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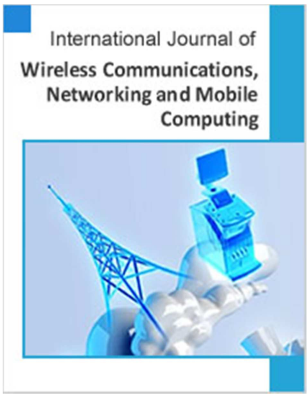

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A Control Mechanism Using Adaptive Router and Markovian Decision Towards Secured MANET Communication

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Abstract
Secured Mobile Ad-hoc Network has drawn the attention of research community in the last 15 years. In the context of Mobile Ad hoc Network (MANET), we are motivated by the design of routing to provide control mechanism that avoids routing congestion and data collision. Currently MANET communication is inherently Transmission Control Protocol (TCP-based) and relies on receives window and inflexible architectural design. This imposes significant challenges into adopting new secured MANET communication to minimize data collision and routing congestion. In this paper we propose a control mechanism Adaptive Router Congestion and Markovian Decision-based Collision Control (ARC-MDCC), to ensure secured communication in MANET. We first developed the proposed Adaptive Router Congestion Control (ARCC) model, considering a simplified network with data packet balancing using assessment control mechanism and thereby reducing the routing overhead. Second considering resultant congestion controlled path obtained through ARCC, a Markovian Decision-based Data Collision Control mechanism is applied along with fair data share rate, we adopted the designed algorithm to minimize data collision rate and therefore increase the packet delivery ratio. Analytical expressions are verified by performing series of simulation experiments. The proposed ARCC-MDCC outperforms similar secured MANET communication model found in the literature reducing the routing overhead and data collision rate by improving the packet delivery ratio in MANET.

1. Introduction

Due to multipath availability and higher data interfere, secured data transmission is considered to be difficult in Mobile Ad hoc Network (MANET). In [1], a congestion control mechanism for Transmission Control Protocol was designed by covering three performance metrics, TCP throughput, Round Trip Time (RTT) and receive window, resulting in higher throughput rate. Despite higher throughput, a major concern that remained unaddressed was security. To ensure security along with throughput, collusion tolerable privacy preservation mechanism was designed in [2] with the aid of sum and product evaluation.

A contextual cooperative congestion control policy was designed in [3], aiming at improving the load reduction. However, with the increasing load, the rate of throughput was reduced. In [4], Explicit Congestion Control (ECC) mechanism was designed to improve the stability and throughput and reduces the routing delay. To address optimal routing, shortest path routing algorithm was investigated in [5].

A priority aware mechanism for assigning priority collision estimation was used in [6] to improve the throughput. But, contention remained unsolved. To address collision and contention related issues, a Mobility and Load Aware Routing (MLAR) mechanism using Markovian Decision Process was designed in [7].

Dynamic Congestion Detection and Congestion Control were investigated in [8] to ensure the reliable communication. But, the detection time was unaddressed in this work. In [9], early congestion detection was made through non-congested neighbors. In [10], for high performance computing, congestion control mechanism was designed with the aid of injection throttling techniques. However, this paper deals with the routing delay, data collision rate as well as the node mobility on ad hoc network. Our motivation is to give an accurate estimation of the Markovian Decision-based data collision control mechanism for ad hoc networks.

The rest of the paper is organized as follows. Section 2 contains a literature overview on the characterization of routing and congestion model in mobile ad hoc networks and associated properties. We describe in Section 3 our method to modeling the router congestion and data collision in MANET by taking into consideration both router congestion and data collision. The Section 4 contains also numerical simulations carried out to validate our analytical framework. We then give in Section 5 the comparison of performance metrics with the state-of-the-art works. Finally, Section 6 concludes the paper.

2. Related Works

One of the major areas of communications is through MANET, which are flooded with data and other allied services. In [11], Load Balanced Congestion Adaptive Routing was designed to increase the packet delivery ratio with minimum average end to end delay. Lyapunov function was applied in [12] to reduce the congestion based on a consensus model.

To provide an effective mean for conflict mobile ad hoc network routing, a Simulated Annealing Approach was presented in [13]. However, the channel estimation does not provide better. An Extended Window estimator method was presented in [14] to address this complexity. Road traffic and congestion mechanism were investigated in [15]. A cross layer based congestion control mechanism [16] using efficient bandwidth was investigated to improve the data delivery but the cost of reduced collision rate.

A proactive congestion avoidance mechanism based on link bandwidth and round trip time was designed and analyzed in [17]. In [18], a survey on congestion control mechanism was designed. Congestion control in air traffic networks using data driven modelling was constructed in [19] that evaluated the impact of traffic load. In [20], optimal routing mechanism using Powel algorithm was examined to improve the routing quality but also maximized the rate of throughput.

In [21], channel selection through cognitive model was designed to increase the network overall utility. In [22], the proposed scheduling method forms non-disjoint cover sets to ensure the coverage and connectivity for every sensor. User authentication scheme using bio hashing facilitated security against the known attacks was proposed in [23]. The author of [24] presented an analytical framework by considering interference and mobility of the link nodes. In [25], distributed trust implementation protocol to ensure security was discussed in detail.

In this context, we develop an Adaptive Router Congestion and Markovian Decision-based Collision Control (ARC-MDCC) method to determine the probability that a transmission is successfully received by a node based on the state transition probability matrix. Starting from modelling the relative distances between the source and destination nodes, based on the path availability, we calculate the probability that the congestion is said to occur or not using Data Packet Rate Request and Optimal Data Packet Share Rate. Moreover, we use a state based on link quality and request rate states for modelling the link state.

3. Control Mechanism for Router Congestion and Data Collision in MANET

In this section, a control mechanism to thwart router congestion and data collision for secured transmission in MANET, called Adaptive Router Congestion and Markovian Decision-based Collision Control (ARC-MDCC) is presented. The control mechanism based on ARC-MDCC ascertains the packets arriving in the network and performs end to end transmission reducing routing delay time and improving packet delivery ratio.

3.1. Problem Formulation

Let us consider a MANET composed of a number of mobile nodes uniformly scattered in monitoring fields and represented by a graph '$G = (V, E)$', where 'V' represents the set of nodes and 'E' corresponds to the set of communication links between the nodes. The whole network comprises of three types of nodes namely, source node 'SN', destination node 'DN' and a router 'R'. Figure 1 show the sample multipath routing practiced in MANET.

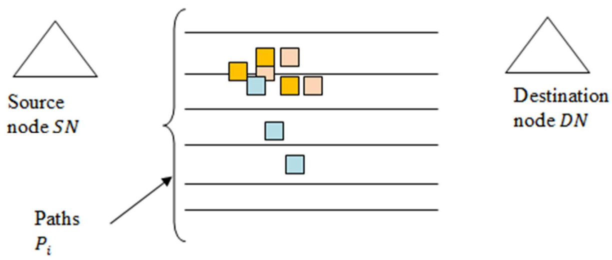

Figure 1. *Multipath routing in MANET.*

Figure 1 show a source node 'SN' with a data packet 'DP_i' to be sent through paths '$P_1, P_2, P_3, .., P_n$' with each path possessing the cryption key 'CK', data parts 'DPs' and control packet 'CP' to the destination node 'DN'. The colored square boxes indicate the data packets to be sent. We also assume that each node is assigned with a triplet of frame '(CK, DPs, CP)', where each frame represents the data packet information of the node.

Table 1. *Structure of frame.*

Node ID	Cryption Key	Control Packet	Data Packets
'$SNID$'	'CK'	'CP'	'DP'

As shown in the Table 1, the control packet holds the information regarding the flow of data parts in the network. The square box with different colors denotes the nodes with cryption key, control packet and data packet. Given with many source nodes to send data packets to different destination nodes, though multipath routing is followed in MANET, with higher amount of congestion, the delay time for routing gets compromised, resulting in collision. Therefore, a method that reduces the routing congestion and data collision rate is designed so that the routing time gets reduced improving the data packet transmission rate.

3.2. Adaptive Router Congestion Control

In this section, congestion control mechanism using adaptive router, called Optimal Data Packet Allocation Congestion Control (ARCC) is explained. ARCC allows the process to initiate with high data packet sending rate and intersect to the optimal share data packet sending rate quickly based on the assessment obtained from the routers. The router generates assessment to control the data packet sending rate of all flows (i.e. through different paths) through it. Figure 2 shows the block diagram of Adaptive Router Congestion Control mechanism.

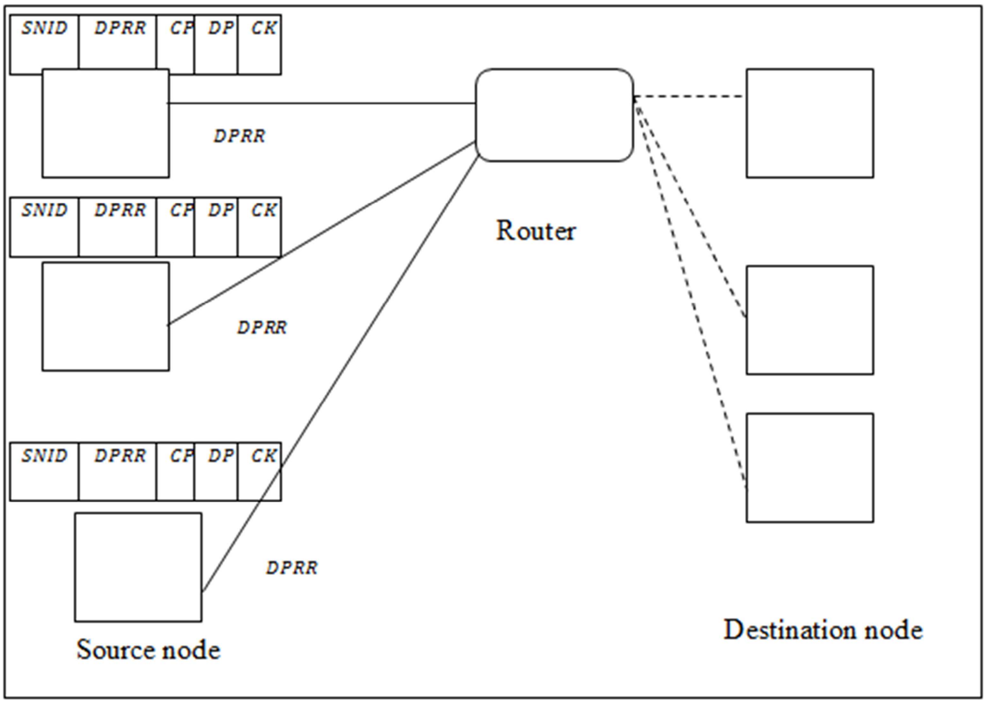

Figure 2. *Block diagram of Adaptive Router Congestion Control mechanism.*

The source sender mobile node includes a Data Packet Rate Request field in the frame and sets the initial value of this field to be the desired data packet sending rate of this sender mobile node and is expressed as given below.

$$SN: R \rightarrow (SNID, DN, DPRR, CP, DP, CK) \quad (1)$$

From (1), each source mobile node 'SN', sends its ID '$SNID$', the data packet request rate '$DPRR$', control packet 'CP', data packet 'DP' and cryption key 'CK' along with the destination node 'DN'. When the data packet reaches a router, the router compares the value in Data Packet Request Rate '$DPRR$' field with the router's own optimal data packet share rate'$ODPSR$' (for the specific node through SNID and cryption key CK) and puts the smaller one back into that field.

$$if\ [VAL\ (DPRR) < VAL\ (ODPSR)] \rightarrow Congestion\ not\ detected \quad (2)$$

$$if\ [VAL\ (DPRR) > VAL\ (ODPSR)] \rightarrow Congestion\ detected \quad (3)$$

The optimal data packet allocation algorithm (i.e. router) using assessment control mechanism in the proposed method assess the optimal data packet share rate '$ODPSR$'for the corresponding mobile node at regular time intervals. The objective behind using the assessment control mechanism is that the router maintains only one optimal data packet share rate for each output interface (i.e. path). The current number of data packet flows through this interface is obtained using the aggregate input data packet traffic rate and the optimal data packet share rate assigned for a specific time interval. Hence, the optimal data packet share rate '$ODPSR$' for each node at time interval 't' is formalized as given below.

$$E\ (t) = \frac{ADPT}{DPT} \quad (4)$$

$$ODPSR\ (t) = \frac{B - p\ (t)}{E\ (t)} \quad (5)$$

From (4), '$E\ (t)$' corresponds to the estimation of data packets at time interval 't', obtained from aggregate input data packet traffic rate '$ADPT$' (i.e. input data packet traffic rate of all the nodes in queue) and input data packet traffic rate as 'DPT' (i.e. data packet traffic rate of a single node). On the other hand, from (5), '$ODPSR$' is the ratio of the difference between the total bandwidth rate 'B' with a path size of '$p\ (t)$' and estimation of data packets at time interval 't' respectively.

On receiving the data packet, the router obtains the data packet rate request and sends it back to the source sender mobile node. When the source sender mobile node receives the ACK packet, it obtains the value and adjusts the data packet request rate accordingly, therefore minimizing the congestion occurring at router. Table 2 shows the Optimal Data Packet Allocation algorithm.

Table 2. *Algorithm for Optimal Data Packet Allocation.*

Input: Source Node 'SN', Destination Node 'DN', Cryption Key '$CK = CK_1, CK_2, \dots, CK_n$', Data Packet '$DP = DP_1, DP_2, \dots, DP_n$', Data Packet Rate Request '$DPRR$', Optimal Data Packet Share Rate '$ODPSR$'	
Output: Minimizing routing congestion	
1:	Begin
2:	For each Source Node 'SN' with Data Packet 'DP' sent to the Destination Node 'DN'
3:	For each Router 'R'
4:	Source Node sends packets with Data Packet Rate Request to router using (1)
5:	Measure Optimal Data Packet Share Rate '$ODPSR$' using (5)
6:	If '$VAL\ (DPRR)$'< '$VAL(ODPSR)$'
7:	Congestion not detected
8:	End if
9:	If '$VAL\ (DPRR)$'> '$VAL(ODPSR)$'
10:	Congestion detected
11:	End if
12:	End for
13:	End for
14:	End

As shown in the Table 2, the Optimal Data Packet Allocation algorithm detects the probability of congestion using Data Packet Rate Request and Optimal Data Packet Share Rate. With these two rates obtained, the possibility of router congestion is detected at an early stage with the aid of assessment control mechanism. In this way, not only the router delay time is reduced but also the routing overhead is significantly improved.

3.3. Markovian Decision-Based Data Collision Control

In this section, a control mechanism for data collision using Markovian decision model is designed with the objective of minimizing the collision and therefore improving the packet delivery rate. The Markovian decision model in the proposed method splits the time axis into equal timeslots and each source mobile node transmits data packets to the corresponding destination node through the router in its allocated time slots. Then the state of a mobile node 'SN_i' at time slot 't' is expressed as given below.

$$p_t^n = (q_t^n, DPRR_t^n) \quad (6)$$

From (6), 'p_t^n' corresponds to the state of 'nth' mobile node at time interval 't','q_t^n' corresponds to the link quality of mobile node 'SN_i', whereas '$DPRR_t^n$' corresponds to the data packet request rate of mobile node 'SN_i' at time slot 't'. Let us further consider that the link quality of each mobile node be divided into 'U' distinct levels and the data packet request rate of each mobile node be divided into 'V' distinct levels. Then, the link quality state space and the data packet request rate state space is expressed as given below.

$$U \rightarrow Q_1, Q_2, \dots, Q_U \quad (7)$$

$$V \rightarrow D_1, D_2, \dots, D_V \quad (8)$$

The states '$Q_1, Q_2, \dots, Q_U$' and '$D_1, D_2, \dots, D_V$' evolve based on 'U' and 'V' distinct levels using Markov chains with state transition probability matrix 'U^n' and 'V^n' is expressed as given below.

$$U^n = q_{ij}^n, where\ i,j \in Q \quad (9)$$

$$V^n = DPRR_{ij}^n, where\ i,j \in DPRR \quad (10)$$

If mobile node 'SN_i' is idle at time slot 't', its state '$p_t^n = (q_t^n, DPRR_t^n)$' keeps unchanged. The state transition probability matrix '$Prob^n$' is then measured based on 'U^n' and 'V^n'. Let 'a_{nk}' represents the action for mobile source node 'SN_i' at time slot 't', then '$Prob^n$' is measured as given below.

$$if\ SN_i \text{ is busy at time slot t + 1, then } a_{nk} = 1 \quad (11)$$

$$if\ SN_i \text{ is idel at time slot t + 1, then } a_{nk} = 0 \quad (12)$$

Once action is accomplished, the mobile source node 'SN_i' obtains a series of observations. Each observation are associated either with a positive acknowledgment '$PACK$' or negative acknowledgment '$NACK$'. Let '$Obs_i = \{PACK, NACK\} = \{\alpha_1, \alpha_2\}$' represents the observation set, where '$\{\alpha_1 = 1, \alpha_2 = 0\}$' then, each observation on '$Obs_t^n \in Obs_p$'. The decision about which source mobile node is selected at each time slot for packet transmission depend on all the actions'a_{nk}' and observations 'Obs_t^n' history, as the mobile nodes' states are only partially observable. In this way, data collision is controlled during packet transmission before being received at the receiver node. Table 3 shows the Markovian Decision-based Collision Control algorithm.

Table 3. *Markovian Decision-based Collision Control.*

Input: Source Node 'SN', Destination Node 'DN', Node ID '$SNID$', Cryption Key '$CK = CK_1, CK_2, \ldots, CK_n$', Data Packet '$DP = DP_1, DP_2, \ldots, DP_n$', Data Parts '$DPs$', Paths '$P = P_1, P_2, \ldots, P_n$', Router '$R$', transmission range '$r$', Data Packet Rate Request '$DPRR$', Optimal Data Packet Share Rate '$ODPSR$'
Output: Optimized data collision
1: Begin
2: For each Source Node 'SN' with Data Packet 'DP' sent to the Destination Node 'DN'
3: For each Router 'R'
4: Measure link quality of mobile node and data packet request rate using (6)
5: Measure link quality state (7)
6: Measure request rate states (8)
7: Measure state transition probability matrix 'U^n' using (9)
8: Measure state transition probability matrix 'V^n' using (10)
9: end for
10: End for
11: End

As shown in the Table 3, for each source mobile node to transmit their packets to the destination node through a router, the Markovian Decision-based Collision Control algorithm measures three important factors. The three factors are link quality of mobile node, its link quality state and the request rate states. With these three factors identified, the algorithm measures the transition probability matrix through which the data collision is controlled.

4. Simulation and Performance Comparison

To evaluate the proposed method is simulated using NS2 network simulator. NS2 simulator is chosen to provide a flexible and extensible simulation environment. In the following simulation, the collision avoidance method including, Incast Congestion control for Transport Control Protocol (IC-TCP) [1] and Collusion Tolerable Sum and Product calculation without Secure Channel (CTSP-SC) [2] are evaluated and compared with the ARC-MDCC on Mobile ad hoc network.

The total dimension is fixed as 1400m*1400m with the maximum transmission range of each mobile node being 300m and the duration of the simulation is 200ms. Random way point model is used as the mobility model for each node. The node speed is varied between 2m/s and 25m/s with the mobile node pause time varied between 0 seconds and 3ms. Table 4 shows the parameters obtained that finally were used in the experiments.

Table 4. *Parameters and values used in the experiment.*

Parameter	Setting value
Network area	1400m * 1400m
Mobile node density	10, 20, 30, 40, 50, 60, 70
Simulation time	200ms
Mobility model	Random way point
Node transmission range	300m
Number of packets sent	9, 18, 27, 36, 45, 54, 63
Data packet size	512bytes
Pause time	5ms

5. Simulation Results

The tested algorithms are run on the same experimental environment as listed in Table 4 so their performance can be fairly compared. To evaluate the efficiency of ARC-MDCC method, the following metrics like routing overhead, data collision rate, packet delivery ratio, packets sent, mobile node density in Mobile Ad hoc network is measured.

Routing overhead is obtained on the basis of the neighboring nodes in network, waiting for packets being transmitted in MANET. The mobile nodes in MANET often change their location due to random change observed in topology.

The routing overhead is formulated as given below. Routing overhead measure total number of routing packets (i.e. number of packets sent) which are transmitted during the simulation time.

$$RO = \sum_{i=1}^{n} DP_i * Time\ (Routing) \quad (13)$$

From (13), the routing overhead 'RO' rate depends on the availability of multiple paths and is measured in terms of milliseconds (ms). Lower routing overhead ensures efficiency of the method.

Next, to measure data collision rate 'DCR', the mobile nodes ready for communication 'DCR', data packets sent by the mobile node 'DP_s', received by the destination node 'DP_r', the size of data packet sent '$Size\ (DP_s)$' and received '$Size\ (DP_r)$', are considered. Lower data collision rate ensures the efficiency of the method and it is measured in terms of percentage (%).

Packet delivery ratio measures the ratio of the number of data packets successfully delivered to the destinations to the total number of data packets actually sent by the sources.

$$PDR = \frac{DP_r}{DP_s} \quad (14)$$

From (14), the packet delivery ratio 'PDR' is measured using the data packets sent 'DP_s' and the data packets received 'DP_r' at a specific time. Higher the packet delivery ratio more efficient the method is said to be.

5.1. Routing Overhead

The number of packets sent was varied from 9 through 63 with each packet being 512 bytes. The routing overhead is measured in terms of milliseconds (ms).

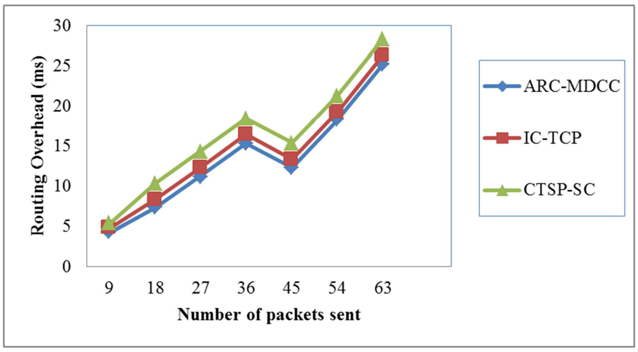

Figure 3. *Routing overhead by varying the number of packets sent.*

Figure 3 shows the routing overhead for data packet transmission in mobile ad hoc network with respect to different number of packets sent. The routing overhead for data packet transmission is improved with the application of Optimal Data Packet Allocation Congestion Control mechanism. The Adaptive Router Congestion Control mechanism intersects with the optimal share data packet sending rate based on the assessment control mechanism. In addition to that the router periodically senses the input data packet arrival rate and the queue size before proceeding towards routing for secured data packet transmission. As a result, the routing overhead using ARC-MDCC method is reduced by 9% compared to IC-TCP and 24% compared to CTSP-SC.

5.2. Data Collision Rate

The experimental results in previous section have indicated that ARC-MDCC method is more efficient than IC-TCP and CTSP-SC respectively in terms of routing overhead. In this section we compared ARC-MDCC method with, IC-TCP [1] and CTSP-SC [2] to illustrate the effectiveness of applying Markovian Decision based algorithm for measuring the data collision rate.

Table 5. *Data collision rate and mobile node density.*

Methods	Data collision rate (%)
ARC-MDCC	68.35
IC-TCP	72.49
CTSP-SC	78.43

From table 5 it is observed that ARC-MDCC identifies more number of route paths than IC-TCP and CTSP-SC and therefore reduces the data collision rate by sending the packets through the other paths. This is achieved using the Markovian decision model. With the aid of Markovian decision model, ARC-MDCC method, the router considers the link quality of the mobile node whose packet has to be transmitted that tends to minimize the data collision occurring between mobile nodes. Therefore, the data collision rate observed in ARC-MDCC method is reduced by 6% compared to IC-TCP and 7% compared to CTSP-SC.

5.3. Packet Delivery Ratio

Finally, we address the third goal of the experiments with respect to packet delivery ratio showing the comparison between ARC-MDCC, IC-TCP and CTSP-SC. It is measured in terms of percentage (%).

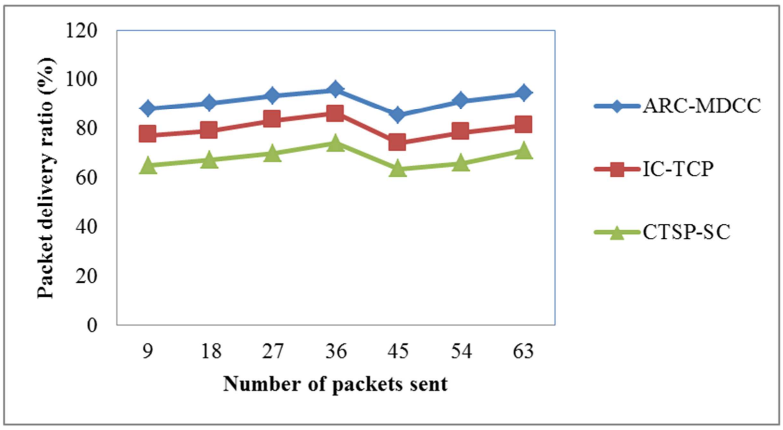

Figure 4. *Packet delivery ratio versus number of packets sent.*

The important observation from the Figure 4 given above is that the packet delivery ratio is directly proportional to the number of data packets sent. Therefore, though major deviations are not being observed, but comparatively the ARC-MDCC method proved to be better than the state-of-the-art methods. Column Difference shows the percentage difference of the particular routing scenario with respect to packet delivery ratio occurrence using three different methods. The packet delivery ratio for 18-data packets and 27-data packets was increased in ARC-MDCC by 13% and 11% in the case compared with IC-TCP; 25% and 23% in the case compared with CTSP-SC.

6. Conclusion

The control mechanism for router congestion and data collision method is formulated as an optimal path model where the communication path is identified based on the assessment control mechanism using adaptive router. By measuring the optimal communication path, the design of an Optimal Data Packet Allocation algorithm based on optimal data packet share rate of each mobile node in the network ensures optimality in routing. With the optimized routing, a data collision mechanism based on Markovian Decision reduces the data collision rate by designing state transition probability matrix based on link quality and request rate states. Extensive simulation is carried out to evaluate the proposed method. The results validate the effectiveness of the proposed method and show that it significantly outperforms two traditional data collision methods.

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Biography

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Steven Nolle received his MS in CS from the University of Kansas in 1981. He is an Associate Professor in the Computer Science Department at Maharishi University of Management, Fairfield, Iowa. He has done extensive software design, architecture, and development in broadband cable networks. He holds 4 U.S. patents in the area of load balancing voice, data, and video traffic in high speed cable networking systems. His new research interest is optimizing and load balancing traffic in Mobile ad hoc Networks.