International Conference on Computer Applications 2016 [ICCA 2016]

ISBN	978-81-929866-5-4
Website	icca.co.in
Received	14 – March– 2016
Article ID	ICCA023

VOL	05
eMail	icca@asdf.res.in
Accepted	02 - April – 2016
eAID	ICCA.2016.023

Robustness Analysis of Buffer Based Routing Algorithms in Wireless Mesh Network

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Abstract: *Wireless Mesh Network rose as a promising innovation for providing quick and productive communication for which numerous algorithms have been proposed in networking infrastructure. For routing there are various performance parameters such as throughput, network congestion, resiliency, fairness, robustness, network jitter, delay, stability, optimality, simplicity, completeness etc. Robustness provides the capability to deal with all the failures that come across during the connection in the network to increase the network performance. In this paper we have studied and analyzed three algorithms namely on robustness parameter Resilient multicasting [2], Resilient Opportunistic Mesh Routing for Wireless Mesh Network (ROMER) [3], and Buffer Based Routing (BBR) [4], in Wireless Mesh Networks. Analysis through various parameters such as network congestion, network throughput and resiliency [5], shows network performance of BBR is better.*

Keywords: *Resilient Multicasting, ROMER, Buffer Based Routing, WMN, Robustness.*

INTRODUCTION

Wireless Mesh Networks propose a decentralized structural engineering for setting multi-hop wireless communications. The decentralized structural planning brings advantages such as ease of deployment, maintenance, scalability and consistency. However, WMN is deficient in high level services such as handoff and mobility management [1]. Routing is process of transferring information across a network from source to destination. It can also be referred to as the process of selecting a path over to send the packet. To provide routing services efficiently and appropriately there are many characteristics that need to be analyzed in a routing algorithm which could help in packet transmission in a network. In context to computer network, robustness is the capability of the network to deal with all the failures that occurs during the transmission of message or packet that take place between source and destination. The most appropriate application for robustness is to make routing algorithm so resistant that if error occurs it should not affect the normal functioning of the network.

The issue that exists during communication is management of bundle transmission from source to destination efficiently and demonstrating the calculation/algorithm that it is powerful in nature. In our previous work [5] Buffer based routing was analyzed on three parameters i.e. system throughput, network congestion and resiliency and it was demonstrated in comparison with Resiliency Multicasting and ROMER that BBR lives up to expectations all the more proficiently because of the way that it has some buffered nodes that help in travelling the packet to its destination. In this paper we consider another critical parameter to further upgrade the power of BBR methodology.

The paper is divided in five sections. In section first we have introduced the problem. Second section discusses the related work in the

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field of routing protocols. The third section introduced the proposed work by comparing the algorithms on the basis of cost. In section fourth the results and analysis is presented. Section fifth concluded the manuscript, which is followed be references of the manuscript.

Related Work

Xin Zhao et al. in [2] presented an approach called Resilient Multicasting requiring two node disjoint path for every pair of source to destination. These disjoint paths are such as, link disjoint and node disjoint. Link disjoint do not have any link in common and node disjoint do not have any node in common except the source and destination. Yuan [3] et al. proposed Resilient Opportunistic Mesh Routing for mesh Network as a solution and provides with the balance between long term and short term performance. It works on R (credit ratio) and T (threshold) value. This mechanism was used to provide differentiated robustness for various categories of data packets. Rathee et al. in [4] projected a approach as Buffer based Routing Algorithm as to overcome resilient multicasting and ROMER. This algorithm is used to maintain buffer at every alternative nodes in the network. These buffered nodes are half to the number of nodes present in the network. This approach maintains a routing table keeping all information of the node. Sangman Cho et al. in [7] developed an independent directed acyclic graph for resilient multipath routing which follows a path from source to root. This graph is link disjoint in nature. They also develop an algorithm for computation of link-independent and node-independent graphs. Zeng [8] et al. proposed a protocol named as opportunistic multicast protocol for improving throughput of the network. This protocol helped to enhance the unicast throughput in the network. Main concept of the protocol is its tree backbone. The protocol presents the tradeoff between traditional multicast protocol and unstructured protocols. Xin [9] studied the multipoint multicasting for distributed environment in the mesh network targeting to minimize the time slots for exchanging messages among many nodes in the network. The paper presented an algorithm for multicasting algorithm and analyzes its time complexity. The time taken by the algorithm is O(d log n + k). Bruno et al. [10] proposed a routing algorithm called as MaxOPP. It takes a localized routing decision for selection of forwarding nodes. The selection of the nodes is on per packet basis and at run time. Xi Fang [11] proposed an opportunistic algorithm for improving the performance of the network. Various problems have been studied for choosing the route for every user so that they can optimize the total profit of various users in the network concerning node constraint. The paper formulated two problems for programming system. By two methods i.e. primaldual and subgradient, an iterative approach named Consort: node constraint opportunistic routing. For every iteration it updates the lagrange multiplier in distributed environment according to user and node. Zhang [12] et al. presented an overview of opportunistic routing, the challenges faced in implementing the routing. The paper presented various routing protocol such as ExOR, ROMER, SROR etc for achieving increased throughput in comparison with traditional routing Aajami [13] et al. studied various approaches such as wireless interflow network and opportunistic routing for enhancing the throughput. A solution have been proposed by combining these approaches. The paper suggested a technique abbreviated as MRORNC as an integrated cross layer approach for determining packet, next hop and transmission rate.

Proposed Work

Robustness Analysis of Resilient Multicasting

Zhao et.al in [5] proposed that the algorithm works on disjoint paths having no node as common except the source and destination. We will be demonstrating the path traversed from source to destination for network with varying number of nodes.

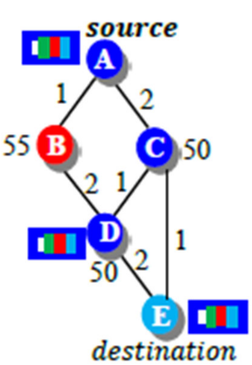

Fig.1. Network showing 5 nodes [5].

For example in the network [5], Fig 1 when there are 5 nodes, the algorithm chooses two nodes disjoint paths to send the packet from source (node A) to destination (node E) are: and A-B-D-E and A-C-E. Choosing first path as A-B-D-E having its cost as 1+2+2 = 5 units, and in A-C-E as 2+1 = 3 units, leads to total of 8 units for the packet to travel.

In Fig 2, for a network with 10 nodes,

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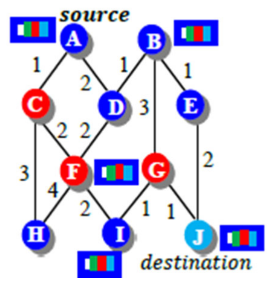

Fig. 2. Network showing 10 nodes [5].

Taking two disjoint paths from source (node A) to destination (node J) are: and A-C-H-F-I-G-J and A-D-B-E-J. Choosing first path as A-C-H-F-I-G-J having its cost as 1+3+4+2+1+1 = 12 units and A-D-B-E-J as 2+1+1+2 = 6 units, leads to total of 18 units for the packet to travel.

In Fig 3, for a network with 15 nodes,

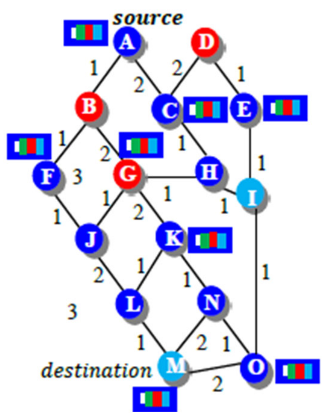

Fig. 3. Network showing 15 nodes [5].

The two disjoint paths from from source (node A) to destination (node M) are: A-C-H-I-O-M and A-B-G-K-N-M. Choosing first path as A-C-H-I-O-M having its cost as 2+1+1+12 = 7 and A-B-G-K-N-M as 1+2+2+1+2 = 8 units, leads to total of 15 units for the packet to travel.

In Fig 4, for a network with 20 nodes,

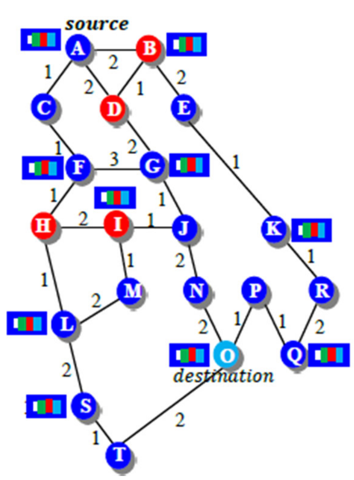

Fig. 4. Network showing 20 nodes [5].

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Taking two disjoint paths from which packet can travel from source (node A) to destination (node O) are: A-C-F-H-L-S-T-O and A-B-E-K-R-Q-O. Choosing first path as A-C-F-H-L-S-T-O having its cost as 1+1+1+1+2+1+2 = 9 units and A-B-E-K-R-Q-O as 2+2+1+1+2+1+1 = 10 units, leads to total of 19 units for the packet to travel.

In Fig 5, for a network with 25 nodes,

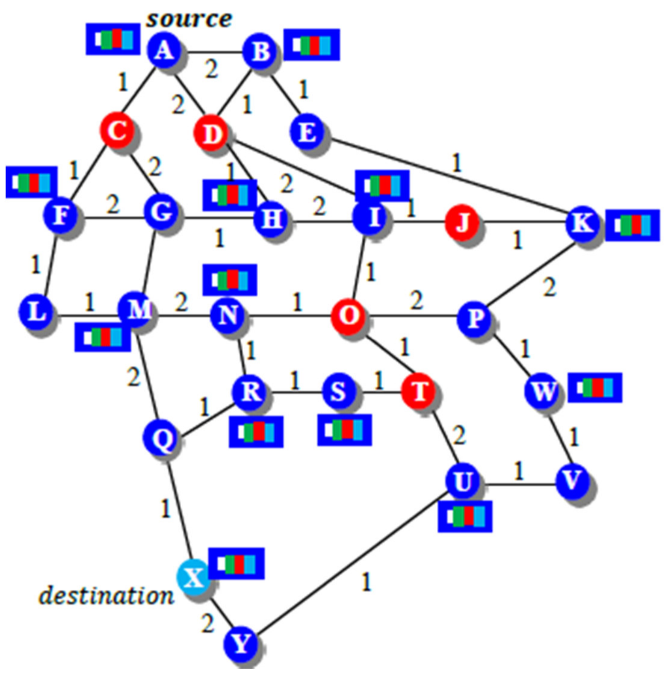

Fig. 5. Network showing 25 nodes [5].

The two disjoint paths from source (node A) to destination (node X) are: A-C-G-M-O-X and A-D-H-I-O-T-U-Y-X Choosing first path as having its cost A-C-G-M-O-X as 1+2+1+2+1 = 7 units and A-D-H-I-O-T-U-Y-X as 2+1+2+1+1+2+1+2 = 12 units, leads to total of 19 units for the packet to travel.

In multicasting algorithm whenever failure occurs in the network the source can prefer another path to route the packet in order to reach to its destination, but when all the routes fail then no packet will travel in the network. Therefore through all this study we can conclude that multicasting algorithm could not pass this robustness parameter as it is unable to route the packet at the time of node failure.

Robustness Analysis of Romer

Due to node failure possibility in Resilient Multicasting another algorithm was developed that overcome all its disadvantages i.e. ROMER. Yuan et.al [3] proposed that the algorithm works on the value of R(credit ratio) and T(threshold) on every node that has its value of R greater than its value of T can forward the packet to the possible route. We will be demonstrating the path traversed from source to destination for network with varying number of nodes for ROMER, cost is written along.

NODE	CREDIT UNIT	NODE UNIT
A	100	100
B	120.5	55
C	120.5	50

Table 1. Credit unit and Node unit of network of 5 nodes as in fig 1.

At node B:

$$R = \frac{(100-(120.5+55-100)}{100}$$

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Where (120.5 + 55 -100) 77.5 is the credit required, (100 - (77.5)) = 22.5 is the remaining credit for node B and 22.5/100 is the ratio of remaining credit to initial credit.
Therefore the value of R = 0.245.

Further threshold value is calculated as T = $\left(\frac{cost\ of\ node\ B}{cost\ of\ source}\right)^2$.

T= (55/100) = 0.3025.
R<T which depicts that node B will discard the packet.

At node C:

R = (100 - (120.5 + 50 - 100)/100)
=0.295.
T = (50/100)2
=0.2500.
R>T which depicts that node C will forward the packet.

NODE	R	T	COMPARISON	FUNCTION
B	0.245	0.3025	$R < T$	Discard the packet
C	0.295	0.2500	$R > T$	Forward the packet

Table 2. Showing the value of R (credit ratio) and T (through put) in network of 5 nodes as in fig 1.

Table 1 and 2 are representation of fig 1 in which there are 5 nodes, the two possible paths (out of three available options) from which packet can travel from source (node A) to destination (node E) are: and and nodes B is having the value of R less than the value of T which shows that this node fails to transmit the packet. Choosing first path as having its cost as 1 units, and in as units, leads to total of 4 units for the packet to travel.

NODE	CREDIT UNIT	NODE UNIT
A	100	100
B	120.5	50
C	120.5	50
D	120.5	55
E	120.5	50
F	121.5	55
H	122.5	51

Table 3. Credit unit and Node's unit of network of 10 nodes as in fig 2.

NODE	R	T	COMPARISON	FUNCTION
B	R=(100 – (122.5 + 50 – 100)/100) =0.275	T= (50/100)2 =.2500	R>T	forward the packet
C	R=(100 – (120.5 + 50 – 100))/100 = 0.295	T= (50/100)2 =.2500	R>T	forward the packet
E	R=(100 – (120.5 + 50 – 100)/100) =0.295	T= (50/100)2 =.2500	R>T	forward the packet
F	R=(100 – (122.5 + 51 – 100))/100 =0.265	T= (51/100)2 = 0.2601	R>T	forward the packet
H	R=(100 – (121.5 + 55 – 100)/100) =0.235	T=(55/100)2 =0.3025	R<T	discard the packet

Table 4. Showing value of R and T in network of 10 nodes as in fig 2.

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Similarly, table 3 and 4 are representation of fig 2 in which there are 10 nodes, the two possible paths (out of all available options) from which packet can travel from source (node J) to destination (node J) are: A-C-F-I-G-J and A-C-F-I-G-B-E-J. Choosing first path as having its cost A-C-F-I-G-J as 1+2+2+1+1 = 7 units and A-C-F-I-G-B-E-J as 1+2+2+1+3+1+2 = 12 units, leads to total of 19 units for the packet to travel.

NODE	CREDIT UNIT	NODE UNIT
A	100	100
B	120.5	51
C	121.5	50
D	121.5	51
E	122.5	50
F	120.5	50
G	122.5	55
H	121.5	51

Table 5. Credit unit and Node's unit of network of 15 nodes as in fig 3.

The units are assumed for explanation.

NODE	R	T	COMPARISON	FUNCTION
B	0.295	0.2500	$R > T$	forward the packet
C	0.285	0.25	$R > T$	forward the packet
E	0.275	0.25	$R > T$	forward the packet
F	0.295	0.25	$R > T$	forward the packet
G	0.225	0.3025	$R < T$	discard the packet
H	0.275	0.2601	$R > T$	forward the packet

Table 6. Showing value of R and T in network of 15 nodes as in fig 3.

As previously performed for 5 and 10 nodes, table 5 and 6 are representation of fig 3 in which there are 15 nodes, the two possible paths (out of all available options) from which packet can travel from source (node A) to destination (node M) are: A-B-F-J-G-K-N-M and A-C-F-J-L-K-N-O-M. Choosing first path as A-B-F-J-G-K-N-M having its cost as 1+1+1+1 = 4 units (till node G) and A-C-F-J-L-K-N-O-M as 1+1+1+2+1+1+1+2 = 10 units, leads to total of 14 units for the packet to travel.

NODE	CREDIT UNIT	NODE UNIT
A	100	100
B	121.5	50
C	120.5	51
D	120.5	50
E	120.5	55
F	121.5	55
G	121.5	51
H	122.5	50
I	122.5	51
J	122.5	55
L	123.5	50
M	123.5	51
N	123.5	55
O	124.5	55
S	124.5	50
T	124.5	51

Table 7. Credit unit and Node's unit of network of 20 nodes as in fig 4.

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NODE	R	T	COMPARISON	FUNCTION
B	0.285	0.25	$R > T$	forward the packet
C	0.285	0.2601	$R > T$	forward the packet
D	0.295	0.25	$R > T$	forward the packet
E	0.245	0.3025	$R < T$	discard the packet
F	0.295	0.2500	$R > T$	forward the packet
G	0.285	0.2500	$R > T$	forward the packet
H	0.275	0.25	$R > T$	forward the packet
I	0.265	0.2601	$R > T$	forward the packet
J	0.225	0.3020	$R < T$	discard the packet
L	0.265	0.25	$R > T$	forward the packet
M	0.255	0.2601	$R < T$	discard the packet

Table 8. Showing value of R and T in network of 20 nodes as in fig 4.

As per table 7 and 8 for 20 nodes there are two possible paths (out of all available options) from which packet can travel from source (node A) to destination (node O) are: A-B-D-G-F-H-L-S-T-O and A-D-G-J-N-O. Choosing first path as A-B-D-G-F-H-L-S-T-O having its cost as 2+1+2+3+1+1+2+1+2 = 15 units and A-D-G-J-N-O as 2+2+1 = 5 units, leads to total of 20 units for the packet to travel.

Therefore this same calculation can be done in the case of 25 nodes and the paths will be discard are according to incapable nodes.

Robustness Analysis of Buffer Based Routing

Rathee et.al proposed in [4] that the algorithm works on two conditions i.e. the packet travels through the route that must contain minimum number of buffered node and if more than one path has same number of buffered node than it will select the least cost path from source to destination. We will be demonstrating the path traversed from source to destination for network with varying number of nodes.

PATHS	COST	BUFFERED NODES
A-B-D-E	5	3
A-C-D-E	5	3
A-C-E	3	2

Table 9 . Network of 5 nodes.

Table 9 represents fig 1 in which there are 5 nodes, having two possible paths (out of three available options) from which packet can travel from source (node A) to destination (node E) are: A-C-E and A-B-D-E. Choosing first path as A-C-E having its cost as 2+1 = 3 units, and in A-B-D-E as 1+2+2 = 5 units, leads to total of 8 units for the packet to travel.

PATHS	COST	BUFFERED NODES
A-D-B-E-J	6	3
A-D-F-I-G-J	8	4
A-C-H-F-I-G-J	12	3
A-C-F-I-G-J	7	4
A-D-B-G-J	7	3

Table 10. Network of 10 nodes.

Similarly, table 10 represents (fig 2) two possible paths (out of all available options) from which packet can travel from source (node A) to destination (node J) are: A-D-B-E-J and A-D-F-I-G-J Choosing first path as A-D-B-E-J having its cost as 2+1+1+2 = 6 units and A-D-F-I-G-J as 1+2+2+1+1+1 = 7 units, leads to total of 13 units for the packet to travel.

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PATHS	COST	BUFFERED NODES
A-B-F-J-L-M	6	3
A-B-G-K-N-M	7	3
A-B-G-K-L-M	7	4
A-B-G-J-L-M	7	3
A-B-G-K-N-O-M	9	5
A-C-H-I-O-M	7	3

Table 11. Network of 15 nodes.

Table 11 represents two possible paths (out of all available options) for 15 nodes from which packet can travel from source (node A) to destination (node M) are A-B-F-J-L-M and A-C-H-I-O-M. Choosing first path as A-B-F-J-L-M having its cost as 1+1+1+2+1 = 6 units and A-C-H-I-O-M as 2+1+1+1+2 = 7 units, leads to total of 13 units for the packet to travel.

PATHS	COST	BUFFERED NODES
A-B-E-K-R-Q-P-O	10	5
A-C-F-H-I-J-N-O	11	4
A-B-D-G-J-N-O	10	4
A-C-F-G-J-N-O	10	4

Table 12. Network of 20 nodes.

Table 12 (represents fig 4) where there are 20 nodes, the two possible paths (out of all available options) from which packet can travel from source (node A) to destination (node M) are: A-C-F-H-I-J-N-O and A-B-D-G-J-N-O. Choosing first path as A-C-F-G-J-N-O having its cost as 1+1+31+2+2 = 10 units and A-B-D-G-J-N-O as 2+1+2+1+2+2 = 10 units, leads to total of 20 units for the packet to travel.

PATHS	COST	BUFFERED NODES
A-C-F-L-M-Q-X	7	4
A-C-G-M-Q-X	7	3
A-D-H-G-M-Q-X	8	4
A-B-E-K-P-W-V-U-Y-X	12	6
A-B-D-I-O-T-U-Y-X	12	5

Table 13. Network of 25 nodes.

Fig 5 (as detailed in table 13) when there are 25 nodes, the two possible paths (out of all available options) from which packet can travel from source (node A) to destination (node M) are: A-C-G-M-Q-X and A-B-D-I-O-T-U-Y-X. Choosing first path as A-C-G-M-Q-X having its cost as 1+2+1+2+1 = 7 units and A-B-D-I-O-T-U-Y-X as 2+1+2+1+1+2+1+2 = 12 units, leads to total of 19 units for the packet to travel.

4. Result and Analysis

We are evaluating the robustness of the three algorithms (in terms of cost units).As we can see that robustness is inversely proportional to the cost. Lesser the cost of the packet higher will be the robustness. Cost evaluated on robustness parameter for packet to reach from source to destination in network of different sizes is shown in table 14 with respect to the three algorithms. In case of multicasting, the cost will be according to two disjoint paths taken in the network. In case of ROMER, the source choose two paths, if in any path there is a node which is unable to forward the packet further in the network then the cost will be considered up to the node causing failure in the network, in addition to the cost of next path (shown in fig 6). In Buffer Based Routing, the cost depends on the path containing least buffered nodes.

ALGORITHMS	5 NODES	10 NODES	15 NODES	20 NODES	25 NODES
RESILIENT MULTICASTING	8	18	15	19	19
ROMER	4	19	14	20	18
BBR	8	13	13	20	/19

Table 14. Table showing the units consumed by the packet from source to destination.

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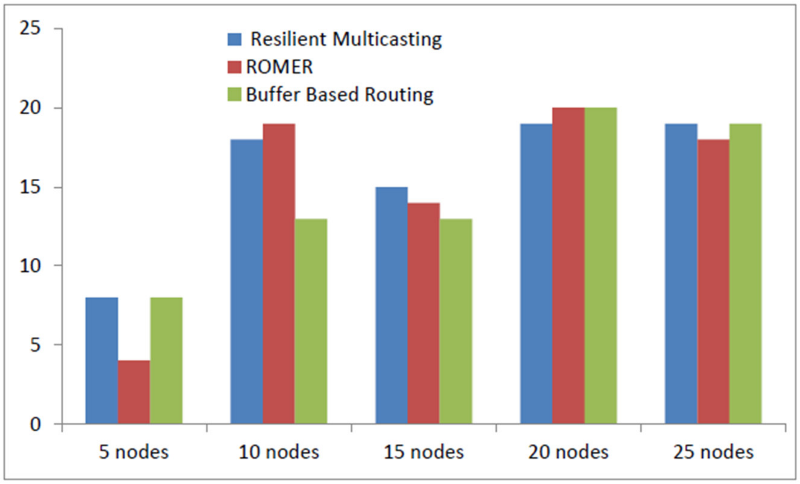

Fig 6. Showing the graphical representation of values Table 14.

5. conclusions And Future Work

This paper explores the robustness parameter in diverse sizes of network that how it deals with errors or failures during the transmission of the packet in all three algorithms. We began our study with resilient multicasting algorithm, then ROMER and finally Buffer based resilient routing approach. We assessed and Compared robustness on the basis of cost consumed while transmitting every packet in the network. By assessing the cost evaluated in distinctive size of the networks, we can conclude that BBR shows better result when contrasted with resilient multicasting and ROMER. As Resilient Multicasting and ROMER algorithm has more likelihood of failures whereas in BBR the failure handling capability is more because buffered nodes are present in the network, which are half of the number of nodes present, which serves to choose another path taken by the previously buffered node whenever the failure occurs.

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Cite this article as: Long CAI, Rajkumar Sugumaran, Kokula Krishna Hari Kunasekaran. "Robustness Analysis of Buffer Based Routing Algorithms in Wireless Mesh Network". *International Conference on Computer Applications 2016*: 115-123. Print.