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THOMSON REUTERS

[Datta * *et al.*, 7(4): April, 2018]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

RATE ADAPTATION TECHNIQUES IN WIRELESS NETWORKS (WLAN)

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DOI: 10.5281/zenodo.1228656

ABSTRACT

The throughput of Rate adaptation in wireless networks 802.11is inclined by many parameters. Few of them are channel conditions, SNR, signal fading due to distance, Frame collisions from simultaneous transmissions and Interference from other sources etc. Among these, channel condition is most significant from the rate adaptation point of view. There are many standards for the data transmission provided by IEEE. IEEE 802.11 wireless networks (WLAN) supports multiple data transmission rates.

There are many techniques and many definition of rate adaptation. The simplest way to describe the rate adaptation - : "Rate adaptation is the determination of the optimal data transmission rate most appropriate for current wireless channel conditions". The Rate Adaptation algorithms used in the wireless network adapters are responsible for selecting the bit-rate used by the hardware when transmitting frames over the wireless channel. This algorithm heavily affects the performance of wireless devices. Rate adaptation is the process through which data may be send from the host node to the destination node with the maximum throughput in which nodes adap the data rate dynamically according to varying channel conditions

Keywords: Rate adaptation, ARF, AARF.

I. INTRODUCTION

It is the very basic and generic question about anything by anyone which may be asked that what is the need for any particular thing, when anyone starts to do a new thing. So before reading the paper, everyone should be aware of rate adaptation and need of Rate Adaptation in our life & importance in the current scenarios

In the current scenario, it might be appreciated that we are living in the era of computers. In every sphere of life, the various applications of computers may be noticed. Everyone is talking about computer and internet. Without internet, computers are not as much attractive &effective (in terms of browsing the web). Our current generation & youth are most interested in "doing things through web". As a result the almost every sector whether it is private or govt. or NGO, all are much more interested in doing things through web. When all are doing all things through web then it is but obvious that it will increase the traffic on the internet and experience a delay in transmission of data or failure in transmission. The enhanced traffic on internet may be the one cause of the congestion. Transmission delayed or transmission failed, it might be because of congestion. Now-a-days, in general all are facing a problem of congestion everywhere and as a result we are not getting the desired throughput. To overcome the problem of congestion, rate adaptation may play an important role. That is why a need was felt for efficient rate adaptation scheme, which improve the good throughputs, so that it may be overcome the problem.

Current scenario requires such algorithms which can intelligently & dynamically switch among the available data transmission rates. Such algorithms may be designed which switch wisely on various level of transmission. It can be seen in future where such algorithms will provide better results and achieve high throughput in which data transmission will switch after each successful packet. There are many algorithms which switch wisely during the transmission but those algorithms are also compromised with the throughputs i.e. not providing the maximum through put as per the expectation of the current scenario. But this is not so simple or easy as it looks like. This is not so easy to judge when to adapt the data rate and which one to adapt data rate to get the maximum throughput. And this is the most challenging area to design a new rate algorithm which gives the maximum throughput while adapting the bit rate intelligently as per channel conditions.

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Shaoen Wu.et.al.,[6] proposed that the wireless medium is exposed and highly sensitive to environmental disturbances like weather conditions, interference from other sources etc. Such sensitivity renders the wireless medium highly unstable and results in fluctuations of wireless channel quality. This unstability that wireless channel experiences calls for data adaptation algorithms to dynamically select appropriate data rate (modulation schema) upon different levels of channel quality.

Biaz S.et.al.,[4]addressed that the wireless medium suffers from unstable channel conditions (e.g. signal fading due to distance, frame collision from simultaneous transmissions, and interference from other sources). Rate adaptation consists of assessing the wireless channel conditions and selecting the most appropriate data rate for the transmission from the available data rates.
Datta, V. (n.d.), et.al.,[10] addressed rate adaptation algorithms with loss differentiation approach are more suitable in the current scenarios of the society as they provide more reliable services and high throughput. It does not mean that the first generation rate adaptation algorithms are not effective but the review revealed that due to changes in the scenarios and the current expectations, those algorithms need to be modified according to the current scenario issues and current scenario demands so that they can perform better as per today's expectations.

Mathieu La.et.al.,[1] addressed that the IEEE 802.11 is the most popular WLAN system in the world today and it is likely to play an important role in the next generation of wireless and mobile communication systems. Initially, IEEE 802.11 DSSS (Direct Sequence Spread Spectrum) offered only two physical data rates: all transmission was done at either the 1Mbps or the 2Mbps rate. In 1999, the IEEE defined two high rate extensions: 802.11b based on DSSS technology, with data rates up to11Mbps in the 2.4GHz band, and 802.11a, based on OFDM (Orthogonal Frequency Division Multiplexing) technology, with data rates up to 54 Mbps in the 5GHz band. In 2003, the 802.11g standard that extends the 802.11b PHY layer to support data rates up to 54 Mbps in the 2.4 GHz band was finalized.

There are many reasons for the highly volatile nature of the wireless medium used by the IEEE 802.11 standard such as fading, attenuation, interference from other radiation sources, interference from other 802.11 devices in an adhoc network etc. We can classify these transmission quality variations as either transient short term modifications to the wireless medium or durable long term modifications to the transmission environment.

This paper is organized as follows-In this paper various rate adaptation schemes are described as per their functionality along with the advantage and shortcoming of the algorithms. In the second section of the paper, some rate adaptation algorithms in wireless networks have been presented in details. In the third section, conclusion about the solutions of the wireless networks problem has been carried out. In the fourth section of the paper, a discussion has been carried out on the future work related to research towards issues of rate adaptation algorithms.

II. CLASSIFICATION

Biaz S.et.al.,[4] have addressed that the rate adaptation schemes may be roughly grouped into two generations. The rate adaptation for IEEE 802.11 networks has been studied at length through more than two decade. In general, there are many bases on which rate adaptation algorithms may be categorized. There are n ways to classify the rate adaptation algorithms. Rate Adaptation is a multistep process which involved N number of stages from the initiation of rate adaptation to the completion of rate adaptation. Generally Rate adaptation algorithms, in broad sense, may be classified in two generations:

(i) First Generation Rate Adaptation Algorithms - Rate adaptation without loss differentiation
(ii) Second generation Rate Adaptation Algorithms - Rate adaptation with loss differentiation

The first generation algorithms were the beginning of the journey of Rate Adaptation (RA) Algorithm. After that N numbers of rate adaptation algorithms have been developed by the various researchers. As time passed away, there are many studies on the development of efficient& intelligent algorithms of rate adaptation which provided us the enhanced throughput in all aspects accordingly. As a result, now-a-days there is a longseries of algorithms, in the first generations of rate adaptation, which investigate almost all aspects of rate adaptation algorithm.

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First Generation Rate Adaptation Algorithms

Most of the first generation rate adaptation schemes implicitly assumed that all frame losses are due to channel degradation with limited congestion losses and thus do not differentiate between congestion and channel degradation losses. The first generation rate adaptation algorithms may also be known as Rate Adaptation algorithm without loss differentiation. In the first generation rate adaptation algorithms, packets loss is not diagnosed for the further analysis. In the beginning, if the packet is lost or sender does not receive the acknowledgement back, simply retransmission process is followed. There may be many reasons for packet loss or non-receiving the acknowledgement by the sender. Further packet lost may occur, it may be because of the channel fading or it may be because of the due to poor channel conditions or because of hidden terminal problem.

The term defined here as rate adaptation without loss differentiation is the rate adaptation algorithms where no differentiation is carried out to know the root cause of packet loss for the further analysis. Further, on the basis of transmitting channel conditions, the first generation rate adaptation algorithms can be classified as follows-

(a) Frame loss based
(b) Signal to noise ratio (SNR) based

There are many algorithms which were developed in the first generation such as auto rate fallback(ARF), adaptive auto rate fallback(AARF), Adaptive Multi Rate Retry (AMAR), Onoe, Sample rate, Receiver Based Auto Rate (RBAR).

Second Generation Rate Adaptation Algorithms

Second generation rate adaptation algorithms are also known as rate adaptation with loss differentiation. The significant difference between the two generations algorithms is that in the first generation, no differentiation is carried out, on the other hand, second generations differentiation is made to know the exact reason of packet loss. There are many ways through which this differentiation is carried out. This paper focused on the First Generation rate adaption algorithms and more particularly present work is exploring the rate adaptation algorithms on frame based loss in the first generation. Whenever a packet loss occurs, no differentiation is carried out exactly why packet loss occurs? This may be due to some channel fading reason or due to some hidden terminal problems or due to some other reason. Every time the retransmission is required. Due to this, algorithms are not able to achieve the high throughput, as expected. By the industry, both the algorithms of rate adaptation are used but, as rate adaptation with differentiation provide more throughput, so it is preferred. Now-a-days the rate adaptation algorithm with differentiation is more likely and widely used.

Second Generations Rate adaptation algorithms - Loss Differentiating ARF (LD-ARF), Collision-Aware Rate Adaptation (CARA),Loss Differentiation Rate Adaptation (LDRA),Robust Rate Adaptation Algorithm (RRAA).

III. RATE ADAPTATION SCHEMES

Rate Adaptation schemes:-

Auto Rate Fallback (ARF)

Mathieu La.et.al.,[1] addressed the Auto Rate Fallback (ARF) was the first rate adaptation algorithm to be published. It was designed to optimize the application throughput in WaveLan II devices particularly, which implemented on the 802.11 Direct Sequence Spread Spectrum (DSSS). In ARF, each sender attempts to use a higher transmission rate after a fixed number of successful transmissions at a given rate and switches back to a lower rate after 1 or 2 consecutive failures. The original ARF algorithm decreases the current rate and starts a timer when two consecutive transmissions fail one after another. When either the timer expires or the number of successfully received acknowledgments by sender reaches up to 10(say), the transmission rate is increased to a higher data rate and the timer is reset and same process repeats for the current data rate. When the rate is increased, the first transmission after the rate increase (generally acknowledged as the probing transmission or probing packet) must succeed or the rate is immediately decreased and the timer is restarted rather than trying the higher rate a second time. Mathieu La.et.al.,[1] has addressed that ARF suffered from two problems-

- ✓ If the channel conditions change very rapidly and frequently, it cannot adapt effectively in that scenario. For example, in an adhoc network where the interference bursts are generated by other 802.11 packet transmissions, the optimum rate fluctuates from one packet to the next. Because ARF requires 1 or 2

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

packet failures to decrease its rate and up to 10 (say) successful packet transmissions to increase it on next higher rate, it will never be synchronized with the sub-packet channel condition changes. So it was very much difficult for ARF to attain that level (i.e. 10 successful transmissions) to increase the data rate.

- ✓ If the channel conditions do not change at all, or change very slowly-slowly (i.e. channel conditions changing rate is very low), ARF will try to achieve a higher rate every 10 (say) successfully transmitted packets. This results in increased retransmission attempts even after achieving the maximum transmission data rate. As a result again decreases the application throughput. So in stable channels conditions not ARP not giving the maximum throughput.

The algorithm operates in very simple manner. Initially transmission is started at a basic rate. After a fixed number of successful transmissions, say N, ARF tries to increase the data rate attained the next higher available transmission data rate. If the transmission of the probe packet at the new higher data rate failed or acknowledgement is not received, then an ARF return back to the previous rate and starts the transmission with the 2N packet threshold. But if the transmission of the probe packet is successful at the new higher data rate and acknowledgement is successfully received their transmission will continue on new higher rate for the N number of transmissions. Same process is repeated for the next two higher rates.

The problem with the Auto Rate Fallback (ARF) is that after attaining the maximum data rate, the algorithm tries again to achieve the higher data rate, which is not possible and this happens in the stable channel conditions. In the unstable channel conditions also, the ARF performs poorly. That is why; the algorithm is not stable and not performs well in either of conditions.

Adaptive Auto rate Fallback (AARF)

AARF is the extension of ARF in scenarios of the stable channel conditions. The AARF shows the enhancement in the throughputs as the threshold for the next higher rate is increased. Adaptive Auto rate fallback (AARF) is generally the extension of ARF. The disadvantages of ARF are attempted to overcome because ARF was not able to achieve the optimal throughput. AARF tried to solve the problem of ARF.

Mathieu La.et.al.,[1] addressed the "Adaptive Auto Rate Fallback (AARF)" to improve performance in stable environments. The algorithm is generally a solution for the stable channel conditions in ARF scenarios. The transmission starts at basic rate and after N success transmission, AARF tries for next higher rate. At the next higher rate, if the probing packet success then it continue on the next higher data transmission rate and reset the threshold but if the probing packet fails, then return back to the previous lower rate and increased the threshold as 2N. Same process is repeated whenever AARF tries for the next higher rate. In AARF, threshold is reset if the probing packet is not success for the next new higher rate.

Biaz S.et.al.,[4] addressed the Adaptive Auto Rate Fallback (AARF) to improve performance in stable environments. Unlike ARF keeping the rate increase threshold constant *(N)*, AARF adaptively adjusts this threshold. More specifically, a sender increases its data rate *rold* to a new rate *rnew* after *N* consecutive successful transmissions. Biaz S.et.al.,[4]., mentioned that if the first transmission at this new rate *rnew* fails, the sender falls back on the prior rate *rold* and doubles the threshold to 2N for the next rate increase. Otherwise, i.e., the first transmission at the new rate succeeds, the threshold is reset. With such adaptive threshold updates, AARF increases the time interval between rate increases over astable channel and produces fewer rate fluctuations than *ARF.*

Automatic Rate Fallback is the most well-known rate adaptation algorithm among the rate adaptation schemes, which is used in Lucent Technologies Wave LAN-II networking devices particularly. Zanyu Chen et.al.,[8] addressed that the Auto Rate Fallback (ARF) used the consecutive ACKs, consecutive frame losses, or timeout to switch different rates. While on the other side Adaptive Auto Rate Fallback (AARF), is an extension of ARF, which doubles the threshold of the consecutively successful ACKS. AARF can perform better in the stable channel condition scenario and achieve a high throughput in a stable environment as compared to ARF. AARF reduces trials for a higher rate while may degrade the system performance. Zanyu Chen et.al.,[8] also mentioned that ARF and AARF use consecutive ACKs to raise the rate, but consecutive ACKs is not easy to achieve. Therefore those algorithms tend to choose modulation and coding schemes (MCSs) with lower transmission

ISSN: 2277-9655
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rate. Besides, consecutive ACKs have less and less correlation with regard to the channel conditions in a multi-station environment

Onoe

The Algorithm was the first open source Rate Adaptation algorithm implemented in the Linux 802.11driver developed by madwifi organization for wireless adapters with Atheros chips. It is an opportunistic algorithm that looks for the highest bit rate with a loss less than 50%. It is a credit based algorithm. It uses a credit system where for each link the current bit-rate and its accumulated credits are tracked. It can be implemented in 801.11a/g or 802.11b. When Onoe starts for a particular links, it selects an initial bit-rate of 24Mbps for 802.11a/g and 11Mbps for 802.11b and sets it credits to zero. The bit rate is adjusted periodically (every 1000ms cycle) as follows:

- ✓ If the average number of retries per packet is higher than one, fall back to the next lowest bit-rate.
- ✓ Increment the current bit-rate credit, if less than ten percent of the packet needed a retry, otherwise decrement the credits.
- ✓ If the current bit-rate has 10 or more credits points, increase the bit-rate, reset the credits score and return, otherwise continue with current bit-rate.

Bicket,J. C.et.al.,[9]., addressed that Onoe is less sensitive to individual packet loss as compared to auto rate fallback(ARF) and Adaptive MultiRate Retry (AMRR). The Onoe rate adaptation scheme is relatively conservative; once it decides a bit-rate will not work, it will not attempt to step up again until at least 10 seconds have gone by. The Onoe algorithm can also take time to stabilize. It will only step down one bit-rate during each period, so it can take a few seconds before the Onoe algorithm can send packets if it starts at a bit-rate that is too high for a given link. Hence, drawback of this scheme is that it is insensitive to bursty losses and irresponsive to fast changes

Sample Rate

This rate adaptation algorithm aims to provide the highest possible application throughput by using statistics and sampling over rates which could provide a better throughput than the current rate. Biaz S.et.al.,[4] addressed based on transmission statistics over a sliding window period. SampleRate adjusts its rate to the bit-rate that would achieve the smallest average transmission time in the last sampling period. The transmission time for a frame is defined, in such a way, as the time to send this frame successfully, till the acknowledged is received, which includes the time for retransmissions and backoff stipulated by IEEE 802.11. SampleRate adaptation scheme starts transmitting at the highest rate from the available data rate and decreases the rate immediately if it experiences four consecutive transmission failures. This scheme calculates the average transmission time per frame for different rates every 10 second period i.e. after every tenth frame, it randomly selects a different data rate whose average transmission time is less than the lossless transmission time of the current rate.. To explore more potential for better channel conditions in the sampling period, SampleRate randomly selects one from all other rates whose average transmission time is less than the average lossless transmission time of the rate in use for every tenth frame. This helps in exploring better channel conditions.

IV. CONCLUSION

In this paper, various rate adaptation schemes of the first generation were explored and discussion was carried out about the various aspects of the Rate Adaptation in Wireless Networks and its application in various domains. After the review of various aspects of application throughput, it seems that among all the parameters in the frame loss based rate adaptation scheme, channel condition play vigorous role in the enhancement of the application throughput. Even though it doesn't have direct inference that stable channel conditions is the only cause for the high application throughput, it also depends on which rate adaptation schemes has been implemented.

V. FUTURE WORK

Based on the above discussions, work in this domain may be extended to direct research towards issues of rate Adaptation algorithms, Stable environment, throughput enhancement and cost effectiveness and fast transmission are the few areas where the need is felt for improvement

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CITE AN ARTICLE

Datta, V. (n.d.). RATE ADAPTATION TECHNIQUES IN WIRELESS NETWORKS (WLAN). *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY*, *7*(4), 615-620.