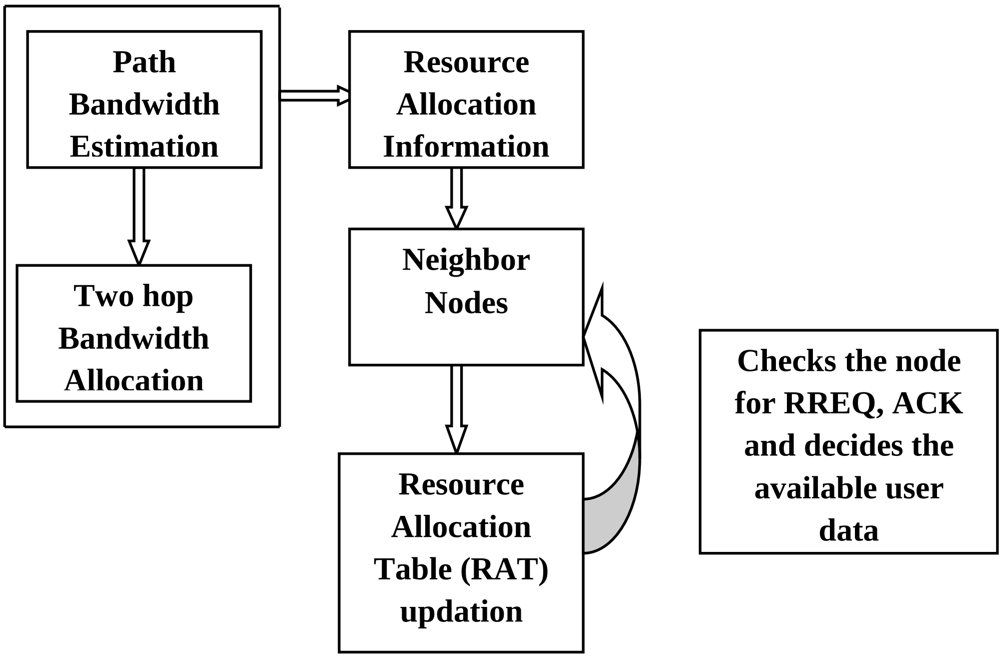
CHAPTER 5

CROSS-LAYER BASED FAIR RESOURCE ALLOCATION FOR MANET

5.1 OVERVIEW

In this chapter, a resource allocation technique for the selected routes has been proposed to ensure fair distribution in resource utilization. Using TDMA-MAC protocol (Myunghwan Seo et al. 2011), the path bandwidth can be estimated using the two-hop bandwidth allocation (Xu-Zhen et al. 2008). Here, path bandwidth between two nodes defines a number of available timeslot between the nodes and these timeslots do not interfere with another transmission. In each hop, the neighbor node records the timeslots of its current node. Similarly, when two nodes are in the neighbourhood, the path bandwidth is the link bandwidth. Next, the resource reservation information of each node is denoted by Resource Allocation Table (RAT) in TDMA MAC frame structure (Myunghwan Seo et al. 2011).

When nodes receive information on resource allocation message from a neighbour node it updates its own RAT. Every node checks the RAT, when it receives a Resource Request message, and decides the requested user data slots available or not. Figure 5.1 is the block diagram of the proposed fair resource allocation technique.



(Source: Narayanan S & Rani Thottungal 2015)

Figure 5.1 Block Diagram

5.2 PATH BANDWIDTH ESTIMATION

The path bandwidth between two nodes is termed as BW (P). Here, the path bandwidth between two nodes defines the number of timeslots available between the nodes. These timeslots do not interfere with another transmission. In each hop, the neighbour node records the timeslots of its current node. If the two nodes are in the neighbourhood, path bandwidth is link bandwidth.

For a given path $P^m = \{n_0 -> n_1 .... -> n_m\}$ (5.1)

TS_i - set of free timeslots of node ni

1. For m=2, the path bandwidth is BW (P2) with a two-hop link.
2. If m=3, BW(P2) is calculated and then the timeslots reserved for the link (n0, n1) and link (n1, n2) is removed from common

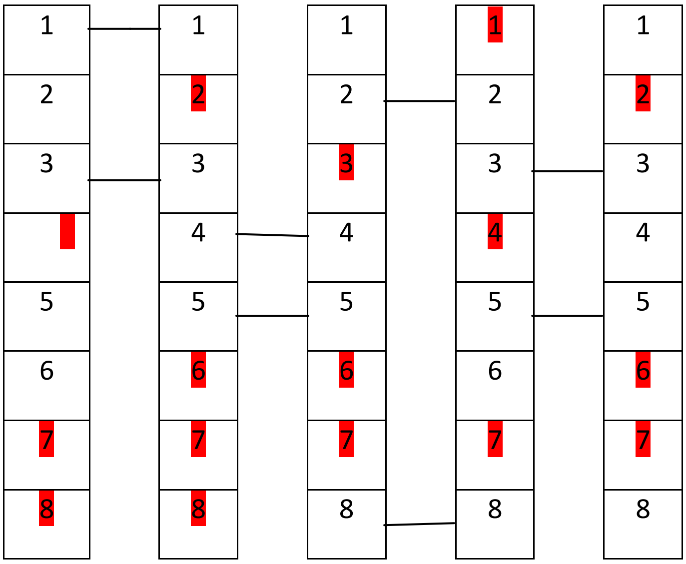
timeslots between node n2 and n3 and is then compared with the number of the remaining timeslots with BW(P2).

3. BW (P3) is the smaller value. The number of the timeslots on these three adjacent links has to be adjusted by BW (P3).

4. The bandwidth calculation process is iterated over from node n4 till destination node nm.

5. BW (Pm) is the path bandwidth from source node n0 to destination node nm.

5.2.1 Bandwidth Calculation of a Path by Hop



(Source: Narayanan S & Rani Thottungal 2013)

Figure 5.2 Estimation of path bandwidth by hop

Figure 5.2 illustrates the estimation of path bandwidth by hop.

1. For the given path, node c records the free time slots of node a and node b.

2. Initially, the path bandwidth between node a and node c is calculated.

3. The Free timeslots of link (a, b) are {1, 3, 5}, and free timeslots of link (b, c) are {1, 4, 5}. From this the common timeslots between link (a, b) and link (b, c) are {1, 5}.

4. At first, the timeslot between 4 and 3 is assigned to link (a, b) and link (b, c), and then the common timeslots 1 and 5 are allocated to link (a, b) and link (b, c) correspondingly.

5. Both link (a, b) and link (b, c) have 2 timeslots, so path bandwidth between node a and c is 2 timeslots. The result from this is forwarded to node d.

6. Node d finds that common free timeslot of the link (b, c) and link (c, d) is 5, and link (a, b) and link (c, d) have no common timeslot. Therefore, timeslot 5 is not available for the link (c, d), and timeslot 2 and 8 will be for the link (c, d).

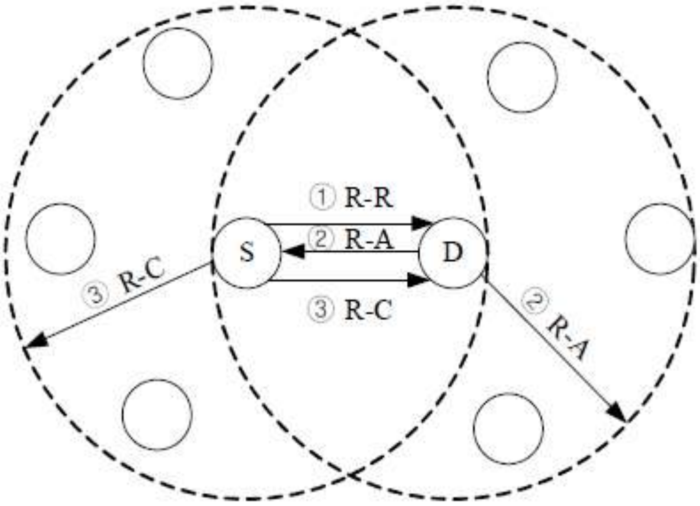
7. Path bandwidth between node a and d is 2. Node e finds that timeslots 5 and 8 in common timeslots between node d and e are occupied by link (b, c) and link (c, d) and has to assign timeslot 3 to link (d, e).

8. Finally, the Path bandwidth between node a and e is 1. Link (b, c) and link (c, d) only take one timeslot.

5.3 RESOURCE ALLOCATION TABLE (RAT)

The RAT maintains a network for each node in the form of a table. By referring to a resource allocation information message a node creates its own RAT. After receiving a resource allocation information message from a node a neighbour nodes receive its updates from its own RAT. The RAT includes the resource allocation information for 3-hop neighbours to maintain user data slot occupation information of neighbours. The nodes over 3 hops do not interfere with one another and can produce the same user data slot simultaneously.

Reservation messages are exchanged in resource reservation (RR) slots. The reservation is performed in a 3-way hand shake manner. The source node which wants to send data transmits a Resource Request (R-R) message in the pre-defined RR slot. This message includes a source ID, destination ID, sub-frame index, number of slots to use, and duration of slots to use in a sub-frame. When a node receives an R-R message, the node checks its own RAT and decides the requested user data slots are available.



(Source: Narayanan S & Rani Thottungal 2015)

Figure 5.3 Resource reservation procedure during an R-R slot

From the Figure 5.3,

a. When a node receives an R-R message, it checks its own RAT and decides the requested user data slots are available.

b. When the requested slots are available, the node transmits a Resource ACK (R-A) message along with the original information of the R-R message.

c. When the slots are not available, the node does not transmit anything. The source node waits for the R-A message before expiry of R-A timer.

d. When the source node receives the R-A message, the source node transmits a Resource Confirm (R-C) message including the information of the original R-R message.

e. When the source node does not receive the R-A message before expiry of R-A timer, the source node tries reservation again in the next TDMA frame.

f. Finally, the node which listens to the R-A and/or R-C messages updates its own RATs.

5.4 OVERALL PROCESS

1. Initially the path bandwidth is estimated using the two-hop bandwidth allocation.

2. Available timeslots are classified by the estimation of the path bandwidth between nodes.

3. Next, by using the Resource Allocation Table, a network is maintained for each node in the form of a table.

4. A node creates its own RAT referring to the resource allocation information message.

5. The RAT includes the resource allocation information for 3-hop neighbours to maintain user data slot occupation information of neighbours.

6. When neighbour nodes receive a resource allocation information message from a node, the neighbour node updates its own RAT.

5.5 SIMULATION RESULTS

5.5.1 Simulation Setup

The performance of the Cross-Layer based Fair Resource Allocation (CFRA) is evaluated through NS2 (Network Simulator: http //www.isi.edu/nsnam/ns) simulation. A random network deployed in an area of 1000 X 1000 sqm is considered. The packet sending rate is varied as 100, 200, 300, 400 and 500Kb. The number of flows is varied as 2, 4, 6, 8 and 10. The distributed coordination function (DCF) of IEEE 802.11 is used for wireless LANs as the MAC layer protocol. The simulated traffic is CBR with UDP source and sink. Table 5.1 Simulation Parameters.

Table 5.1 summarizes the simulation parameters used

No. of Nodes	150
Area Size	1000 X 1000 sqm
Mac	802.11
Simulation Time	50 sec
Traffic Source	CBR
Packet Size	512
Rate	100,200,300,400and 500Kb
Propagation Model	TwoRayGround
Antenna Type	OmniAntenna
No.of Flows	2, 4, 6, 8, 10

5.5.2 Performance Metrics

The performance of CFRA is compared with Distributed TDMA (DTDMA) (Myunghwan Seo et al. 2011) protocol. The performance is evaluated mainly, according to the following metrics.

Average end-to-end Delay: The end-to-end-delay is averaged over all surviving data packets from the sources to the destinations.

Average Bandwidth Utilization: It is the amount of data that can be transmitted successfully.

Residual Energy: It is the average residual energy after data transmission.

5.5.3 Results

A. Varying the Traffic Flows

In the initial experiment, the number of flows is varied as 2, 4, 6, 8 and 10 with rate 100Kb.

Table 5.2 Results for Varying Traffic Flows

Number of Flows	Delay (Sec)		Bandwidth Utilization(Mb/s)		Residual Energy (Joules)s	
	CFRA	DTDMA	CFRA	DTDMA	CFRA	DTDMA
2	10.25685	20.85248	1.647521	1.486217	5.984628	5.574982
4	19.58427	25.94752	0.984282	0.587618	5.163748	3.997514
6	20.98413	26.08475	0.587483	0.476385	5.008421	3.999785
8	22.95762	28.94728	0.674598	0.512873	5.128462	4.025872
10	23.85146	30.94722	0.497622	0.408752	5.068475	4.967482

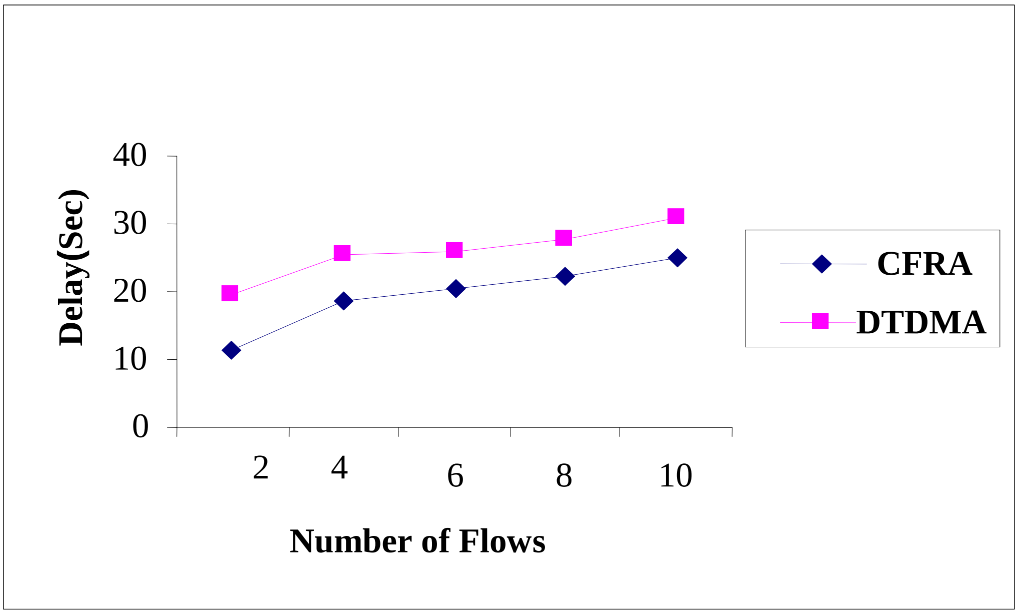


Figure 5.4 Flows Vs Delay

Figure 5.4 shows the delay of CFRA and DTDMA techniques for different flows scenario. For the flows 2, the delay of the proposed CFRA is 50.81% lower than the existing DTDMA technique; for the flows 4, the delay of the proposed CFRA is 24.52% lower than the existing DTDMA technique; for flows 6, the delay of the proposed CFRA is 19.55% lower than the existing DTDMA technique, for flows 8, the delay of our proposed CFRA is 20.69% lower than the existing DTDMA technique; for flows 10, the delay of the proposed CFRA is 22.92% lower than DTDMA technique. The overall conclusion is that the delay of the proposed CFRA approach has 28% of lower than DTDMA approach.

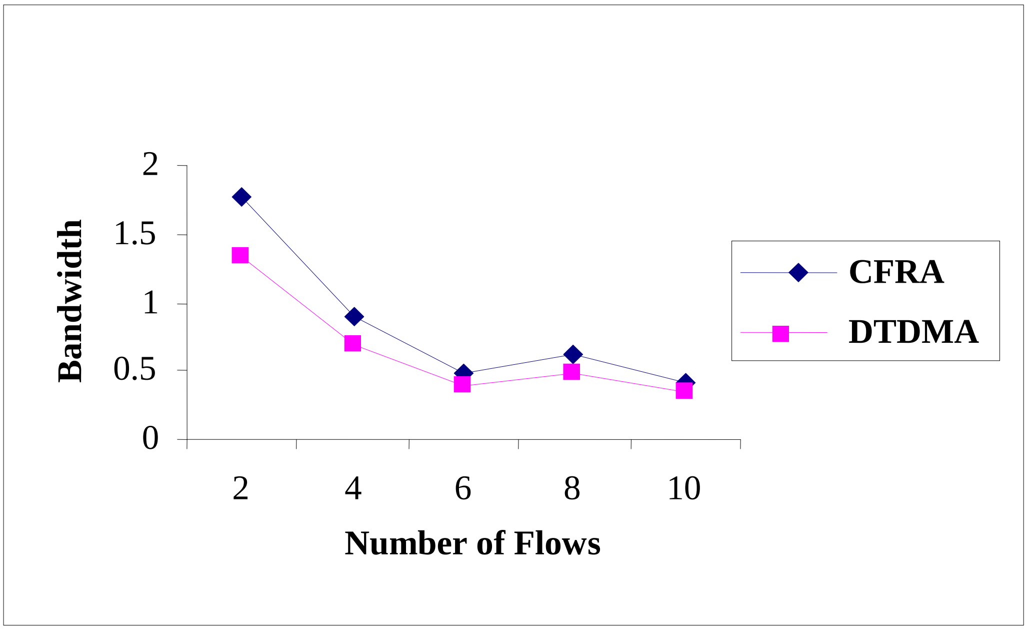


Figure 5.5 Flows Vs Bandwidth Utilization

Figure 5.5 shows the bandwidth utilization of CFRA and DTDMA techniques for different flows scenario. For the flows 2, the bandwidth utilization of the proposed CFRA is 9.79% higher than the existing DTDMA technique; for the flows 4, the bandwidth utilization of the proposed CFRA is 40.29% higher than the existing DTDMA technique, for flows 6, the bandwidth utilization of the proposed CFRA is 18.91% higher than the existing DTDMA technique; for flows 8, the bandwidth utilization of the proposed CFRA is 23.97% higher than the existing DTDMA technique; for flows 10, the bandwidth utilization of the proposed CFRA is 17.85% higher than DTDMA technique. The overall conclusion is that the bandwidth utilization of our proposed CFRA approach has 22% of higher than DTDMA approach.

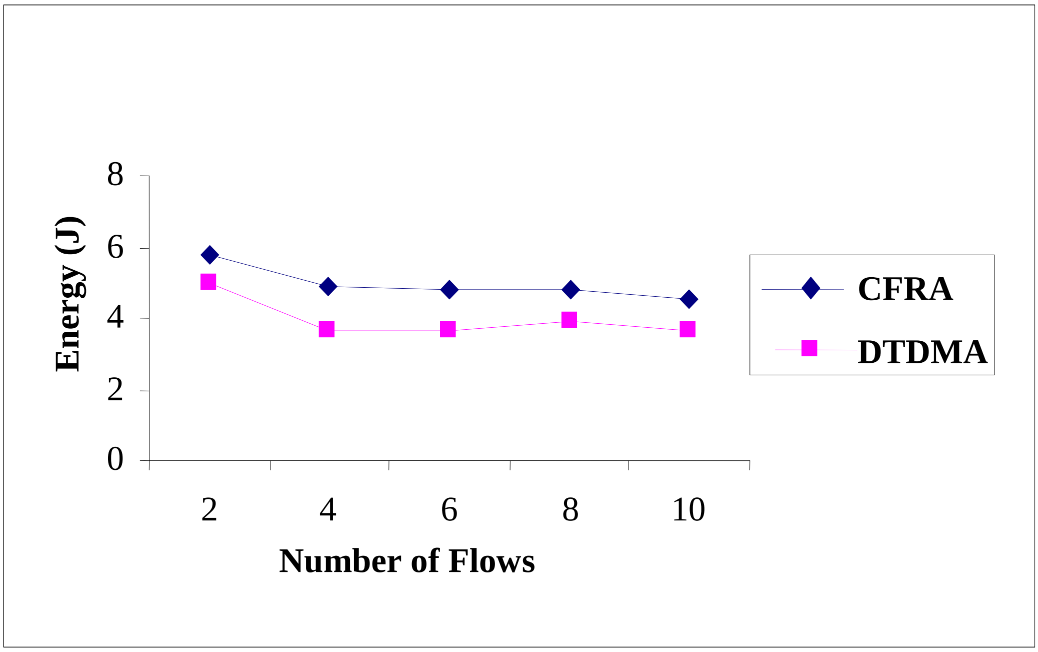


Figure 5.6 Flows Vs Energy

Figure 5.6 shows the residual energy of CFRA and DTDMA techniques for different flows scenario. For the flows 2, the residual energy of our proposed CFRA is 6.84% higher than the existing DTDMA technique; for the flows 4, the residual energy of the proposed CFRA is 22.58% higher than the existing DTDMA technique; for flows 6, the residual energy of the proposed CFRA is 20.13% higher than the existing DTDMA technique; for flows 8, the residual energy of our proposed CFRA is 21.49% higher than the existing DTDMA technique; for flows 10, the residual energy of the proposed CFRA is 2% higher than DTDMA technique. The overall conclusion is that the residual energy of our proposed CFRA approach has 15% of higher than DTDMA approach.

B. Varying the Traffic Rate

Next, the packet sending rate is varied as 100, 200, 300, 400 and 500Kb with 10 flows.

Table 5.3 Results for Varying Traffic Flows

Data Rate (kb)	Delay (Sec)		Bandwidth Utilization (Mb/s)		Residual Energy (Joules)	
	CFRA	DTDMA	CFRA	DTDMA	CFRA	DTDMA
100	25.84153	30.84257	0.417284	0.384125	4.287248	3.997518
200	26.84257	30.64722	0.467212	0.394182	4.487259	3.999784
300	31.82543	33.86172	0.471524	0.354781	4.157249	3.694751
400	30.12848	34.4673	0.417852	0.304572	4.199874	3.724816
500	30.08732	33.07814	0.571843	0.458721	4.087419	3.954781

Figures 5.7 to 5.9 show the results of delay, bandwidth, and energy for the packet sending rate as 100,200,300,400 and 500 in CFRA and DTDMA protocols. The inference when comparing the performance of the two protocols, is that CFRA outperforms DTDMA by 13.25% in terms of delay, 20.34% in terms of bandwidth utilization, and 19.91% in terms of residual energy.

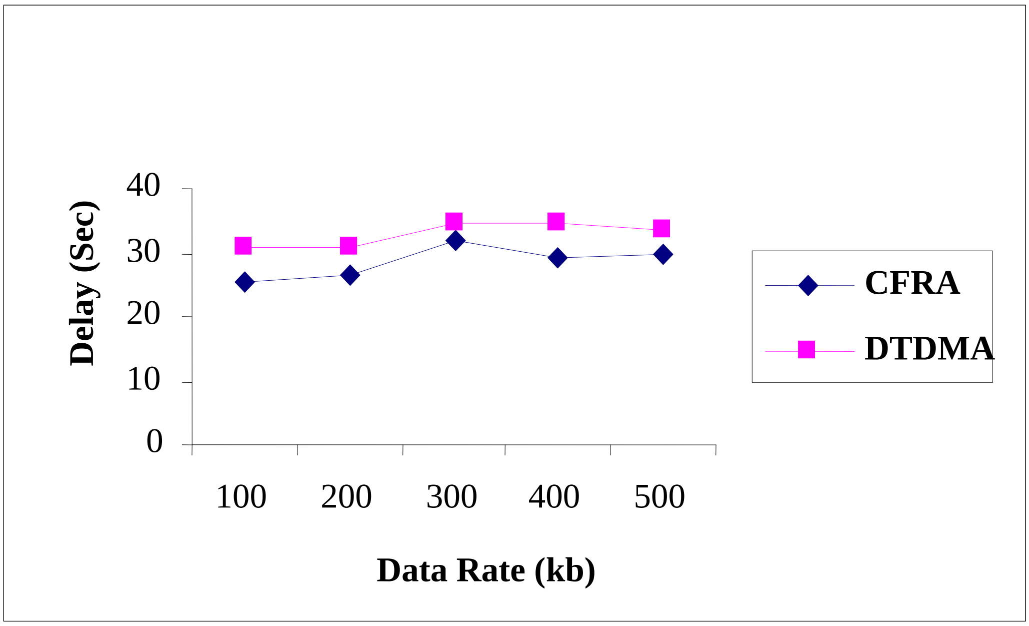


Figure 5.7 Rate Vs Delay

Figure 5.7 shows the delay of CFRA and DTDMA techniques for different rate scenario. For the rate 100Kb, the delay of the proposed CFRA is 16.21% lower than the existing DTDMA technique; for the rate 200Kb, the delay of our proposed CFRA is 12.41% lower than the existing DTDMA technique; for rate 300Kb, the delay of the proposed CFRA is 6.01% lower than the existing DTDMA technique; for rate 400Kb, the delay of the proposed CFRA is 12.58% lower than the existing DTDMA technique; for rate 500Kb, the delay of the proposed CFRA is 9.04% lower than DTDMA technique. The overall conclusion is that the delay of the proposed CFRA approach has 11% of lower than DTDMA approach.

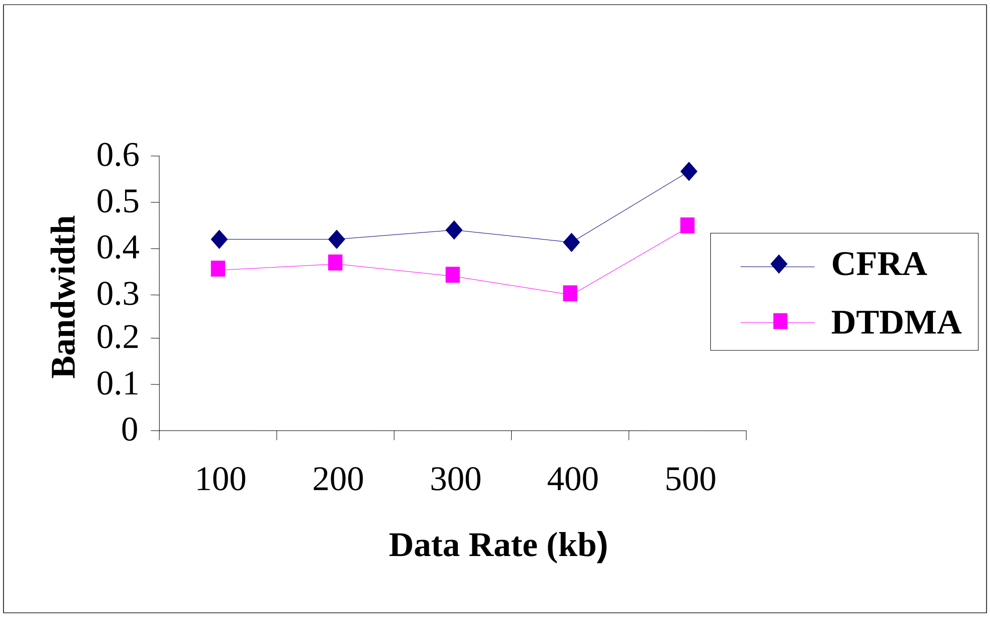


Figure 5.8 Rate Vs Bandwidth Utilization

Figure 5.8 shows the bandwidth utilization of CFRA and DTDMA techniques for different rate scenario. For the rate 100Kb, the bandwidth utilization of the proposed CFRA is 7.94% higher than the existing DTDMA technique; for the rate 200Kb, the bandwidth utilization of the proposed CFRA is 15.63% higher than the existing DTDMA technique; for rate 300Kb, the bandwidth utilization of the proposed CFRA is 24.75% higher than the existing DTDMA technique; for rate 400Kb, the bandwidth utilization of the proposed CFRA is 27.11% higher than the existing DTDMA technique; for rate 500Kb, the bandwidth utilization of the proposed CFRA is 19.78% higher than DTDMA technique. The overall conclusion is that the bandwidth utilization of the proposed CFRA approach has 19% of higher than the DTDMA approach.

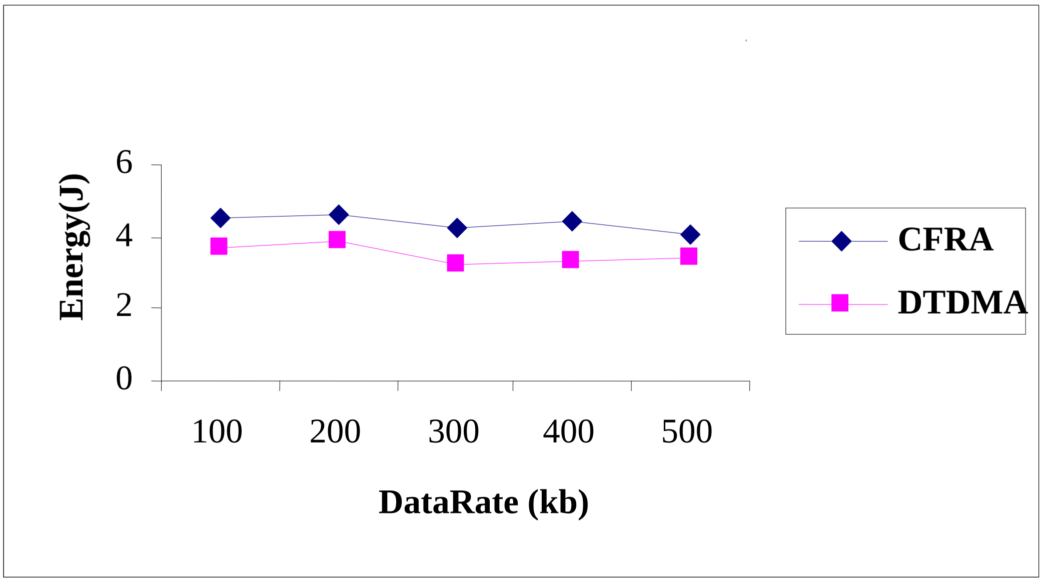


Figure 5.9 Rate Vs Energy

Figure 5.9 shows the residual energy of CFRA and DTDMA techniques for different flows scenario. For the rate 100Kb, the residual energy of the proposed CFRA is 6.75% higher than the existing DTDMA technique; for the rate 200Kb, the residual energy of the proposed CFRA is 10.86% higher than the existing DTDMA technique; for rate 300Kb, the residual energy of the proposed CFRA is 11.12% higher than the existing DTDMA technique; for rate 400Kb, the residual energy of the proposed CFRA is 11.31% higher than the existing DTDMA technique; for rate 500Kb, the residual energy of the proposed CFRA is 3.24% higher than the DTDMA technique. The overall conclusion is that the residual energy of the proposed CFRA approach has 9% of higher than DTDMA approach.

5.6 CONCLUSION

In this chapter, a fair resource allocation technique is proposed for the selected routes to ensure fair distribution in resource utilization. In TDMA-MAC protocol; the path bandwidth can be estimated using the two-hop bandwidth allocation. The Cross-Layer based Fair Resource Allocation (CFRA) protocol is implemented in NS-2 and compared with the Distributed TDMA (DTDMA) protocol. The performance is evaluated in terms of end-to-end delay, bandwidth utilization and residual energy. The inference when comparing the performance of the two protocols is that CFRA outperforms DTDMA by 25.1% in terms of delay, 20% in terms of bandwidth utilization, and 19.98% in terms of residual energy, when the number of data flows is varied from 2 to 10. Similarly, it outperforms DTDMA by 13.25% in terms of delay, 20.34% in terms of bandwidth utilization, and 19.91% in terms of residual energy, when the transmission rate is varied from 100 to 500Kb.