RARRA: Receiver-Assisted Robust Rate Adaptation in Wireless Networks

Nafiul Rashid, Syed Sabir Salman-Al-Musawi, and Muhammad Mahbub Alam*

***Abstract*—The IEEE 802.11 wireless local area network (WLAN) standard, especially 802.11a remains the most popular way to exchange data over wireless links. The major requirement is to adapt to highly dynamic channel conditions with minimum overhead and ensure robustness and speed of transmission. However, switching to the optimal transmission rate is a problem as 802.11 specification fails to specify via SNR measurement, the accurate channel condition at receiver. A further problem lies in calibrating such SNR values to the optimal rate. To this end we propose a novel Rate Adaption Scheme RARRA (Receiver Assisted Robust Rate Adaptation). Our key contributions include exploiting the more precise channel estimation of SNR-based Rate Adaptation coupled with estimating the channel condition at the receiver and finally sending this estimated information to the transmitter with minimum overhead. In other words we avoid RTS/CTS overhead to send the channel condition to the transmitter and use acknowledgment rates to serve' this purpose. Secondly, we differentiate the cause of frame loss as either due to channel error or collision using RTS/CTS in an adaptive fashion. This minimizes overhead but at the same time ensures that rate is not falsely changed due to frame loss caused by collision. RARRA exploits the best of SNR based approaches and provides channel condition at the receiver to the transmitter with minimum overhead aided by Adaptive RTS.**

***Keywords*—Rate adaptation, WLANs, channel condition.**

I. INTRODUCTION

The IEEE 802.11 [1] standard defines a set of transmission rates at the physical layer, the most widely used being 802.11a with 8 supporting rates. The role of Rate Adaptation lies in dynamically selecting the transmission rate of wireless networks based on time-varying channel quality thereby affecting throughput performance at the receiver. In theory, SNR based approaches should ideally increase rate when SNR values at the receiver improves but decreases rate when SNR values become poor at which a low transmission rate offers improved throughput. In either case the necessity is to adapt transmission rate to an optimal one based on time varying dynamic channel conditions.

However it is a challenge to switch to the optimal rate especially due to the limitations faced in providing the transmitter with accurate channel conditions at receiver as SNR. Furthermore, challenge lies in calibrating these representative SNR values to the optimal transmission rate. The 802.11 specification fails to specify any means of delivering this channel measurement at the receiver. Hence it is a challenge to devise one incurring minimum overhead and provide the information at appropriate time intervals to aid optimal rate selection.

Among the traditional rate adaptation algorithms which can be broadly classified into Frame-based and SNR-based, it is observed that Frame-based algorithms are widely used and deployed especially ARF (Auto Rate Fallback) [2] and SampleRate [3] (which is now the default Rate Adaptation scheme in many drivers). Meanwhile, advancements in this field has proved SNR-based approaches to provide accurate channel condition estimation since it uses physical layer metric SNR provided by the wireless devices to select the transmission rate [4]–[6]. Conversely, channel estimation of Frame-based approaches is less accurate as it uses consecutive frame successes/losses as an indicator of channel condition. Moreover it switches rate sequentially which fails to utilize dynamic channel conditions to maximize throughput. Among the well-established SNR-based algorithms, CHARM [7] assumes channel symmetry between sender and receiver

* Corresponding author.

Nafiul Rashid and Muhammad Mahbub Alam are with the CSE department of Islamic University of Technology (IUT), Gazipur, Bangladesh. e-mail: nafiul.rashid@iut-dhaka.edu and mma@iut-dhaka.edu.

Syed Sabir Salman-Al-Musawi is working as a Software Developer at Therap Services LLC. e-mail: sabir.salman@therapservices.net.

Manuscript received February 26, 2015; revised May 20, 2015.

which is infeasible as channel condition at receiver is desired. RBAR [4] measures channel condition at receiver but fails to minimize overhead of RTS/CTS in sending this information to the transmitter. Lastly, REACT [8] improves the above situations but sticks to sequential rate switching which does not lead to optimal rate and maximum throughput at the receiver.

Taking these into consideration we propose a novel Rate adaptation scheme RARRA that implements a receiver-side and a sender-side algorithm. Channel condition is estimated via SNR measurement at the receiver. The receiver side algorithm selects a rate based on a mapping of the SNR to data rate according to our implemented lookup table. The acknowledgment is sent to the transmitter at the selected rate to inform it of the channel condition.

The sender side algorithm sends the next data rate at the received ACK-rate but if ACK is not received then it diagnoses the cause of frame loss using Adaptive RTS. Our goal is to pass a packet through as soon as possible to get the channel condition based on which we adapt our rate. Hence, on two consecutive failures RARRA switches to the lowest rate and transmit the data frame with high success probability to get the channel condition.

In a nut shell RARRA has the following key advantages:

- As compared to other existing closed loop rate adaptation approaches RARRA minimizes the overhead in sending the channel condition information to the receiver.
- It is a receiver assisted approach meaning that channel quality is measured at the receiver which is the ideal case and the improvement or degradation of channel condition is fed to the transmitter via acknowledgment rates.
- It can clearly distinguish the cause of frame loss as due to collision or channel error using Adaptive RTS to avoid false rate change at the cost of on-demand RTS overhead.
- Finally RARRA does not require any modification of the frame format as specified by 802.11 standard. The acknowledgement rate can be determined at the receiver by synchronization with the sender and chopping the received bits.

The paper is organized as follows. Section II includes the state-of-the-art rate adaption methods and Section III critiques on those methods. Section IV explains the proposed mechanism in detail. In Section V, we explain the simulation setup and compare the performance of the proposed method with existing methods, and finally, we conclude the paper in Section VI with summary and future research directions.

II. State-of-the-Art Methods

Existing rate adaptation approaches operate in two phases namely Channel quality estimation and Action of rate switching based on the channel condition. At first we focus on these two aspects and then give some insight on some state-of-the art rate adaptation approaches in terms of how they deal with these two phases.

A. Rate adaptation operation

Channel quality estimation: As we have already stated, rate adaptation approaches can be broadly classified into Frame-based or SNR-based. The distinguishing factor lies in the fact that channel quality is measured in terms of PHY layer metric i.e., SNR or success/loss of MAC layer frames. SNR based approaches map the SNR values to the transmission rate and in some cases even maintain a long history of SNR values to make rate decision at any point of time. Whereas, on the other hand Frame-based approaches estimate channel quality based on success/loss of previously transmitted frames.

Rate switching Action:There are two main approaches to adjust the rate upon channel estimation. The sequential approach switches rate to the next higher/lower one based on channel condition whereas the optimal rate switching opts for the rate that optimally utilizes the channel condition to maximize throughput at the receiver.

B. Existing Rate Adaptation algorithms

Several rate adaptation algorithms exist as follows: *ARF (Auto Rate Fallback)* [2]:This is one of the first proposed rate adaptation algorithm which follows a frame-based approach. Channel quality estimation is based on success/loss of MAC layer frames. It increases rate sequentially to the next higher or lower rate based on 10 consecutive successes and 2 consecutive failures respectively.Detailed pseudo code that describes formally the behavior of ARF is available in [9]

SampleRate [3]:One of the earliest but still widely deployed rate adaptation approach. It is frame based and hence uses the corresponding channel estimation metric. SampleRate starts at the highest rate supported by the 802.11 standard and sequentially decreases to the next lowest rate on 4 consecutive failures. However, on 10 consecutive successes it randomly chooses from among the higher rates.

RBAR (Receiver Based Auto Rate) [4]: RBAR is the first proposed SNR based approach. It ideally measures SNR at the receiver and informs the channel condition at receiver end to the sender via CTS frame. However, it proposes using RTS/CTS before every transmission. On receiving this channel quality information the sender switches to the optimal rate.

CHARM (Channel-aware Rate Adaptation Algorithm) [7]: One of the ground breaking rate adaptation approach was CHARM. It is an SNR-based approach that does not use RTS/CTS at all. It measures channel condition at the receiver and assumes link symmetry between sender and the receiver to estimate channel condition at the sender. CHARM maintains a history of all SNR values weighted by time to make rate decisions. It switches to the optimal rate based on rate-SINR mapping.

REACT (Rate Adaptation Using Coherence Time) [8]: One of the latest rate adaptation approaches include REACT. Its contribution includes providing an SNR-based algorithm where the receiver informs the transmitter of the improved channel condition via altering the ACK transmission rate. The channel status information obtained via the preceding ACK frame will be valid for the following data frames. Upon receiving an ACK frame indicating the good channel condition, the transmitter increases the data rate to the next higher rate. REACT identifies the reason of frame losses by exploiting the feed-back from the preceding ACK frame and the coherence time. Thus, the data frames that are lost during this interval are deemed to be lost due to occurrence of collisions, and not by channel errors. However, REACT switches rate sequentially which does not guarantee optimal utilization of dynamic channels.

III. Critiques on Existing Algorithms

State-of-the-art rate adaptation algorithms described above use their own mechanisms. In this section we focus on the implication of using these mechanisms and to what extent they serve robustness and optimal rate selection.

A. Frame Based or SNR Based

We are familiar that Frame Based approaches estimate channel condition based on previously transmitted frames. This use of link layer metrics causes rate under selection and channel underutilization. ARF and SampleRate are two such frame based approaches each of which uses success/failure of previously transmitted frames and switches rate sequentially and randomly respectively. Hence they pose the disadvantages of traditional frame-based approaches. On the other hand SNR based approaches which switch to optimal rate as governed by SNR as a measure of channel condition has optimal channel utilization. RBAR, CHARM and REACT obtain such benefits as being SNR-based approaches. They switch to optimal rate and use SNR as a physical layer metric for judging channel conditions.

B. Channel Quality Estimation

It is always desirable to measure channel condition at the receiver since that is the end where frames need to be received and decoded. Channel condition measurement at the sender does not give us an accurate picture of channel conditions at the receiver since we cannot assume channel symmetry. ARF and SampleRate measures channel condition at the sender. CHARM is also in the group but it uses Channel Reciprocity to assume a symmetric channel between sender and receiver which is practically infeasible. On the other hand RBAR and REACT estimates channel condition at the receiver which is good thing so it sends the best rate at which the data can be sent.

C. Rate Switching Techniques used

Sequential rate poses the problem of rate under selection while optimal rate switching leads to optimal rate selection. Random rate switching results in improper channel utilization. ARF and REACT relies on sequential rate switching and so they only switch to the immediate higher or lower rate when channel condition changes but this does not utilize dynamic channels which may suddenly improve or get worse. However RBAR and CHARM uses optimal rate switching techniques. CHARM maps SNR values to data rates while RBAR uses the rate advertised by the CTS frame. Lastly, SampleRate increases rate randomly from a set of data rates higher than the current.

D. Use of RTS/CTS

RTS (Request to Send) and CTS (Clear to Send) are control frames which ensures channel occupancy but incurs overhead so its use should be minimized. RBAR uses RTS/CTS always. It minimizes collision based losses because every transmission is guarded by RTS/CTS but incurs huge overhead and is unnecessary. ARF, SampleRate and CHARM never use RTS/CTS which reduce overhead but increases vulnerability of collision based losses. REACT on the other hand uses RTS/CTS in a different and most desirable fashion. Not using RTS/CTS at all increases collision based losses and leads to inaccurate rate selection. Overusing RTS/CTS compensates the gain. REACT incurs the marginal overhead with respect to RTS/CTS for delivering the channel status information but changes the RTS window (number of RTS protected frames) adaptively.

E. Differentiating the Cause of Frame Loss

The rate avalanche effect is one of the main reasons why rate under selection degrades channel performance. Usually frame based RA algorithms experience it because they under select rates. It is important to differentiate between frame losses as either due to collision or channel-error because collision based losses falsely lower rates and degrades performance. The main use of RTS/CTS frame is to differentiate between the causes of frame loss. ARF, SampleRate and CHARM never use RTS/CTS frames. Hence they are vulnerable to collision from hidden stations. Moreover they fail to differentiate the cause of packet loss and may falsely reduce rate due to collision based losses. RBAR on the contrary uses RTS/CTS before every transmission and hence reduces collision based losses and prevents rate under selection. However huge RTS overhead is incurred. Lastly, REACT uses Adaptive RTS. It uses RTS/CTS on demand to differentiate the cause of frame loss and avoid inaccurate rate selection due to collision based losses. It exploits the benefit of RTS but uses it adaptively depending on the channel coherence time. An RTS window gives protection to only a few frames. So overhead is reduced but differentiation of cause is achieved.

IV. Receiver Assisted Robust Rate Adaptation (RARRA)

Among all the previous algorithms that we have discussed so far, each seems to address a particular issue and make its improvements on the others. However, none succeeds in fulfilling all the criteria that determines an algorithm to be robust and optimal. A brief comparative analysis is made to bring forward a clear picture along with the potential features that we promise to provide in our implementation that will overcome the weaknesses of each.

A. Motivation

We are highly motivated to focus on the fact that our algorithm will address robustness and optimality as well as address the issue of Rate Avalanche Effect. That is our main motivation is to develop such an algorithm that fulfills all the criteria of a robust and optimal algorithm.
With this motivation we develop a Robust Rate Adaptation algorithm with the following objectives:

- A SNR Based approach : As SNR Based approach provides more precise estimation of channel quality due to use physical layer metric that is the SNR value.
- Uses 802.11a Standard rates : As 802.11a rates are widely used.
- Channel condition is measured at receiver : As channel condition is best measured at receiver.
- Receiver informs transmitter without RTS/CTS overhead : Receiver uses acknowledgement rate to inform the transmitter.
- Differentiate the cause of frame loss : Uses Adaptive RTS to differentiate the cause of frame loss.
- Switch to Optimal rate : Switches to optimal rate according to channel condition.

B. Design

Our design implementation spans the receiver side as well as the sender side. More specifically, we use the channel condition measurements at the receiver to decide the rate selection at the sender while adaptively using RTS/CTS mechanism to suppress **Rate Avalanche Effect**.

1) Receiver Side Mechanism: After a successful data reception we use acknowledgement rate to inform the transmitter about the channel condition. To select the ACKrate (Acknowledge Rate) that will determine the following transmission rate by the sender we use the following steps:

- We maintain a Table of SNR ranges that maps to the ACKrate called SNR-ACKrate lookup table.

TABLE 1: Comparative Analysis

Algorithm	Type	Switching Techniques	Channel Quality Estimation	RTS/CTS Used
ARF	Frame Based	Sequential	Sender	Never
SampleRate	Frame Based	Random	Sender	Never
RBAR	SNR Based	Optimal	Receiver	Always
CHARM	SNR Based	Optimal	Sender	Never
REACT	SNR Based	Sequential	Receiver	Adaptive
RARRA	SNR Based	Optimal	Receiver	Adaptive

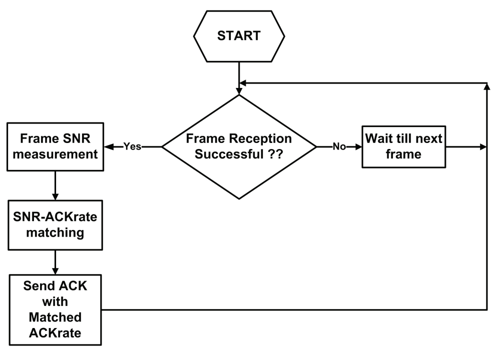

Fig. 1: Receiver side algorithm.

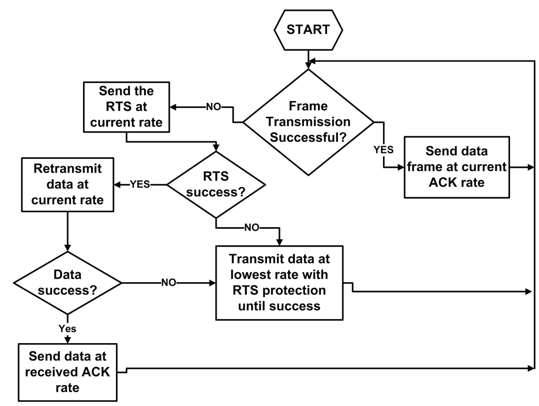

Fig. 2: Sender side algorithm.

- Nextly we determine the SNR value of the received data frame.
- We then use estimated SNR value to find an ACKrate from the SNR-ACKrate lookup table.
- Finally we send the ACK(Acknowledgement) at the selected ACKrate.

The SNR-ACKrate lookup table we used is described in [10].

This SNR-ACKrate lookup table in [10] was implemented in the sender side but we have used this table in the receiver side as channel condition is best measured at receiver. Figure 1 illustrates a clear picture of the receiver side implementation.

2) Sender Side Mechanism: After receiving the ACK at the rate determined by the receiver, our algorithm considers that the transmitter without any RTS/CTS gets informed of the channel condition at the sender and acts accordingly by sending the next data frame at that ACK rate.The steps that are followed at the sender include:

- If ACK is received, send the next data frame at received ACKrate.
- However, if ACK is not received, retransmit the frame with RTS protection.
- Even after RTS protection, a frame loss indicates channel error because if it was due to collision then RTS use would result in successful transmission.
- In case of two consecutive failures, send the next frame at lowest rate.
- The rationale behind this lies in the fact that a successful transmission is very likely at lowest rate.
- Thus, we make sure that the sender is aware of the dynamic changes in channel conditions by ensuring that data gets through to the sender at the lowest rate in poor channel conditions such that the ACKrate of the subsequent ACK can facilitate rate adaptation.The sender side mechanism is demonstrated in Fig. 2.

3) RARRA and Adaptive RTS: RTS/CTS incur overhead and tend to degrade performance when used excessively in a rate adaptation algorithm. Now the question lies in when RTS use is necessary? In the context of our algorithm RTS/CTS is used to identify the cause of frame loss. We term this as "Adaptive" use of RTS i.e-using it only when necessary. The next question may arise why we need to find out the cause of frame losses? In simple words, one of our main motives is to avoid the vicious cycle of Rate Avalanche Effect. More specifically, when the frame loss is due to channel error then we can lower the rate immediately to improve the performance. But if the frame loss is due to collision then reduction of transmission rate will worsen the condition. To combat this we use Adaptive RTS at the sender side to differentiate the cause of frame loss and ensure robustness simultaneously by preventing excessive use.

4) Operation Rationale: Before we delve deep into the simulation results of our algorithm it is imperative to demonstrate the operation rationale of RARRA and how it is supposed to outperform a widely used Frame based method ARF [2] as well as one existing SNR based method REACT [8].

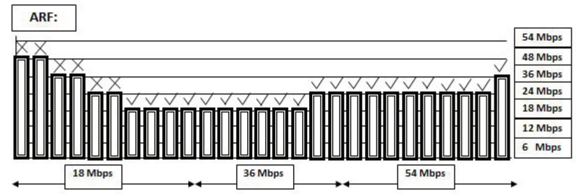

Fig. 3: Operation rationale of ARF.

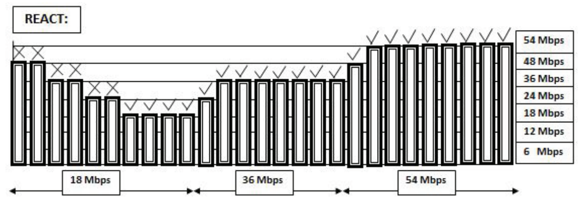

Fig. 4: Operation rationale of REACT.

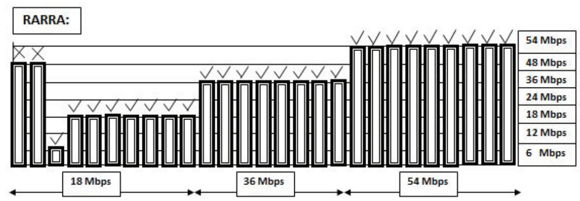

Fig. 5: Operation rationale of RARRA.

Figure 3 shows that the ARF scheme underutilizes the channel capacity due to sequential rate switching techniques. Suppose the channel now supports 18 Mbps while the sender sends at 48 Mbps. So to decrease to 18 Mbps it will get two consecutive failures (indicated by a cross) at 48, 36, 24 then it will get to 18 for a successful transmission (indicated by a tick). Similarly when the channel condition becomes suitable for 36 Mbps, from 18 Mbps it will sequentially increase data rate every after 10 consecutive successful transmissions. A sequential rate switching in this fashion fails to calibrate the rate in line with channel conditions that are highly dynamic which eventually leads to the underutilization of channel capacity.

Similarly, Fig. 4 shows the case of REACT which sends ACK packets at a rate from among the Basic Rate Sets, we observe underutilization of channel capacity. When channel condition supports 18 Mbps and the current transmission rate is 48 Mbps, REACT decreases rate sequentially on having two consecutive failures and therefore have the same limitations of rate decrease as in ARF. In case of rate increase it performs better than ARF but fails to switch to optimal rate directly. It performs poorly when channel condition fluctuates frequently.

To the contrary, our proposed scheme provides optimal performance in case of rate decrease and rate increase (Fig. 6). In case of rate decrease, when the channel condition supports 18 Mbps, after two consecutive failures it sends the data at lowest rate which increases chance for packet to get through and get the acknowledgement. Once we get the acknowledgement we can know about the channel condition and switch to the optimal rate directly without having 6 failures as was the case of ARF and REACT before reaching 18 Mbps. On the other hand rate increases fairly quickly based on improved channel conditions as well.

V. Simulation Setup and Performance Evaluation

In this section we evaluate the performance of RARRA by using the ns-3 [11] simulator. Our simulation experiments follow the 802.11a standard which defines all the physical layer parameters including a set of transmission rates. We simulate the indoor environment where WLAN is mostly used. We perform simulation using static as well as mobile nodes. Unless

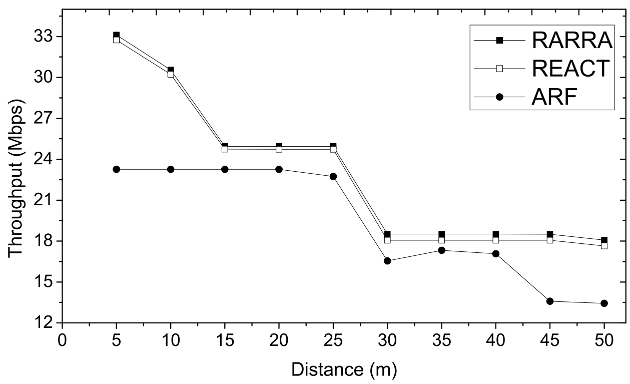

Fig. 6: Log-distance path-loss model in static scenario.

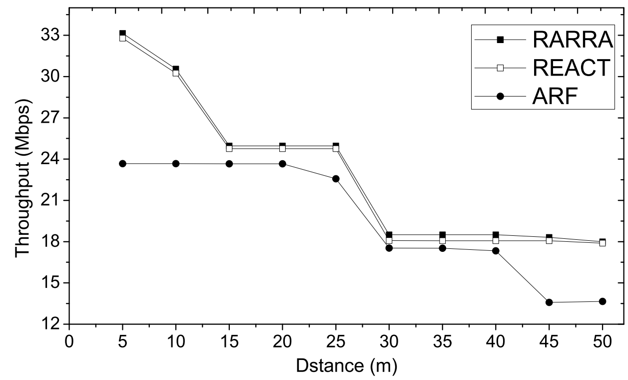

Fig. 7: Log-distance path-loss model in mobile scenario.

stated otherwise, we use a default configuration consisting of log-distance path-loss model with the path-loss exponent of three [12] as well as two-ray ground propagation loss model and the MAC layer payload length is set to 2048 bytes. We evaluate the following schemes in terms of the throughput (in Mbps): (1) our proposed scheme (referred to as RARRA), (2) the ARF scheme (referred to as ARF) and (3) the REACT scheme (referred to as REACT by varying distance, speed of mobility, number of contending flows to an AP and Packet size. The rationale behind this is to justify the improvement of RARRA over a well-established frame-based algorithm ARF as well as over a recently proposed SNR-based algorithm REACT.

A. *Results with varying distances*

At first we discuss our result based on various distances since distance is a major factor of radio signal attenuation. We configure a topology consisting of a single flow between 2 nodes with a flow data rate of 54 Mbps configured to have the Adhoc wifi mac which is default in ns-3 [11]. Apart from the default configuration we perform the simulation using ConstantPositionMobility model for static scenario and RandomWalk2dMobility model for mobile scenario. We generate 100000 packets and by varying distance between the stations from 5 to 50m we evaluate throughput both for static and mobile scenarios. In general, the throughput of all the schemes decreases as the distance between the two stations increases. From the figures below we can deduce some important observations for each of the path loss models.

1) Log-distance path-loss model: In the static scenario (Fig. 6), ARF performs very poorly as compared to both REACT and RARRA. However in all cases RARRA is a clear winner over REACT even though the performance improvement is less apparent at smaller distances but more pronounced at larger distances. This is mainly due to the fact that at static scenarios channel conditions do not change much.At more or less stable channel conditions smaller distance or less attenuation results in more or less similar performance between RARRA and REACT. However, we outrun REACT to a greater extent when signal attenuation is more at larger distances. In the mobile scenario (Fig. 7) on the other hand, throughput curve follows a more or less similar trend with ARF performing poorly as compared to both REACT and RARRA. Here also our proposed scheme RARRA ensures more robustness at larger distances and similar performance at smaller distances. Hence both static and mobile scenarios are more robust with increasing distance.

2) Two ray ground propagation loss model: We obtained much better performance as compared to the previous path loss model. As the figure illustrates, in both static (Fig. 8) and mobile (Fig. 9) scenarios ARF demonstrates a more or less similar throughput which is much less than both REACT and RARRA. However in static scenarios where channel conditions are varying less RARRA outperforms REACT even at smaller distances when nodes are nearby and also at larger distances thereby showing robustness at short range as well as long range. Most importantly, the optimal rate switching of RARRA exploits transient channel conditions much better than the sequential rate switching of REACT. To back it up we can see from the figure that at any distance RARRA is much ahead in throughput than REACT when nodes are mobile.

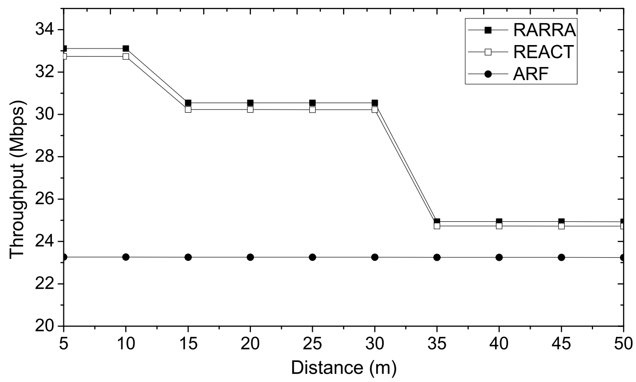

Fig. 8: TworayGround propagation-loss model in static scenario.

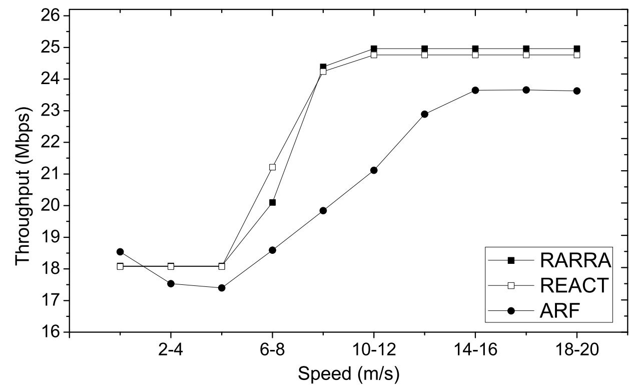

Fig. 10: Log-distance path-loss model with various speed of mobility.

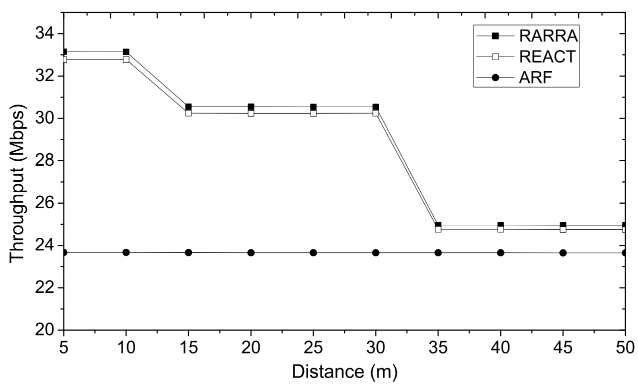

Fig. 9: TworayGround propagation-loss model in mobile scenario.

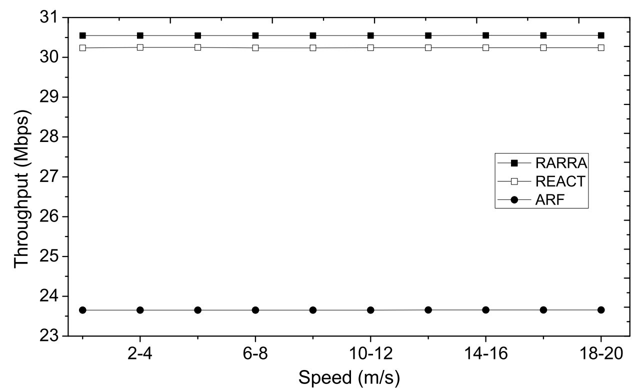

Fig. 11: TworayGround propagation-loss model with various speed of mobility.

B. Results with various speed of mobility

We move on with our observations based on various speed of mobility as the degree of variation in channel condition is directly related to speed. We configure a similar topology as used in the previous section except that we only use RandomWalk2dMobility model for mobile scenario and instead of varying distance we evaluate throughput by varying speed of mobility and keep distance to a constant 30m. In general, the throughput of all the schemes shows a similar trend with speed. From the figures below we can again deduce some important observations for each of the path loss models.

1) Log-distance path-loss model: REACT and RARRA far outperforms ARF at various speeds (Fig. 10). Even though initially our proposed scheme RARRA demonstrates similar performance to REACT when nodes are moving slowly and maintaining fixed distance mainly due to the fact that in such cases channel conditions vary less. However with increasing speeds channel conditions changes more dynamically and this is when RARRA's optimal rate switching and instant feedback is better able to adapt than the sequential approach followed by REACT. Results demonstrate that after about 10 m/s RARRA constantly outperforms REACT hence better exploiting dynamic channel conditions.

2) Two ray ground propagation loss model: Similar to varying distance, we observed a much greater performance gap here for the different schemes (Fig. 11). All schemes show a similar trend with throughput changing less throughout the speed range. However, ARF performs very poorly and remains at around 23 Mbps. REACT and RARRA follows a similar trend but at all speeds ranging from 0 to 20 m/s RARRA performs better. The rationale behind this performance gap is the instant feedback and optimal rate switching. RARRA uses RTS adaptively to get the packet through as soon as possible so that receiver

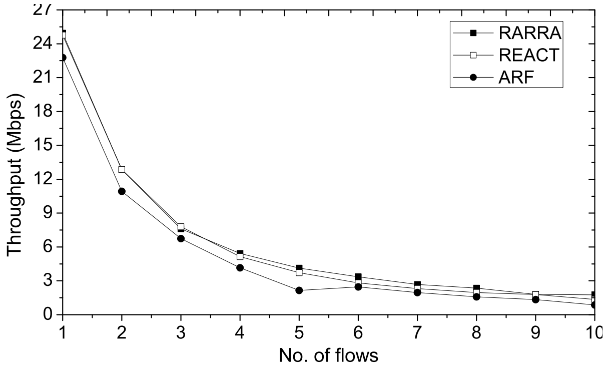

Fig. 12: Log-distance path-loss model with various contending stations.

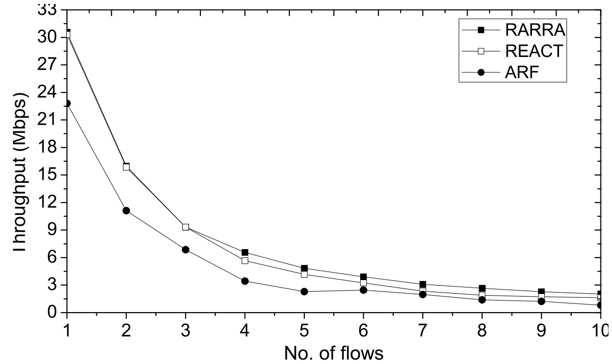

Fig. 13: TworayGround propagation-loss model with various contending stations.

has instant feedback about channel. This helps our scheme to switch to the optimal rate as quickly as possible even at high mobility. But this calibration is not possible using sequential rate switching as in REACT.

C. Results with various number of contending flows to an AP

To study how efficiently RARRA operates in collision-prone environments, we now switch from a single link topology to a multiple link topology. We introduce an infrastructure based network and configure a grid of contending stations with an AP. We gradually increase the number of contending stations from 1 to 10 and we place 2 stations in a row along the grid with a horizontal separation of 20 and a vertical separation of 5 between nodes. We place the AP at x=10 and y=25 in the grid. The AP is stationary and follows ConstantPositionMobility model while the nodes are mobile and follows RandomWalk2dMobility model. There is a general decrease of throughput with increasing number of contending flows. Using this configuration we find the following results.

1) Log-distance path-loss model: ARF lags behind in performance while RARRA and REACT perform similarly at the start where there is less contending flows (Fig. 12) . However, as this number increases especially when number of flows contending for the AP exceeds 4 RARRA performs better than REACT. An increase in the number of flows leads to higher probability of collision and more frame loss. RARRA recovers faster from this collision based losses and switches to optimal rate much quickly than REACT.

2) Two ray ground propagation loss model : As before, RARRA performs better here (Fig. 13). Even though both start off with almost same performance but after about 3 contending flows RARRA has better throughput then REACT and this performance gap widens further indicating RARRA is more robust to even collision based losses. An increase in number of flows leads to greater contention and a higher possibility of collision. RARRA and REACT both make use of adaptive RTS but the difference lies in the fact that a packet lost when channel condition is very poor is retransmitted with RTS protection at the lowest supported rate by the former whereas the latter switches rate sequentially. Since the probability of getting the packet through to the receiver is greater at the lowest rate hence channel information is updated faster at the receiver which eventually leads to optimal rate selection.

D. Results with various packet sizes

Lastly, we test the impact of frame sizes on throughput for each of the schemes. We use the default configuration with a single flow of 2 static nodes following ConstantPositionMobility model at a fixed distance of 30m.The flow data rate is fixed at 54Mbps.We generate 100000 packets and vary the size from 250 to 2048 bytes. There is a general increase in throughput with an increase in packet size. Notable observations include the following.

1) Log-distance path-loss model: ARF is much less in throughput throughout the entire range(Fig. 14). Both REACT and RARRA tend to start off together in terms of performance but with increase in packet size especially those exceeding 500 bytes, RARRA shows better performance. Both RARRA and REACT uses the default RTS/CTS threshold defined by ns-3 [11]. Larger packets are more prone to loss by

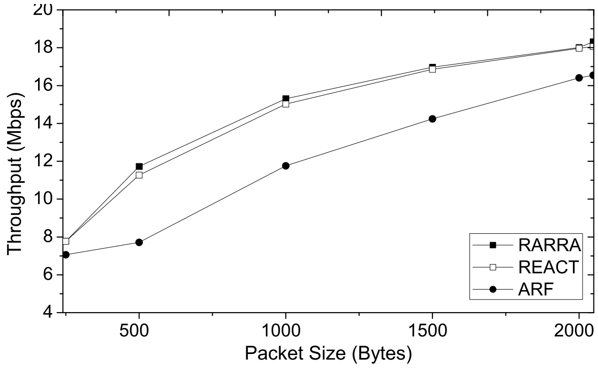

Fig. 14: Log-distance path-loss model with various packet sizes.

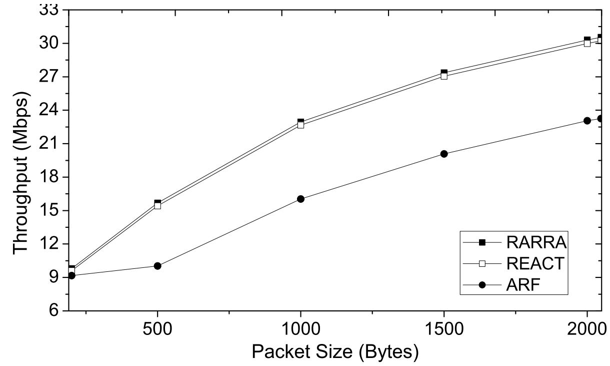

Fig. 15: TworayGround propagation-loss model with various packet sizes.

collision since they occupy the channel for greater duration. Even though both schemes apply adaptive RTS, RARRA succeeds in switching to the optimal rate sooner than the sequential switching by REACT. This provides optimal rate for larger packets to get through with higher success probability and so our proposed scheme provides robustness for such packets.

2) Two ray ground propagation loss model: The trend in throughput performance is the same as the previous path loss model(Fig. 15). However, the performance gain of RARRA over the entire range of tested packet sizes is less pronounced here. Both RARRA and REACT perform closely with RARRA being at the forefront over the entire range of packet sizes. The rationale behind this is already discussed above.

VI. Conclusion

In this paper, we discussed about our proposed Rate Adaptation algorithm, Receiver Assisted Robust Rata Adaptation (RARRA). RARRA has a two-fold implementation. At the receiver side RARRA maintains an SNR-ACKrate lookup table which is used to map the SNR of received data packet to the corresponding ACKrate. We measure channel condition at receiver which is more realistic and based on SNR we then transmit the ACK at a suitable rate. This selected ACK rate then becomes input to the sender side implementation. It is an indicator of channel conditions and the feedback is used to transmit next data frame. Our algorithm is robust against collision based losses and Rate Avalanche Effect by making use of RTS adaptively. It is quick to switch to the optimal rate because even after two consecutive frame losses it transmits at lowest rate, i.e., 6Mbps. The possibility of success is higher at this rate so that sender is informed soon enough about the poor channel condition and optimal rate switching can follow. We performed a comprehensive simulation of RARRA using the ns-3 [11] simulator by varying distance, speed of mobility, number of contending flows to an AP and Packet size. Our results show better performance in terms of throughput than a well-established frame based algorithms ARF and a recent SNR-based scheme REACT. However, our design still possesses limitations. Notably, our SNR-ACKrate mappings are less indicative of real scenarios which is a barrier to determining real world performance of the design. Moreover, our calibration of SNR to corresponding ACK rates demands implementation of the algorithm in real devices for better performance. In the future we plan to augment our scheme in a number of ways. Firstly, we plan to better calibrate our SNR-ACKrate mappings so that the range is even more indicative of real scenarios and provides even better performance. We plan to overcome this current limitation by implementing RARRA in real WLAN devices like the MADWIFI [13] driver. Finally, we can see clearly from our simulation results that RARRA outperforms REACT especially in dynamic cases when nodes are mobile and channel conditions are dynamic. This robustness paves a way for its use in highly dynamic networks like VANETs which we hope to achieve in the near future.

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Nafiul Rashid received his B.Sc. Engg degree in Computer Science and Engineering from Islamic University of Technology, Gazipur, Bangladesh in 2013, and currently pursuing his M. Sc. Engg. degree from the same university. Since 2013 he has been working as a Lecturer in the Department of Computer Science and Engineering of Islamic University of Technology, Gazipur. His research interests include wireless networking,data mining,cloud computing ,artificial intelligence and expert systems.

Syed Sabir Salman-Al-Musawi received his B.Sc. Engg. degree in Computer Science and Engineering from Islamic University of Technology, Gazipur, Bangladesh in 2013. Currently he is working as a Software Developer in Therap Services LLC, one of the leading software firms in the country. His research interests include wireless networking, software engineering, cloud computing, artificial intelligence and expert systems.

Muhammad Mahbub Alam received his B.S. degree in Applied Physics and Electronics and M.S. degree in Computer Science from the University of Dhaka, Bangladesh in 1998 and 2000, respectively. He received his PhD from Kyung Hee University, South Korea in February 2009. Since 2002, he has been working as a faculty member in the Computer Science and Engineering (CSE) department in Islamic University of Technology (IUT), Dhaka, Bangladesh. Currently, he is working as a Professor in the department. His research interests include wireless networks, and performance analysis of networking systems.