ANALYSIS OF ARQ FLOW CONTROL PROTOCOLS ON

WiMAX - IEEE 802.16

Abstract:

A transport-layer protocol provides for logical communication between application processes running on different hosts. It also provides services such as end - end flow control, error control and congestion control. ARQ flow control protocols take care of the most important service by providing reliable data transmission over an unreliable channel communication. We have discussed three types basic types of ARQ starting from the simplest to the most complex and a widely used one. These protocols reside in the Data Link Layer and in the Transport Layer of the OSI (Open Systems Interconnection) reference model. WiMAX is a wireless communications standard designed for creating metropolitan area networks (MANs). It is similar to the Wi Fi standard, but supports a far greater range of coverage. In this paper a deep analysis of the three protocols have been done on grounds of channel utilization and throughput on WiMAX network model and graphs have been plotted for the same.

Keywords:

Stop and wait ARQ, go back-n ARQ, selective repeat ARQ, normalized stability, delay and throughput, WiMAX

Introduction:

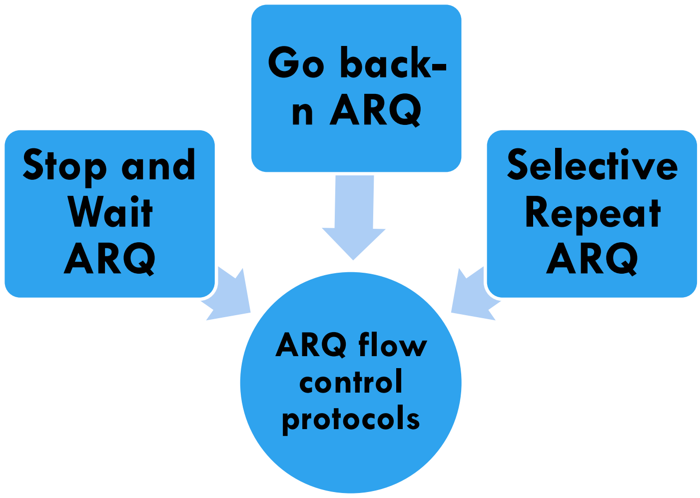
Automatic **R**epeat re**Q**uest (**ARQ**) protocols are widely used to deal with erroneous or lost packets during the transmission from the sender to the receiver. These protocols also handle the flow control mechanism by either improving or descending the pace to the match the receiver's acceptance rate.

- *Stop and Wait*
- *Go back-n*
- *Selective Repeat*

Stop and wait: Also known as an alternating bit protocol where the sender sends a packet and waits for the acknowledgement of the sent packet from the receiver. Once the acknowledgement reaches the sender, it transmits the next packet. If the acknowledgement is not received, it re-transmits the previous successfully received packet.

Go back-n: A theoretical protocol where the sender sends a collection of packets of size equal to the sender's sliding window and waits for a cumulative acknowledgement from the receiver for the sent packets. Receiver discards the out of order packets and sends acknowledgement for the perfectly received previous packet. In case of such loss or time-outs the sender has to re-transmit the packets in the entire window.

Selective repeat: Here similar to go back-n, the sender sends a group of packets of window size and waits for an individual acknowledgement of each and every sent packet, from the receiver. Receiver accepts out of order packets also and just requests the sender to send the packet in case if, one has been lost during transmission. Number of re-transmissions are reduced as only the selective packet gets transmitted again in case of loss.



ARQ protocols are one of the simplest mechanisms in use. These protocols are adaptive based on the conditions given. They are also known as **PAR** (Positive acknowledgment and re-transmission) as they accept only positive acknowledgement and re-transmit in the either case. Based on their pros and cons protocols are given preference based on the scenario.

Usually stop and wait and selective repeat protocols are preferred when the distance between the networks is relatively small, otherwise for wide area networks go back-n is chosen.

ARQ Fundamentals:

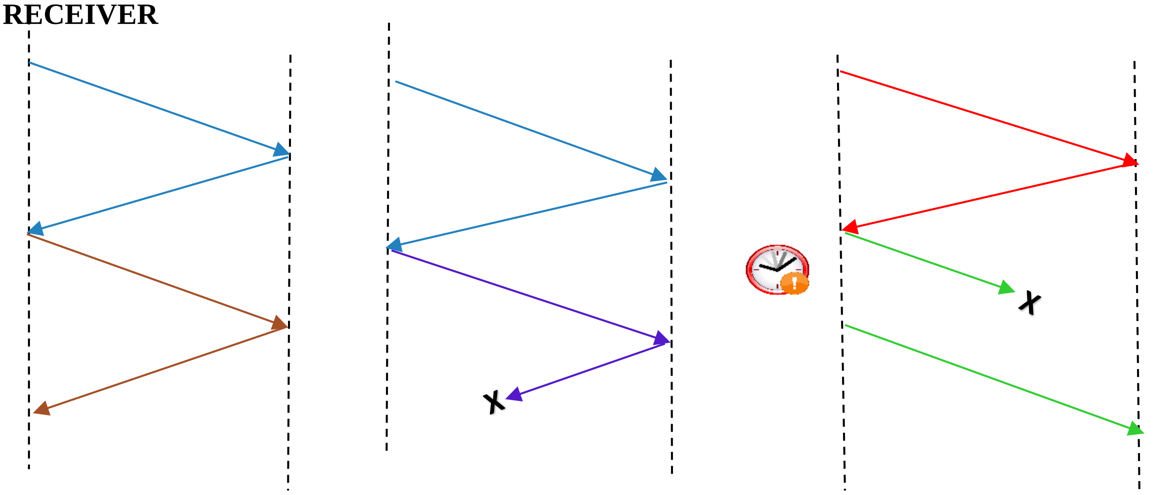
STOP AND WAIT ARQ:

i) The sender transmits only one packet at a time. On successful receival of the packet, receiver sends back a positive acknowledgement (**ACK**). This process continues until the packets available to the sender gets exhausted.

ii) If the ACK from receiver is not received by the sender within a stipulated time allocated for a packet, a timeout occurs. The timeout countdown is reset after every transmission. This, may be because of either of the two reasons:

- **Data packet sent by the sender is lost.**
- **Delayed/Lost acknowledgement from receiver.**

SENDER RECEIVER SENDER RECEIVER SENDER RECEIVER



Drawbacks:

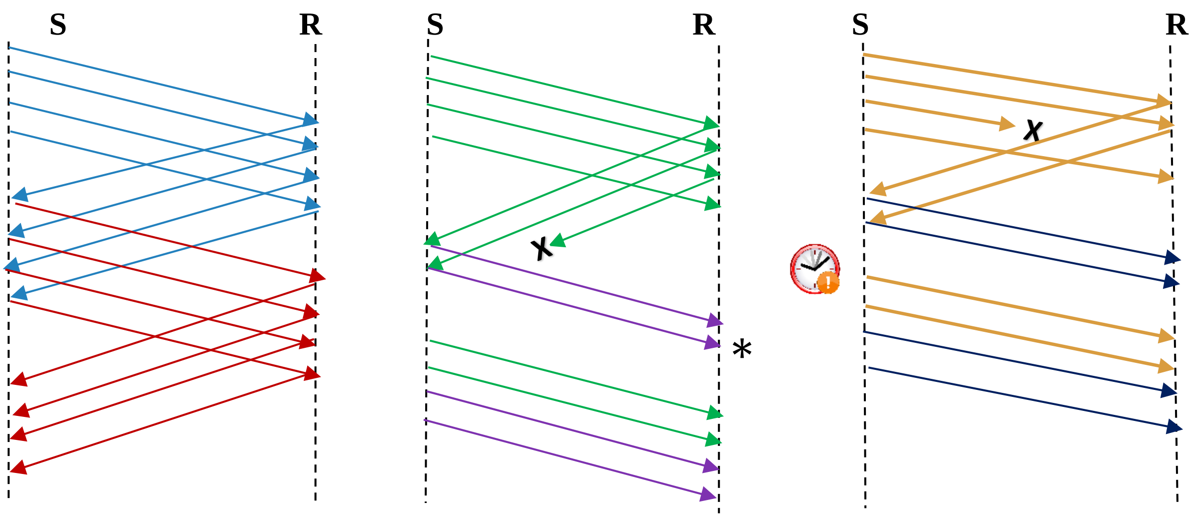
- Sender needs to wait for a long period of time (infinite waiting) and can send only 1 data packet per RTT.
- Retransmission at the time of packet loss. (duplication)
- Poor communication for long distance networks and no pipelining concept.

GO BACK-n ARQ:

i) The sender is allowed to send multiple frames at a time with size equal to the size of the sliding window. It can transmit the entire window without waiting for the ACK from the receiver.

ii) The receiver accepts only the in-order packets based on their sequence numbers. It discards the out of order and corrupted packets and sends ACK for the previously received packet. One ACK can acknowledge more than 1 packet which means cumulative acknowledgement is possible in GBN.

iii) Retransmission of all packets in the current window takes when the sender does not receive any ACK.



Drawbacks:

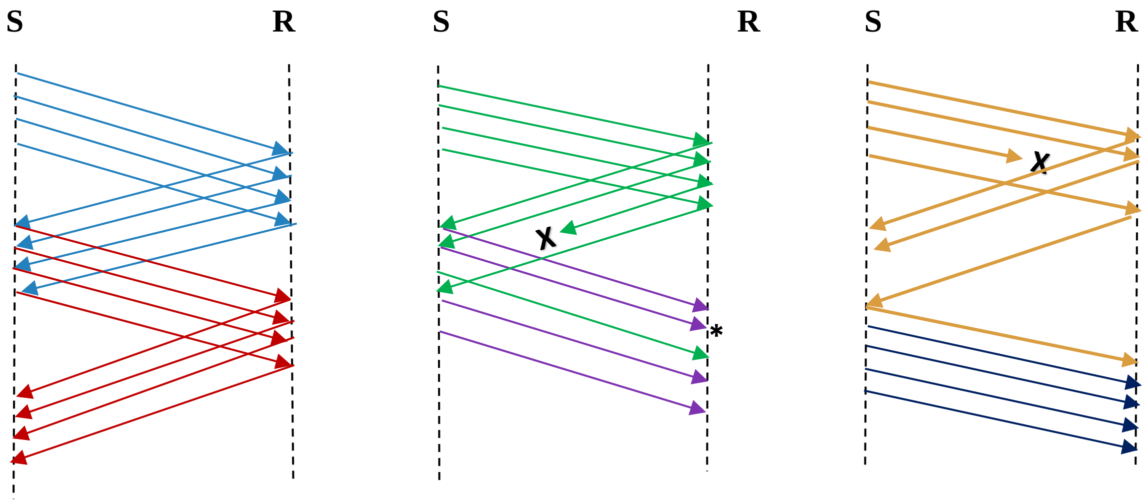
- Not efficient when RTT is large as there are many re-transmissions.
- Has no memory to store the last packets. Buffer is not available.
- A packet loss in the beginning results in the retransmission of the entire window.

SELECTIVE REPEAT ARQ:

i) Similar to GBN, the sender is allowed to send multiple frames at a time with size equal to the size of the sliding window. It can transmit the entire window without waiting for the ACK from the receiver.

ii) Receiver even accepts out of order packets as it has a separate buffer to store packets in sorted order. Also, the successfully received packets are acknowledged individually.

iii) In case of receiving a corrupted packet/ packet loss receiver expects the sender to retransmit just the lost/erroneous packet.



DRAWBACKS:

- Complex to implement from sender and receiver perspective.
- Receiver has to acknowledge individually and may sometimes lead to silly window syndrome.

Analysis:

STOP AND WAIT ARQ PROTOCOL:

WITHOUT ERROR:

Channel utilization = with ARQ / without ARQ

s = 1/(1+2a) where $a = d_p/d_t$ $d_p = D/V$ $d_t = L/R$

d_p is the propagation delay, d_t is the transmission delay, D is the distance between networks V is the speed of light, L is the size of packet and R is the bandwidth.

WITH ERROR:

p = probability of getting an erroneous packet.

1-p = probability of no error.

P[attempting k times] = P[successful attempts]P[unsuccessful attempts] = P[k-1]P[1]

$N = P^{k-1}*(1-p)$ where N=Average number of retransmissions

N = E(i^{th} Re-transmission) = $\sum_{i=1}^{\infty} i * P[i]$

⇨ $\sum_{i=1}^{\infty} i * P^{i-1} * (1-p)$

⇨ $(1-p)\sum_{i=1}^{\infty} i * P^{i-1}$

⇨ $(1-p) * 1/(1-p)^2$

N = 1/(1-p)

$s = (1/N*(d_t+2*d_p)/(1/d_t) = d_t/N(d_t+2*d_p) = 1/N(1+2a)$

s = 1-p / 1+2a

GO BACK-n ARQ PROTOCOL:

<u>WITHOUT ERROR:</u>

w = window size

i) *if* $w \geq 2a+1$:

s = 1+2a/1+2a => **s = 1**

ii) *if* $w < 2a+1$:

s = w/2a+1

<u>WITH ERROR:</u>

Considering i^{th} packet as a corrupted one. Then it has to be retransmitted and along with the remaining transmitted packets which are there in the window without being acknowledged. Let the number of such packets be k.

N = average number of packets to be transmitted.

N = E(i^{th} Re-transmission) $=\sum_{i=1}^{\infty} f(i) * P^{i-1} * (1-p)$

Where f(i) = 1 + (i-1) k = 1 – k + ki

- ⇨ $\sum_{i=1}^{\infty}\left((1-k)+ki\right) * (P^{i-1} * (1-p))$
- ⇨ $\sum_{i=1}^{\infty}(1-k)(P^{i-1} * (1-p)\ + \sum_{i=1}^{\infty} ki(P^{i-1} * (1-p))$
- ⇨ $(1-k)(1-p)\sum_{i=1}^{\infty} P^{i-1} + (1-p)k\sum_{i=1}^{\infty} i * P^{i-1}$
- ⇨ $(1-k)(1-p)*1/(1-p) + (1-p)k*1/(1-p)^2$

  N=(1-p+kp)/(1-p)

i) *if* $w \geq 2a+1$:

s = 1/N = 1-p/1-p+kp where k = 2a+1

s = 1-p/1+2ap

ii) *if* $w < 2a+1$:

s = w/(2a+1)N = w(1-p)/(2a+1)(1-p+kp)

s = w(1-p)/(2a+1)(1-p+wp)

SELECTIVE REPEAT ARQ PROTOCOL:

<u>WITHOUT ERROR:</u>

w = window size

i) *if* $w \geq 2a+1$:

s = 1+2a/1+2a => **s = 1**

ii) *if* $w < 2a+1$:

s = w/2a+1

WITH ERROR:

N = E(i^{th} Re-transmission)

=> $\sum_{i=1}^{\infty} i * P^{i-1} * (1-p)$

N = 1/1-p

i) *if w ≥ 2a+1:*

s = 1/N => **s = 1-p**

ii) *if w < 2a+1:*

s = w/N(2a+1) => **s = w(1-p)/2a+1**

Result Evaluation for WiMAX network:

WiMAX IEEE standards:

Length of the packet: approx. 1500(max)

Bandwidth: 100 Mbps(max)

Distance coverage: 30-40 miles(60000 meters at max)

Probability of error: 20%

WITHOUT ERROR:

Changing L, R, D values and plotting against Channel utilization and Throughput considering the channel to be error free.

FIG:1

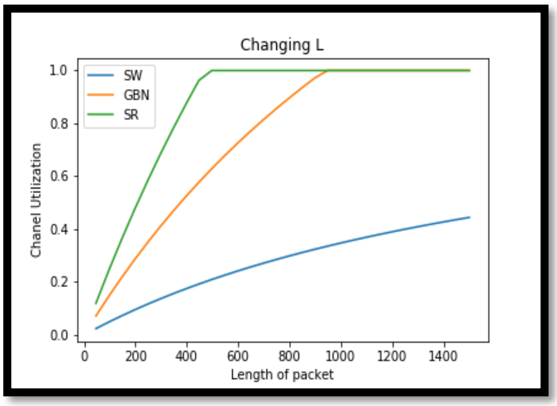


FIG:2

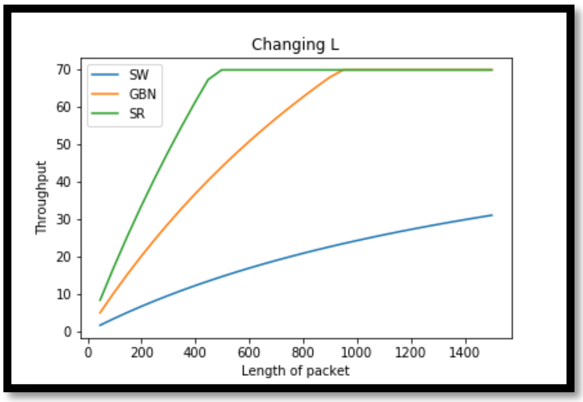


FIG:1 gives the plot highlighting the variation in channel utilization for different values of packet length.Length of the packet has been taken randomly from the prescribed IEEE standard range.

FIG:2 is the graph plotted between packet length and Throughput.Since throughput is directly proportional to utilization ,hence a similar graph has been obtained.

FIG:3

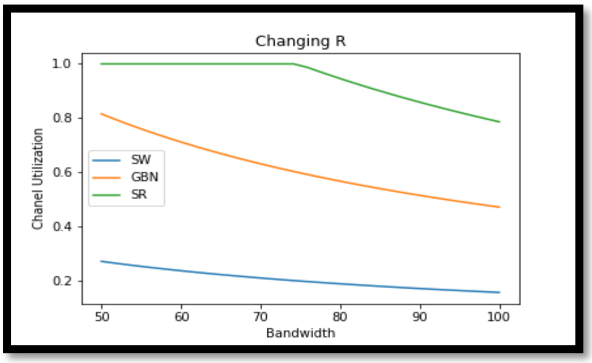


FIG:4

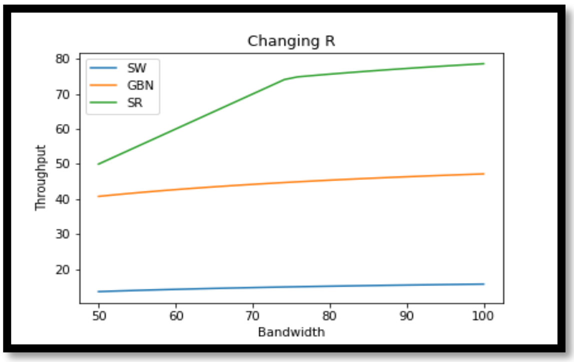


FIG:3 gives the plot highlighting the variation in channel utilization for different values of bandwidth.Different values has been taken randomly from the prescribed IEEE standard.Different values of w have been taken in order to differenciate GBN and SR.

FIG:4 is the graph plotted between Bandwidth and Throughput.Since throughput is directly proportional to utilization ,hence a similar graph has been obtained.

FIG:5

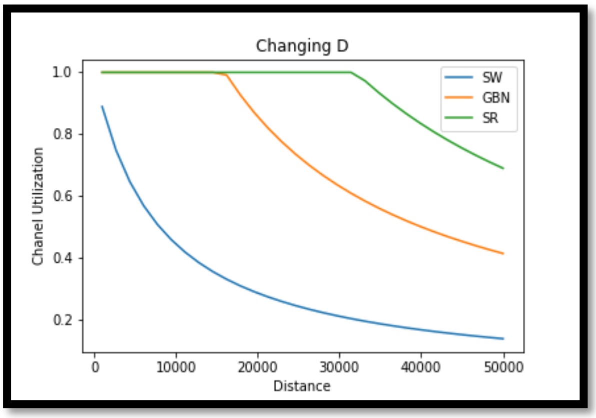


FIG:6

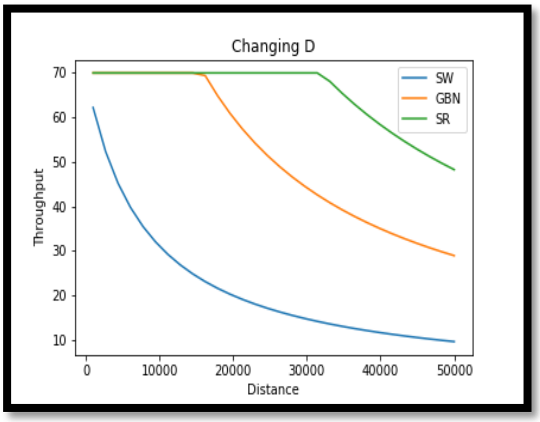


FIG:5 gives the plot highlighting the variation in channel utilization for different values of distance between the communicating networks.These values have been taken randomly between the prescribed IEEE standard.

FIG:6 is the graph plotted between distance and Throughput.Since throughput is directly proportional to utilization ,hence a similar graph has been obtained.

Its observed that Go back n has good channel utilization for long distance communications, while stop and wait has a poor recording.

WITH ERROR:

Changing L, R, D values and plotting against Channel utilization and Throughput considering error .

FIG:7

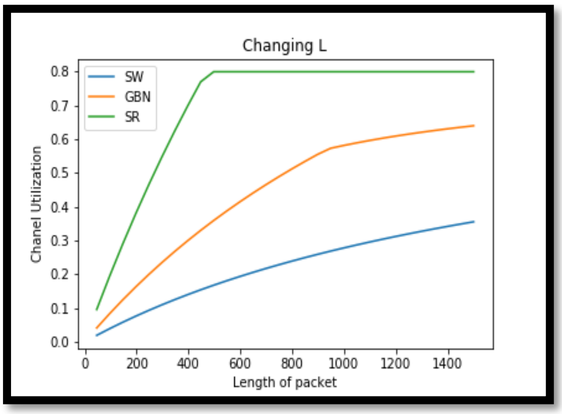


FIG:8

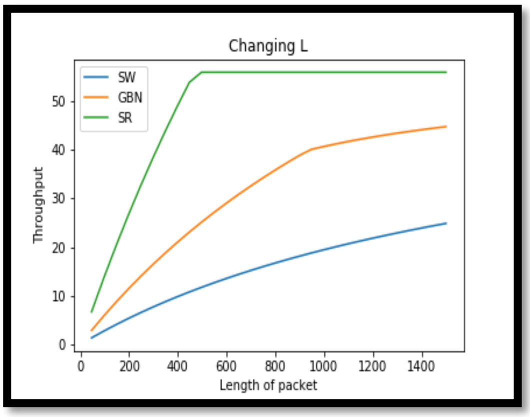


FIG:7 gives the plot highlighting the variation in channel utilization for different values of packet length.Length of the packet has been taken randomly between the prescribed IEEE standard.Also now the channel is considered to be erroneous and hence the probability of error is considered to be 20%.

FIG:8 is the graph plotted between packet length and Throughput.Since throughput is directly proportional to utilization ,hence a similar graph has been obtained.

FIG:9

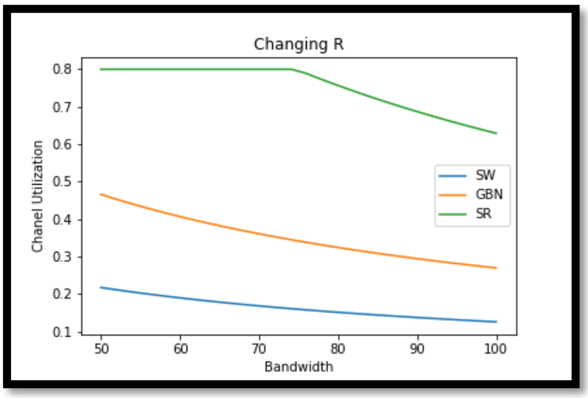


FIG:10

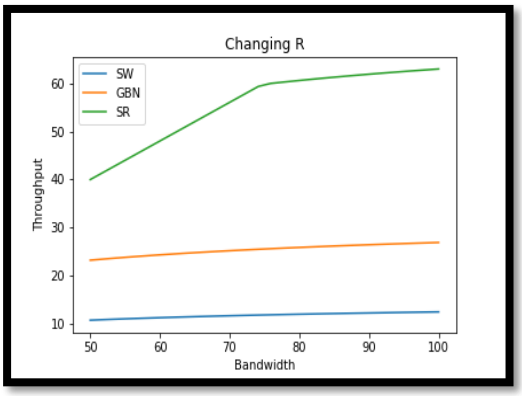


FIG:9 gives the plot highlighting the variation in channel utilization for different values of bandwidth.Those values have been taken randomly from the prescribed IEEE standard.Same as before percentage of error is again 20%.

FIG:10 is the graph plotted between packet length and Throughput.Since throughput is directly proportional to utilization ,hence a similar graph has been obtained.

FIG:11

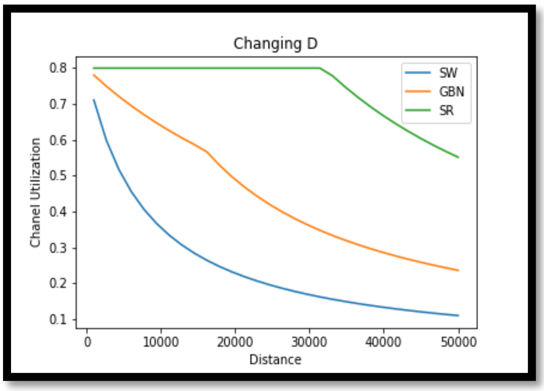


FIG:12

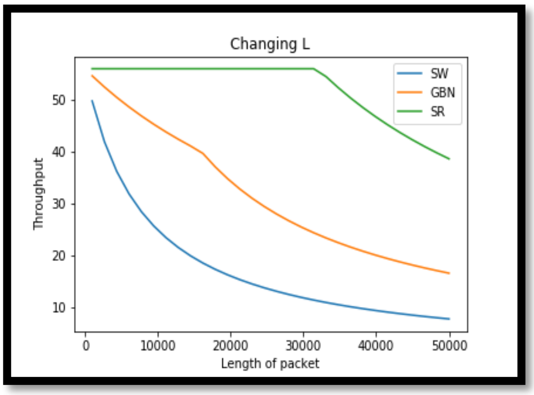


FIG:11 gives the plot highlighting the variation in channel utilization for different values of distance between the communicating networks.These values have been taken randomly between the prescribed IEEE standard.

FIG:12 is the graph plotted between distance and Throughput.Since throughput is directly proportional to utilization ,hence a similar graph has been obtained.

Its observed that Go back n has good channel utilization for long distance communications, while stop and wait has a poor recording but has good reading for short distances.

Conclusion:

WiMAX, thus can cover several miles using a single station. This makes it much easier to maintain, rapidly deploy and offer more reliable coverage. Since WiMAX has such a large signal range, it will potentially be used to provide wireless Internet access to entire cities, large areas and sometimes may even to different parts of the Earth. Comparing the results from the above graphs, go back-n has proved to be efficient for long range communications. Stop and wait and selective repeat protocols are suitable for short distance communications. Of all selective repeat proves to be efficient as it reduces no of re-transmissions. Thus, the analysis of the three ARQ protocols have been done on grounds of channel utilization and throughput.

References:

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