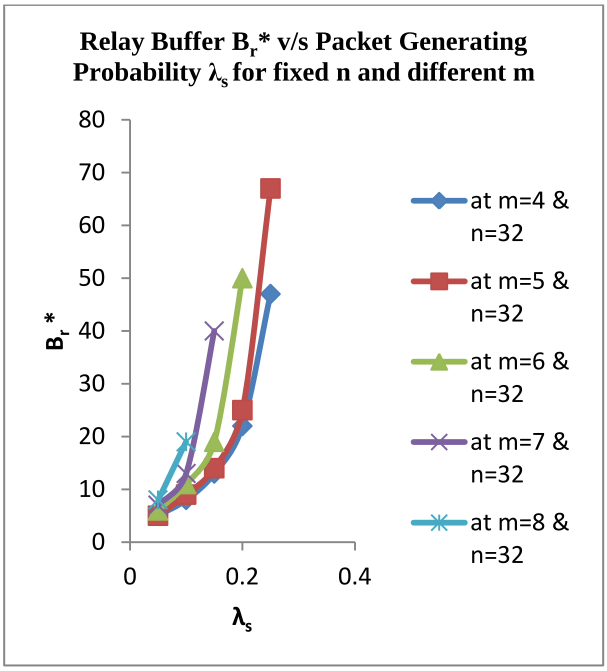

*Fig VI.VIII- Effect of B_r * for fixed nodes and different area*

If the packet generating rate λ_s increases then gradually the size of the relay buffer B_r increases correspondingly for different values of m and fixed values of n. When the size of the torus area increases then the size of the relay buffer B_r also increasesbut the B_r values doesnot exist for λ_s =0.15, 0.2, andλ_s =0.25 when m= 8, 7, and 6,respectively. This happens because of the reason that all the three cases do notsatisfythe condition $\alpha \le 1$.

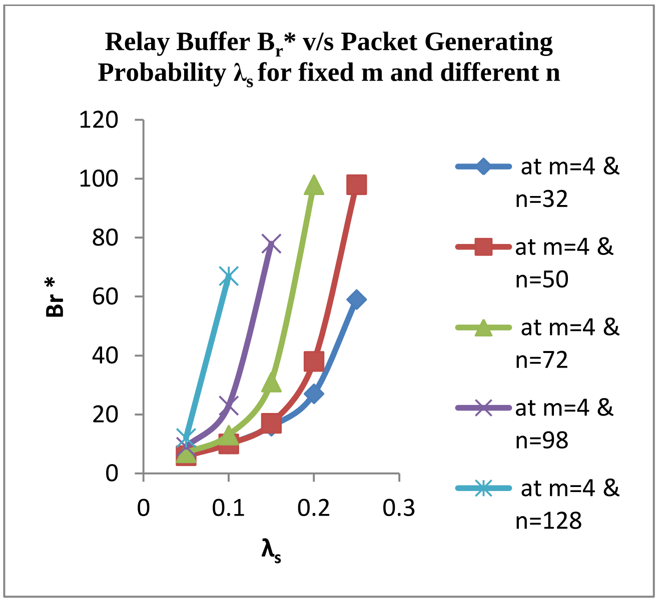

*Fig VI.IX- Effect of B_r * for fixed area and different node density*

If the packet generating rate λ_s increases then gradually the size of the relay buffer $B_r$also increases correspondingly for different values of n and fixed values of m. When the number of nodes increases then the size of the relay buffer $B_r$is increasing but the B_r values not exist for λ_s=0.15, 0.2 and λ_s = 0.25 when m=8,7, and 6 respectively.This happens because of the reason that all the three cases do notsatisfy the condition $\alpha \le 1$.

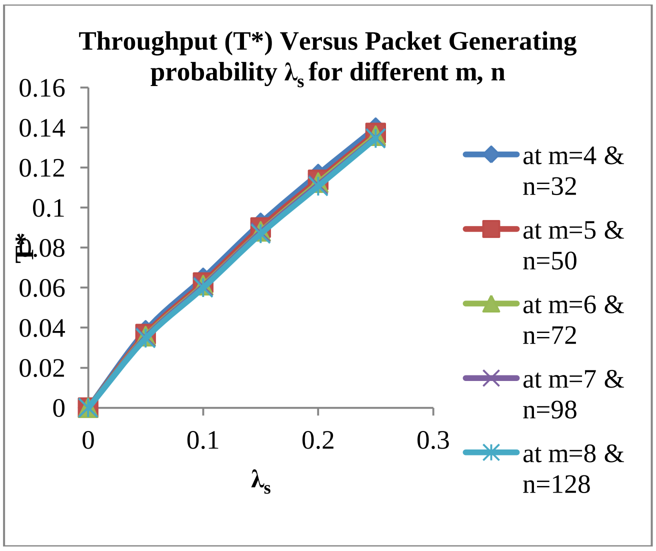

Fig VI.X- Effect of T for different m,n*

The graph presents approximately identical values for any network conditions i.e. for any given network area parameter. The corresponding routing control parameter, corresponding size of the source buffer and relay buffer are generated. Different cases are presented in the graph and clearly one can observe that they are identical at any packet generating rate of probability because of interdependency issues that exists between α*, B_s*,B_r*, and T*.

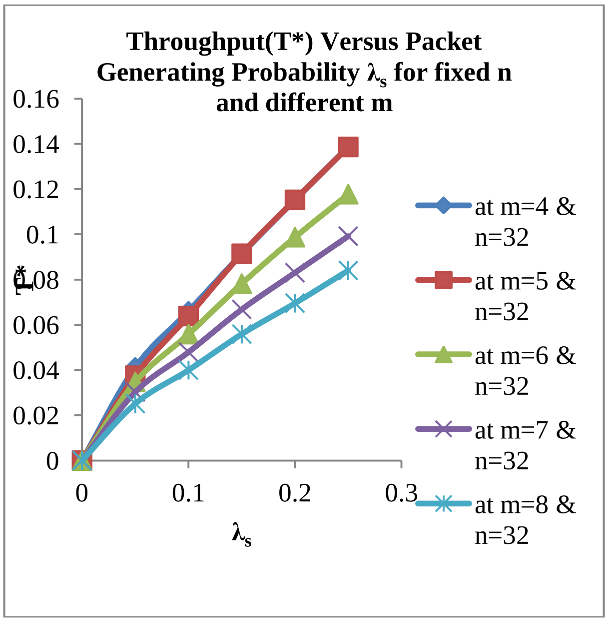

Fig VI.XI- Effect of T* for fixed nodes and different area

When packet generating rate λ_s is increasing then the per node throughput T* also increases gradually. The Throughput is at a higher plane for varied values of area for the fixed number of nodes because of the very obvious reason that throughput increases for the same number of nodes and increased area.

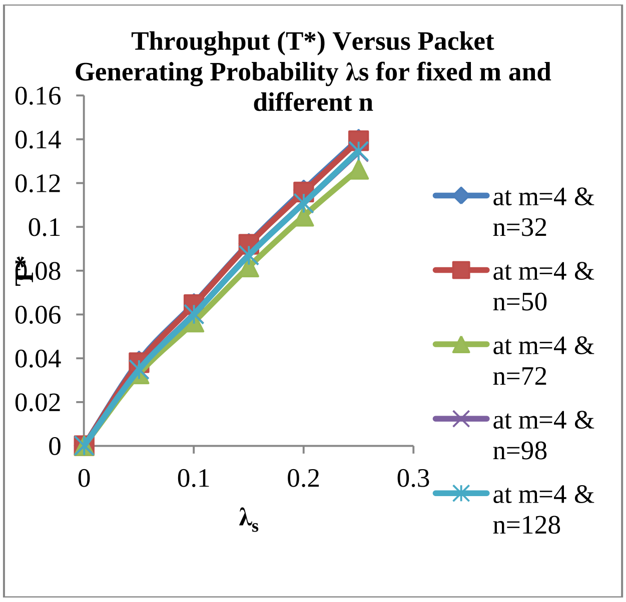

Fig VI.XII- Effect of T* for fixed area and different node density

When packet generating probability λ_s is increasing then the per node throughput T* also increases gradually is almost identical for same area and different number of nodes.

VII. CONCLUSION

Based on the findings of [9 to 12] a novelistic NSC Search algorithm is proposed for maximizing the throughput when the optimum values for α, $B_r$and B_s of a 2HR MANET under limited buffer constraints. To derive the necessary and sufficient conditionsthrough partial derivative method with NSC Search algorithm for maximizing throughput and numerically illustrated and then results are presented. For different network setting parameters the throughput shows same type of behavior when increasing the λ_s. α* is adjustable with different values for different network setting parameters. Boththe buffer sizes increases when λ_s increases for all network setting parameters. This paper concludes that the throughput maximization depends on the three parameters that is control parameter and size of the source buffer and size of the relay buffer that is used in the torus network. The maximization of throughput is done by using the NSC Search algorithm that has generated optimized values for the source buffer, relay buffer and control parameter. The given values are area size of the ad hoc network, number of nodes contained in the area, packet generating rate, using these values first the control parameter of the network is determined then the size of the source buffer is generated after that size of the relay buffer is determined finally these are used to arrive at per node throughput. It is to conclude that maximization of per node throughput is possible by optimizing the control parameter of the network, size of the source buffer and size of the relay buffer. This workcan be extended to find the impact of node density and packet generating ratev/s throughput as well as other performance metrics.

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