Performance Measure of GBN-ARQ Protocol in a Fading Network using Error Correction Code

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Abstract— **Modified Packet Combining (MPC) and Packet Reverse Packet Combining(PRPC) are inferred to provide superior throughput and correction of error for big bit error rate (BER) and huge packet size . Inspection has been done for upholding the claim that greater throughput and better error correction ability may be achieved for both high and low bit error rate (BER) in case of medium and huge size of packet. Some researchers proposed applying Error Correction Code (ECC) in ARQ for large error rate of bit. But no such impressive result is available to verify this concept with respect to throughput. This present work is an endeavor to review the throughput. Here we apply both PRPC and MPC in a moderate manner over ordinary PRPC, and watch the results. Modified PRPC and MPC together are utilized, and watch higher throughput and better error correction at high and low BER for both medium and huge size of packet. MPC with PRPC are utilized here with mix of BEC (Backward Error Correction) and FEC (Forward Error Correction) Codes .Space-Time Ring-Trellis Coded Modulation (ST-RTCM) code likewise utilized for Fading Networks in MATLAB TM programming**

Introduction

In case of multipath fading, automatic repeat request (ARQ) is acted for synchronizing and affirmation of transmitted information from base node to mobile node for error free reliable data transmission.BCH code is used to evaluate throughput of packets. To ensure error free transmission of the packets in noise wireless channel ARQ protocols acknowledge error free packet [1].Transmission consumes double energy that of reception, hence traditional ARQ is send acknowledgement for each error free received packet and require considerable energy The principle for proposed protocols is intuitive, where receiving node sends a single acknowledgment for a bunch of packets. For multi-hop communication, consumption of energy should be taken care of at each layer. In this work, we emphasize on network routing employing hops of different length. Channel model for Rayleigh fading [2] is employed here for analysis. Interference is also given importance with same geometric disk abstraction. The signal-to-noise-and-interference ratio (SINR) is a random variable as nature of fading channel is stochastic. these facts are ignored. With this model, energy gain is $n^{\alpha-1}$, where α = path loss exponent . number of hop is n over distance d. However for wireless networks, channel volatility cannot be ignored [3]. The “prevalent all-or-nothing model” [4] says that a transmission is unsuccessful totally or completely successful for multi-hop path, that ignores probability increase of end-to-end data loss for number of hops (unless transmitted power is adjusted) [5]. Simple Rayleigh fading link model is employed to overcome some limitations of “disk model” relating to power of transmission, large amount path loss and success of transmission [6]. In multi hop route, probability of packet delivery from one end to another can be calculated with multiplication of reception probabilities at link-level. ARQ retransmit for removing error in channel and Forward Error Correction (FEC) add redundant to reduce error. A narrow band channel of Rayleigh block fading is assumed that SINR γ_{ij} of more than threshold Θ determined by the modulation and coding technique and the used hardware [7], then transmission from node *i* to *j* is successful where SINR γ , a random process of discrete nature is

$$\gamma = \frac{R}{N+I} \quad (1)$$

Received power(R) is distributed exponentially with mean R, for distance $d = \| x_i - x_j \|^2$ and attenuation d^{α}, $R_{mean} = P_0 d^{-\alpha}$. Here P_0 is proportional to transmitted power. N = noise power and I = interference power. Reception probability $p_r = P\,[\gamma \geq \Theta]$ can be achieved by the multiplication of reception probability of zero noise network and reception probability of zero-interference network [8] for Rayleigh fading network. For light load, SIR ≥ SNR as interferers k is relatively small, thus accurate results can be achieved from noise analysis alone. The throughput is proportional to *p*, where *p is* small transmit probability in case of slotted ALOHA i.e. no losses due to collisions ,so $p_r^I \approx 1$[9].
For high load, all nodes’ transmit power scaling by a factor, does not affect the SIR but the SINR gets litte increase. So , for energy-efficient routing strategies we may use network of no interference. Hence the reception probability for distance *d* with transmit power P_0, p_r: = $P\,[\gamma_N \geq \Theta] = \exp(-(\Theta N/P_0 d^{-\alpha}))$, for this

$$P_0 = (d^{\alpha}\,\Theta\, N) / -(\ln p_r) \quad (2)$$

here the probability packet loss $1-p_r$ is upper bounded by the normalized mean NSR $\Theta N/R_{mean} = \Theta/\gamma_{N\,mean}$. Since $-\ln$

$p_r \approx 1 - p_r$, so, packet loss probability and transmit power are inversely proportional to each other.

A. Previous work review

In previous works, satisfactory examination and definite investigations were not done in support of higher throughput. Error correction schemes generally correct the one bit error. More than one bit error probability in a packet is not so important to that of single bit error.

In the MPC, the transmitter sends i (i>1) requested packet at retransmission call from receiver. The receiver XOR ed these copy pair wise to identify error. [10].

Symbol TCM for rings of integers perform better than binary TCM and this increase small decoding complexity [11]. we consider delay constraint of *n* time slots for single and multi hop as *n* timeslots are there for a single-hop transmission, with and without channel state information (CSI) of transmitter [12].

Let , with BER probability P_E and d distance the required transmission energy is $E_{0.}$

$E_0 := -(d^{\alpha}\,\Theta\, N) / (\ln P_E)$. , E_1= Energy required for covering total distance with a single hop = $n^{\alpha}E_0$.

n multi-hop, reception probability in multi m hop

$$p_r = \sqrt[1/n]{PE} \quad (3)$$

For $\alpha = 2$, there is no benefit So, $\alpha = 4$ is used [13].

For a block fading, required single-use reception probability $P_{E1} = 1-(1-P_E)^{1/n}$ (4)

hence energy gain over single-transmission

$$G = \log(P_{E1}) / (n \log P_E) \quad (5)$$

In ARQ , ACK or NACK packet is sent just after data pack reception , retransmission not required any more and the gain gets doubled almost[14].

Sometime, single-hop perform better than that of multi-hop (for $\alpha = 4$) for same delay . When the path loss exponent increase by one, we can say for channel state information (CSI)

$$G_{CSI}(\alpha) = G_{NCSI}(\alpha - 1) \quad (6)$$

B. ANALYSIS OF THROUGHPUT

C. PREVIOUS CASE

MPC with PRPC

It is observed , two duplicate , one of PRPC and another original form of original packet, will be transmitted at negative acknowledgement Up to double bit errors can be corrected at receiver in MPC with PRPC . Packet probability of not having one and two error bit :

$$P - P_1 - P_2 \quad (7)$$

Where, P_1 = Packet probability of one error bit.
P_2 = Packet probability of two error bit.

Packet probability of two error bit is P_2, then $P_2 = {}^kC_2\, P_E^{\,2}\,(1-P_E)^{k-2}$

MPC with PRPC over PRPC-

One error bit packet is corrected in PRPC and up to two error bit packet are corrected in MPC with PRPC Hence probability gain in correcting bit error in a packet by MPC combined PRPC in reference of PRPC:

$$\text{Gain \%} = P_2/P_1 * 100 \quad (8)$$

D. Proposed Case

For establishing in Conventional PRPC, Error Detection Code (EDC) is better than Error Correction Codes (ECC) for high bit in error .But there no impressive result is available to in support of this idea in reference of performance. Here this basic idea is explored.

Modified MPC with PRPC over Conventional PRPC with ECC

We consider here modified MPC with PRPC that correct one and two bit error .Transmitter transmit two packet one in PRPC and another in original form at negative acknowledgment. Here P1 is probability of one bit error and P2 is probability of two bit error then the probability of receiving without one bit and two bit error is [8]:

$$P_1*P_1 + P_1*(1-P_1) + P_2*(1-P_1) + P_2*P_1 + P_2*P_2 + P_2*(1-P_2) = P_1 + 2*P_2 \quad (9)$$

The probability not having one or two bit error is

$$P^2 = P - P_1 - P_2$$

$P_1 = {}^kC_1 \, P_E^{\,1} \, (1 - P_E)^{k-1}$
$P_2 = {}^kC_2 \, P_E^{\,2} \, (1 - P_E)^{k-2}$
P_E = Bit Error Rate (BER)

With Go-Back-N ARQ , *Modified* MPC with PRPC the average number of times, n_{mmpc} for sending and resending for successful transfer is:

$$n_{(MMPC+PRPC)} = [(P_1 + 2.P_2) + N*(P^2/(1-P^2))] \quad (10)$$

Here, N= number of packets

First one is for *Modified* MPC with PRPC that correct up to two error bit and second one is Normal Go-Back-N ARQ that corrects more than two error bit. PRPC corrects one error bit in packet. *Modified* MPC with PRPC corrects two and also one error bit . Now the probability gain of *Modified* MPC with PRPC in correcting packet

$$Gain_{mpcprpc}\ \% = (P_1 + 2*P_2)/P_1 *100 \quad (11)$$

Throughput efficiency of Conventional PRPC Scheme in Normal Go-Back-N ARQ

The Throughput of PRPC with single bit error in Normal go Back N ARQ $(2.P_1 + N*(P^1/ (1-P^1)$ (12)

Here , P^1 = P-P

The first part is for PRPC in correcting single bit error; second part is for Normal Go-Back-N ARQ above single bit error.

Hence Coding Efficiency is: k / (k +c);

Where k is Packet size in Bits and c is the Check Bits

CRC-16 is used here as an Error Detection Code (EDC).

Now Throughput efficiency[12] =

(Throughput) ***** (Coding Efficiency) i.e:

$$Throughputeff_{GBN} = (2.P_1+ N*(P^1/(1-P^1)))*(k/(k+16)) \quad (13)$$

Transmit power

$$P_{01} = - (d^{\alpha}\, \Theta\, N) / (\log (Throughputeff_{GBN})) \quad (14)$$

Where, d = Distance, Θ = Threshold,

N = Noise power, α = Path loss

The reception probability

$$P_{E1} = (1-(1- Throughputeff_{GBN}^{\ (1/n)})) \quad (15)$$

So, the

$$Gain\ (G_1) = (\log (P_{E1}) / (n \log (Throughputeff_{GBN}))$$

Where, n = number of nodes (16)

Throughput efficiency of Modified MPC+PRPC Scheme in Normal Go-Back-N ARQ

If P = packet error probability, P_1 = Single bit error probability and P_2 = Double bit error probability then the probability without single and double-bit error will be

$$P^2 = P- (P_1+P_2),$$

Where, $P = 1- (1- P_E)^k$, k= Packet size (bits)

$P_1 = {}^kC_1 \, P_E \, (1- P_E)^{k-1}$, $P_2 = {}^kC_2 \, P_E^{\,2} \, (1- P_E)^{k-2}$

So, for this scheme in Go-Back-N ARQ system, the throughput'll be, from eq: (10)

$$n_{(MMPC+PRPC)} = [(P_1 + 2.P_2) + N*(P^2/(1-P^2))] \quad (17)$$

From eq(10) we can get 3 cases as in below:

(i) When P^2= 0, P_1 =1, P_2=1, then n=3
(ii) When P^2= 1, P_1 =0, P_2=0, then n= ∞
(iii) When P^2= 0, P_1 =1, P_2=0, then n=1

Now Coding efficiency = k / (k + c), where, c is the check-bits. In eq (13), we have used CRC-16.

Using ST-RTCM (213 132/3) Code [15] we are getting the Coding efficiency = k / (k / 132* (213-132) +k+1)

= (132*k / (213*k +132))

So the Throughput efficiency of Modified MPC+ PRPC scheme will be:

$$Throughput\ eff_{(MMPC+PRPC)} = [(P_1 + 2.P_2) + N*(P^2/(1-P^2))] *(132*k / (213*k +132)) \quad (18)$$

Now transmitted power

$$P_0 = - (d^{\alpha}\, \Theta\, N) / (\log (Throughput\ eff_{(MMPC+PRPC)})) \quad (19)$$

here, d = Distance, Θ = Threshold

N = Noise power, α = Path loss

Probabilty of reception

$$P_{E2} = (1-(1- Throughput\ eff_{(MMPC+PRPC)})^{(1/n)})) \quad (20)$$

So, the

$$Gain\ (G_2) = (\log (P_{E2}) / (n \log (Throughput\ eff_{(MMPC+PRPC)})) \quad (21)$$

here, n = number of nodes.

III. DISCRETE EVENT SIMULATION

Simulation Parameters

Simulation Parameters	**Values**

Time of simulation	10 ms
Length of uplink frame	0.5 ms
Length of downlink frame	0.5 ms
Duplex mode	TDD
Application profile	CBR (100 bytes, 0.2 ms)
Agent profile	UDP
ARQ WINDOW SIZE	500
PHY rate	1 Mbps
Nodes count(n)	24
Power of noise	$2x10^{-7}$ Watts
Loss on path	4
Threshold (Θ)	3

IV. SIMULATED RESULTS AND JUSTIFICATION

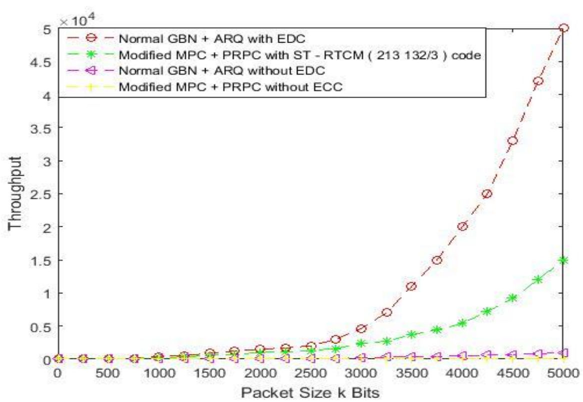

Fig 1.Throughput vs Packet size(k) When ST-RTCM (213 132/3) code used and k = 5120 Bits with BER=0.00001

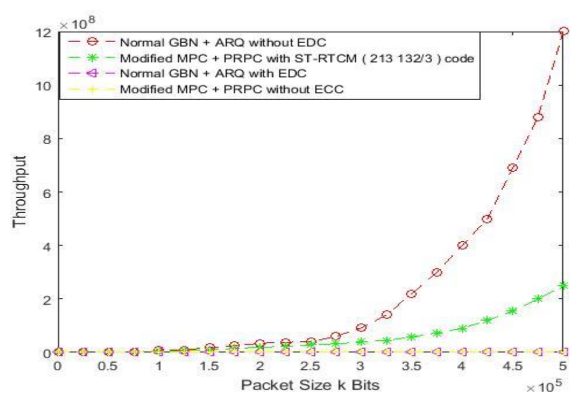

Fig 2.Throughput vs Packet size(k) when ST-RTCM (213 132/3) code used and k = 512000 Bits with BER = 0.00001

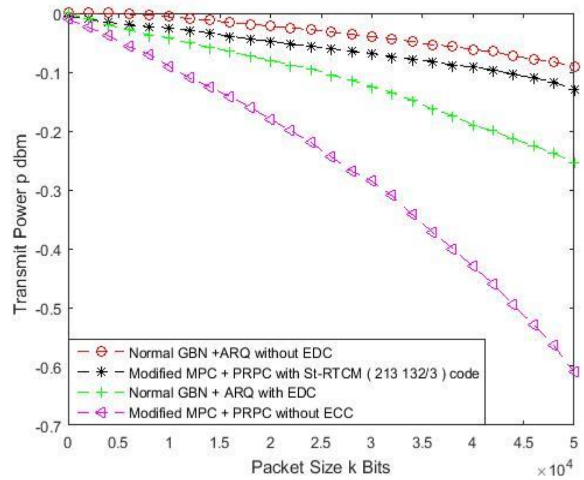

Fig 3. Transmit Power vs Packet size(k) When ST-RTCM (213 132/3) code used and k = 51200 Bits with BER=0.00001

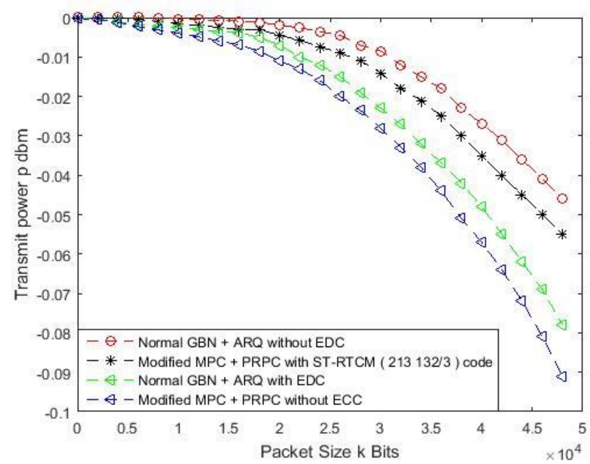

Fig 4. Transmit Power vs Packet size(k) When = ST-RTCM (213 132/3) code used and k = 51200 Bits with BER= 0.0001

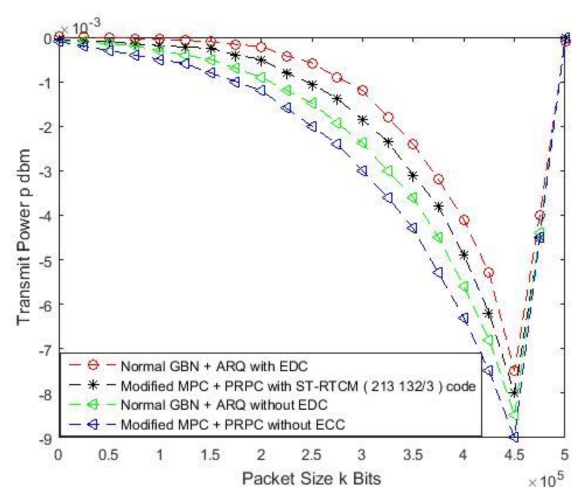

Fig 5.Transmit Power vs Packet size(k) When ST- RTCM(213 132/3)code

used and k = 512000 Bits with BER=0.0001

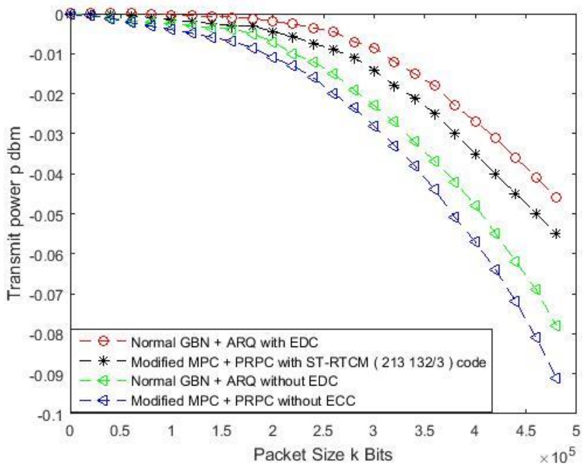

Fig 6.Transmit Power vs Packet size(k) When ST- RTCM(213 132/3)code used and k = 512000 Bits with BER=0.00001

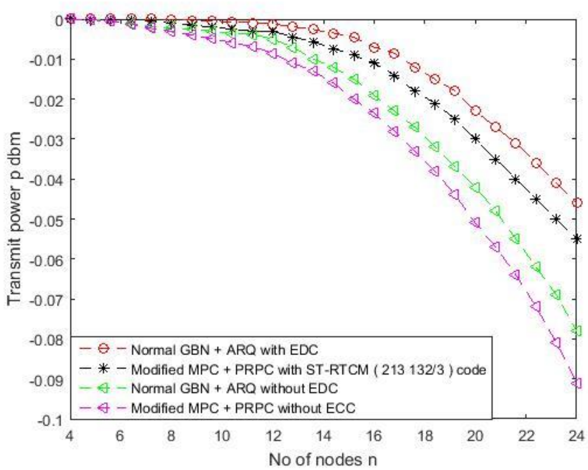

Fig 7. Transmit Power vs nodes (n) When ST- RTCM(213 132/3)code used with Packet size k= 51200 Bits and BER=0.0001

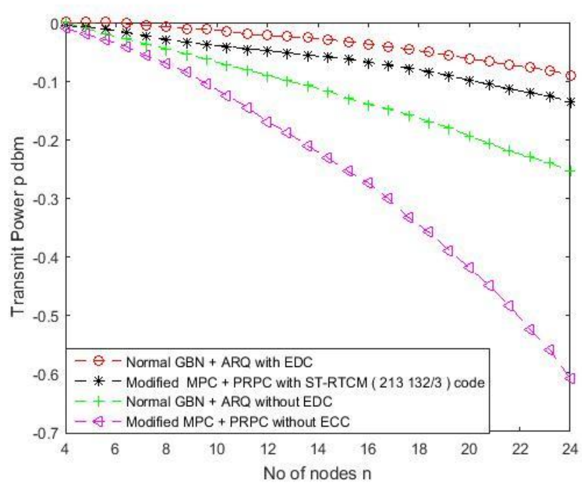

Fig: 8 Transmit vs nodes (n) When ST- RTCM(213 132/3)code used with Packet size k= 51200 Bits and BER=0.00001

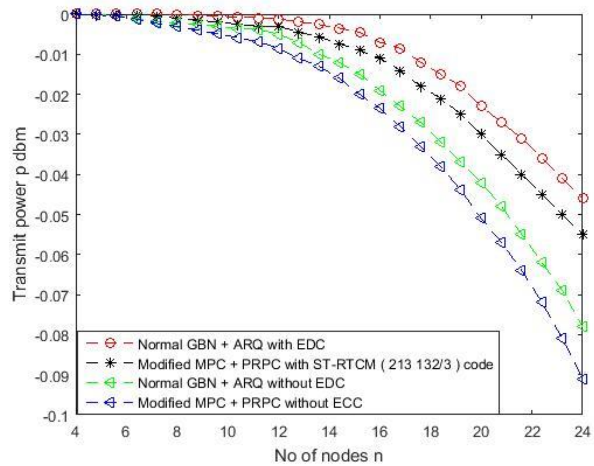

Fig 9 .Transmit Power vs nodes (n)When ST-RTCM (213 132/3) code used with Packet size k= 512000 Bits and BER=0.00001

V. JUSTIFICATION OF THE SIMULATED GRAPHS

Fig: 1 shows combination of Normal Go-Back-N ARQ and CRC-16 gives better throughput than that of Modified MPC+PRPC for medium Packet size of 5120 Bits using ST-RTCM (213 132/3) Code for BER value of 0.00001.

Fig: 2 shows that combination of Normal Go-Back-N ARQ and CRC-16 gives better throughput for large packet size of 512000 Bits than that of combined *Modified* MPC+PRPC and ST-RTCM (213 132/3) Code for BER value of 0.00001.

Fig: 3, shoes that combined *Modified* MPC+PRPC and ST-RTCM (213 132/3) Code performs better than that of *Modified* MPC+PRPC without ECC but not so good as of PRPC of combination of Normal Go-Back-N ARQ and CRC-16 when BER of 0.00001 and packet size of 51200 Bits.

Fig: 4 shows that other method require much more transmitted power than that of combined *Modified* MPC+PRPC and ST-RTCM (213 132/3) with packet size of 51200 Bits and with BER of 0.0001 require.

Fig: 5 & Fig. 6 shows that combined *Modified* MPC+PRPC with ST-RTCM (213 132/3) Code using packet size 512000 Bits in reference of nodes with BER of 0.0001 or 0.00001 require less power to transmit comparing to other process.

Fig: 7 & Fig. 8 also shows that combined *Modified* MPC+PRPC with ST-RTCM (213 132/3) Code using packet size 51200 Bits in reference of nodes with BER of 0.0001 or 0.00001 require less power to transmit comparing to other method.

Fig: 9 shows that combined *Modified* MPC+PRPC with ST-RTCM (213 132/3) Code using packet size 512000 Bits in reference of nodes with BER of 0.0001 or 0.00001 require less power to transmit comparing to other method.

VI. CONCLUSION

Investigation has been done for different parameters as packet size, probability of Bit Error Rate and number of nodes in ARQ protocol for communication using Modified MPC + PRPC in normal Go-Back-N ARQ with CRC-16 and again investigation is made only adding ST-RTCM(213 132/3) code.

Performance of MPC+PRPC is impressible and when ST-RTCM(213 132/3) code is used , throughput also get increased and it provides better reliability than the previous process. It may be more reliable if some extra features using fuzzy . Overall work on two bit error has given encouraging result.

[1] An Asymmetric ;Dynamic , Energy –Conserving ARQ Protocol Jason Redi , Chiara Petrioli,Imrich Chamtac , Proceeding of the 49th annual vehicular technogy conference , Houston ,Texax , May 16 -20 , 1999.

[2] J.A. Sivesteran &L Kleinrock "On the Capacity of Mutihop Slotted ALOHA Networks with Regular Structure," IEEE Trans .Commun , Vol COM – 31 , no. 8 , pp. 974 - 982 , Aug . 1983.

[3] A.J. Goldsmith and S.B. Wicker " Design Challenges for Energy Constrained Ad Hoc Wireless Networks." IEEE Wireless Commun. , Vol.- 9 No -4, pp 8-27 , Aug 2002

[4] H. Takagi and L. Kleinrock " Optimal Transmission Ranges For Randomly Distributed Packet Radio Terminals," IEEE Trans. Commun, Vol. Com- 32, No. 3, PP. 246–257, Mar. 1984.

[5] E.S. Sousa and J.A. Silvester, " Optimum transmission ranges in a direct sequence spread-spectrum multi hop packet radio network" IEEE J. Sel. Areas Commun., vol. 8, no. 5, pp. 762–771, Jun. 1990.

[6] A. Ephremides, "Energy concerns in wireless networks," IEEE Wireless Commun., vol. 9, no. 4, pp. 48–59, Aug. 2002.

[7] L. Hu, "Topology control for multihop packet networks," IEEE Trans.Commun., vol. 41, no. 10, pp. 1474–1481, Oct. 1993.

[8] Martin Haenggi, Senior Member, IEEE "On Routing in Random Rayleigh Fading Networks", IEEE Transactions on Wireless Communications, Vol. 4, No. 4, July 2005..

[9] M. Haenggi, "Probabilistic analysis of a simple MAC scheme for ad hoc wireless networks," in IEEE Circuits and Systems Workshop Wireless Communications and Networking, Pasadena, CA, Sep. 2002.

[10] Prajit Paul, Asok Kumar, Krishna Chandra Roy, "Reliable Approach for ARQ Protocol on Communication and Networks", NCIS 2010, dated 23.04.10-24.04.10, page-31, C2_ES_0013, organized by MCIS, Manipal University, Manipal.

[11] M. Sanchez, P. Manzoni, and Z. Haas, "Determination of critical transmission range in ad-hoc networks," in Multi-access, Mobility and Tele-traffic Wireless Communications (MMT), Venice, Italy, 1999, pp. 293–304.

[12] . L. Wang and J. A. Silvester, "Maximum number of independent paths and radio connectivity," IEEE Trans. Commun., vol. 41, no. 10, pp. 1482– 1493, Oct. 1993.

[13] P. Gupta and P. R. Kumar, "The capacity of wireless networks," IEEE Trans. Inf. Theory, vol. 46, no. 2, pp. 388–404, Mar. 2000.

[14] Prajit Paul et.al, ―An Enhanced Scheme for Using Error Correction Codes in ARQ Protocol, 3rd Int'l Conference, CNC 2012, Chennai, India, February 24-25, 2012, available in Springer Link, ISBN: 978-3-642-35614-8 (Print) 978-3-642-35615-5 (Online), p.p.377-382.