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Assessing the Quality of Voice using E-Model for Optimized Congestion Control approach in Mobile Ad-hoc Network

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***Abstract*—**Congestion is an unsolvable and challenging issue for real time data such as voice especially in MANET. Since mobile devices support limited bandwidth, limited battery power, dynamic links and frequently changing routing decision, controlling congestion is a challenging and critical task. Also voice transmission requires valid data to be delivered at receiver by supporting less End-End-Delay. Hence there exists a need to apply dynamic and efficient routing schemes which handle congestion and reduce its severity, proactively avoid congestion before its occurrence. The state of storing packet continuously causes router queue to overflow and drops the incoming packet. Packet drop at these router queues also forecasts nearing congestion. Hence router queue uses various queue management approaches to minimize the occurrence of packet drop and congestion. RED based flavors of proactive queue management schemes received a lot of attention in recent years in controlling congestion over MANET. In this paper, we propose a congestion control approach that supports three different interdisciplinary approaches to control congestion on voice data transmission. Finally we evaluate the performance of the proposed approach using E-Model and compare the performance of the three approaches in order to identify the best approach that supports improved quality at user level. Fuzzy logic based congestion control approach shows improved performance.

Keywords— CLHCC, PEACR, LPWAP, FANT, BANT

I. INTRODUCTION

This work is concerned with the study and analysis of approach that can be applied dynamically to avoid the occurrence of congestion proactively and also to control it reactivity during VoIP data transmission in a dynamic network environment such as MANET. It is an interdisciplinary work that includes adaptive filter based linear prediction and TCP dynamic window adjustment, ant colony optimization, fuzzy logic with flow control at sender side for an unstable and dynamic infrastructure having characteristics entirely different from other types of stationary networks. This implementation is difficult to perform at real time and also it requires more attention to be paid in simulation environment since mobile devices support dynamic links and frequently changing routing decision, data transmission is a critical task that requires efficient dynamic routing schemes that solves the issues of congestion at its maximum best effort level.

The rest of the article is organized as follows. Section II presents the existing approaches in the area of voice over MANET. Section III gives an overview of the proposed approach. Specifically, LPWAP, PEACR and CLHCC approaches. Section IV discusses the simulation results of proposed work. Section V presents the E-Model analysis of the results. The article finally concludes in section VI giving directions for future work.

II. RELATED WORK

Router queue uses proactive, reactive and predictive queue management schemes. Proactive routing protocols exchange control information by broadcasting or propagating and each node should preserve routing table to save routing information as discussed in [13]. Proposed work is a cross layer based approach which combines proactive queue management scheme (PAQMAN) and Performance Improved RED (PIRED) to perform flow control by predicting queue size and adjusting TCP Window [7]. It uses adaptive Recursive Least Square (RLS) to predict the average queue size and to compute Packet Dropping Probability (PDP) to drop packets when there is nearing congestion [2]. PAQMAN has no support to flow control for Voice data to control congestion. It focused only on Average Queue Size to control congestion. K.Dinesh Kumar et.al[3] analysed the performance of PAQMAN with Drop-tail which is a reactive approach that drops packets only after detecting incipient congestion. Hariom Soni et.al [8] proposed a new mechanism to estimate and avoid congestion. It is based on the detection of incipient congestion using Random Early Detection. It has no accurate method to predict the queue size prior. M-ADTCP is another method that presents a Modified AD-hoc Transmission Control Protocol where the receiver detects the probable current network status and transmits that information to the sender as feedback. The sender behaviour is altered appropriately [6]. Feedback packet should include quality parameters to control congestion in M-ADTCP. Congestion control policies are classified into three types namely window based, rate based and hybrid. Rate based congestion control policy increases or decreases the data rate of the sender as per the current status of the network [9]. But they need to consider additional measures which improve the quality of VoIP. Security in mobile ad hoc network is hard to accomplish due to vibrantly changing and fully decentralized topology as well as the vulnerabilities and limitations of wireless data transmissions [11]. [5] Proposed a new on demand QoS routing algorithm based on ant colony is highly adaptive, efficient and scalable and mainly reduces end-to-end delay in high mobility cases but failed to support optimized route in terms of energy, link stability, etc., [4] proposed new routing protocol combined with the flow control mechanism which selects the routes having more resources in an intelligent manner and uses a new metric to find the route with higher transmission rate, less latency and better stability. The routing protocol has no focus on quality perspective. Each artificial agent has many characteristics as discussed in [12]. A multi objective unicast MANET route optimization problem and Multi-objective Ant Optimized Routing (MAOR) algorithm uses network performance measures such as delay, hop distance, load, cost and reliability to converge to better routes [10]. Hence the proposed work needs a multi-objective based ant routing which supports energy, link stability, bandwidth, transmission delay to control congestion and to construct optimized route for voice based transmission.

III. PROPOSED METHODOLOGY

Nowadays many research works have focused on real time traffic. There is no focus on the factors that nearly cause congestion. Hence they fail to meet the services that the network offers and the quality. For real time traffic the factors that causes severe congestion are queue size fluctuation, poor flow control by end systems or intermediate nodes, insufficient bandwidth, short link expiration time, business of communication channel. Based on the control of these factors proposed methodology is designed and developed to control congestion and to optimize the route.

A. Linear Predictive queuing based Window Adjustment Policy (LPWAP) Algorithm

The main objective of the proposed approach LPWAP is to control the flow of data and to send feedback packet to sender in case of congestion. It is hybrid in nature and based on linear prediction. In the first stage, the algorithm uses PAQMAN to predict the Average queue size for TCP based VoIP flows. It uses past observations of sampled queue sizes and computes average queue size which provides accurate prediction of weighted sum of average queue sizes of past observations and tunes its value by adjusting the error rate using Recursive Least Square (RLS) algorithm. It also minimises the Mean Square Error by adjusting the vector W(n). In the second stage, the algorithm calculates drop probability using PredAvgQS computed during stage1. It dynamically adjusts TCP Window either to shrink or expand by regulating queue sizes and checking it with minimum and maximum queue thresholds. In its worst case it sends feedback packet to sender to reduce the flow of data, if severity increases before incorporating flow control, Drop Tail based packet dropping is done at router queues if PredAvgQS exceeds maximum threshold limit. It calculates drop probability using equ.(1) at each state of congestion to control the flow.

$$DP = Max_{DP}(predavgqs\text{-}PMin^{th})/(LPMax^{th}\text{-} LPMin^{th}) \quad (1)$$

For each Prediction Interval, queue size is predicted for the next interval, window based and rate based congestion control are repeated until voice transfer is over. This approach has very low performance in terms of R Factor, MOS, Average MOS, Equipment impairment effect. Hence Ant Colony Optimization based routing approach has been proposed to improve the performance in terms of the above said parameters.

B. PEACR Algorithm

The proposed approach is based on Ant Colony based Routing. It calculates stable route for transmitting VoIP data between sender and receiver by constructing Forward ANT (FANT) and Backward ANT (BANT) where FANT uses parameters Energy, Bandwidth, Transmission delay and Link Expiration Time. Each receiver node updates node and Link parameters; from the energy E_i and distance $dist_i$ metric, the normalized energy and normalized distance value is calculated in the form of the probability of the energy and distance. It also calculates the distance between the previous node and itself. Pheromone is calculated at two levels. At first level pheromone value is computed by taking the ratio of the addition value of the probability of energy (E_P) with the weighted product of the distance (D_P) to the ratio of the cumulative probability of energy and weighted product of the distanceDE_P. The second level pheromone value is computed from the ratio of the weighted exponential of the bandwidth B_w and Link Expire Time (LET) with the transmission delayT_D. If the message is already received from other nodes then the message is discarded by validating the sequence number of the FANT Message. By combining the first level and second level of pheromone value, the new pheromone value of the path is computed at the Destination Node (DN). Once the FANT message reaches the DN then it constructs the BANT message along with the reverse route. The BANT message is transmitted over the optimal path by validating the maximum pheromone deposition at the each hop. Based on the pheromone value of the path, the final path is selected for transmitting the data. In its worst case FANT reconstructs the route if no food available on the path or the pheromone evaporates before reaching the particular node. A node rejects an FANT that it has previously seen. The FANT uses sequence numbers to make sure that the paths are loop free and that the middle node responds to FANT are the freshest. When a node rebroadcasts an FANT to its neighbours, it also updates in its Path Table (PT) with needed parameters the node from which the primary copy of the message came. This PT record is used to build the reply to the BANT. The BANT message is originated by DN with the reverse path and it is forwarded to the Source Node (SN) by unicast manner. When the BANT message reaches the SN, then it starts transmitting the data packet through the constructed path. Each node maintains the PT with the estimated pheromone value of the each forwarder nodes. During the data transmission, the next-hop node is selected based on the maximum pheromone value. This approach has moderate performance than LPWAP. But it is yet to be improved to attain expected level of user quality. Hence Fuzzy logic based routing approach has been proposed to improve the performance in terms of the above said parameters.

C. CLHCC Algorithm

It is a fuzzy based hybrid approach that calculates MPSD, MBS, TB and sets threshold limits and if the congestion exceeds than the set threshold then the network is said to congest. MBS is computed as the ratio product of successful transmission duration with collision duration and successful transmission probability along with collision probability to the entire probability duration as delay. The MBS is estimated in Mac layer and attached in the CH header field named MBS metric. The Fuzzy Inference System (FIS) operates at destination node. After collecting delay, ongoing rate and MBS parameters, they are given as an input to the FIS based congestion detection system which employs fuzzification, rule set matching and detection of congestion state. In fuzzification stage, using the lower and upper bound the input parameters are converted into fuzzy linguistic variables. The linear relationship growth model is used in rule set formation since these parameters have uniform deviations in the parametric values. Identified fuzzy linguistics are compared with the rule set to compute the exact match in the rule set to select current state of congestion. Congestion states are classified as VLOW, LOW, MEDIUM, HIGH, VHIGH. If congestion is detected in the network state, then the CH is marked in the acknowledgment message. Once the acknowledgment packet with congestion notification reaches the source node, it reduces the current data rate to decrease the outgoing packet count. If congestion state is VLOW or LOW then destination calculates new data rate using multiplicative increase. If congestion state is MEDIUM then destination calculates new data rate using additive increase. If congestion state is HI or VHI then it calculates new data rate using multiplicative decrease. It updates the new data rate and sends the acknowledgement packet to sender. Intermediate nodes increase or decrease the data rate per the feedback they receive from the neighbour. This approach has improved expected level of user quality than the two approaches LPWAP and PEACR. The following section discusses the results obtained during simulation.

IV. EXPERIMENTS AND RESULTS

The proposed system is developed using NS-2.34 simulator to analyze the performance of TCP. MANET is formed with number of mobile nodes. Voice is used as a data packet to deliver from source to destination. Random deployment with random mobility model is used in the network within the selected areas 800 x 800 square meter area. The following graph shows the performance of the proposed research using E-Model.

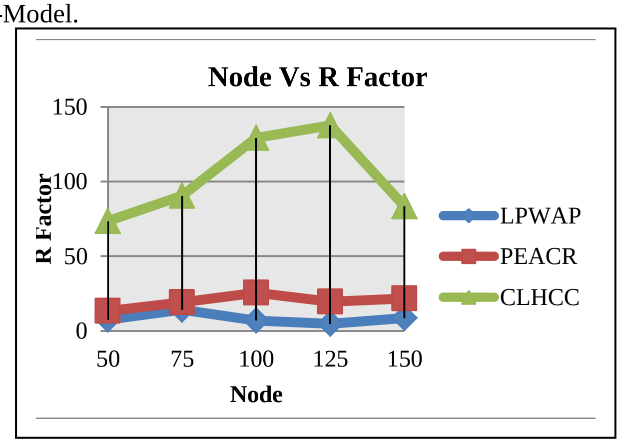

Figure 1. Node Vs R Factor Comparison of LPWAP, PEACR, CLHCC

The above graph shows high rating factor R for fuzzy logic based CLHCC approach than the previous two approaches. It relates to high Mean Opinion Score(MOS).

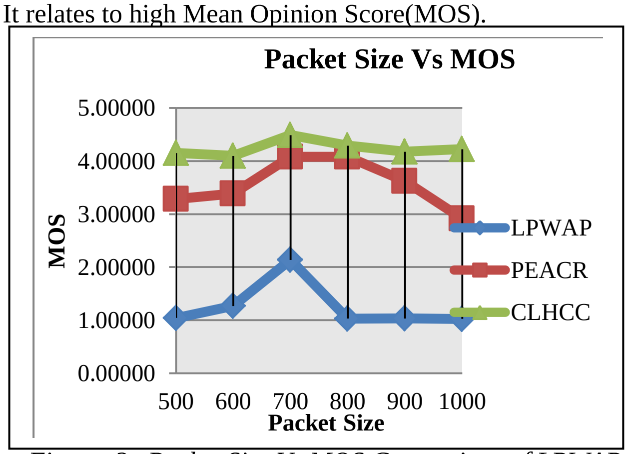

Figure 2. Packet Size Vs MOS Comparison of LPWAP, PEACR, CLHCC

In the above graph MOS value attainment is shown. CLHCC has high MOS value ranging from 4-4.5 than the two approaches. It proves that it supports high user satisfaction.

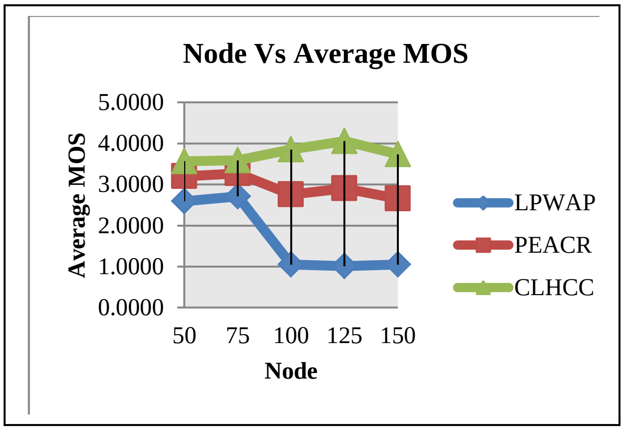

Figure 3: Packet Size Vs Average MOS Comparison of LPWAP, PEACR, CLHCC

In the above graph CLHCC shows improved performance in terms of average MOS attained through E-Model.

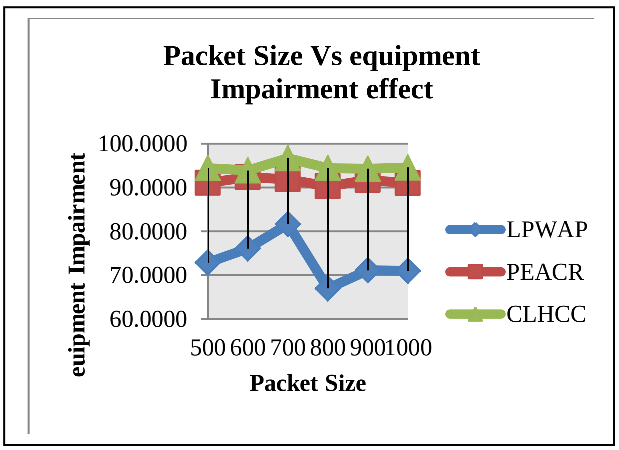

Figure 4: Packet Size Vs Ie Comparison of LPWAP, PEACR, CLHCC

Equipment impairment shows the performance of codec used to compress and decompress the voice in the above three approaches. CLHCC has highly improved performance than the two approaches. The above graph shows the clear picture of the quality of voice at user side. It also shows the comparative analysis of three different approaches that can be applied for congestion control.

V. PERFORMANCE EVALUATION

Proposed work is evaluated using a well known subjective measurement called E-Model which is a computational model that can be used to measure the quality of VoIP. It ensures whether users are satisfied with end-to-end transmission performance. The main output of the model is a scalar rating of transmission quality. The rating factor *R* is composed of the basic formula as shown in (2):

$$R = Ro - Is - Id - Ie\text{-}eff + A \qquad (2)$$

Ro (signal to noise ratio) is a mathematical summary of how the voice levels compare to the different noise sources including circuit noise and room noise.

Id (delay impairments) is a mathematical summary of transmission delay, talker echo and side tone.

Is (simultaneous impairments) considers non-optimum side tone, quantizing distortion, overall loudness and other impairments which occur more or less simultaneously with the voice transmission.

Ie (equipment impairment) and A (Advantage Factor) are both single value quantities.

To assist with calculations, default values and permitted ranges have been established.

It calculates MOS value from R factor and ranks the quality which lies between the scale factors 1-5 [1]. The ITU-TG.107 defines the relationship between R and Mean Opinion Score (MOS) as in (3).

MOS = 1 for R<0 (3)

MOS = 1+0.035R+R(R-60)*(100-R) 7*0.000001 for 0<R<100

MOS = 4.5 for R>=100

The highest R value shows high user satisfaction for voice. The following table shows user level quality of voice for MOS value.

Table 1. Relationship between MOS value and User Quality

Rating	Label
5	Excellent
4	Good
3	Fair
2	Poor
1	Bad

From the above discussed results using E-Model the following are analysed. LPWAP has very low performance in terms of R Factor, MOS, Average MOS, Equipment impairment effect. PEACR supports low R Factor, high MOS value ranges between 3-4, Average MOS within the range 3, 90% of high Equipment impairment effect than LPWAP and lower performance than CLHCC. CLHCC has obtained MOS value of approximately 4.5. Hence its obtained user satisfaction level is between Excellent and Good. Among the three approaches of proposed work, CLHCC shows improved user level performance. It can be used to control congestion with improved voice quality at user level.

VI. CONCLUSION AND FUTURE SCOPE

The proposed work improves the performance of voice over MANET in many aspects. It offers more advantages in terms of user level performance indicators such as MOS, R factor, Equipment impairment effect for voice. It provides valuable support dynamically by combining proactive and reactive queue management measures and supports hybrid congestion control to assess voice quality. Among the three approaches, fuzzy based hybrid congestion control approach CLHCC shows improved performance in all of the above performance indicators. It can be further extended to control congestion with high user satisfaction for other types of multimedia data in MANET.

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