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GC-ZRP: Cross-Layer Architecture Based Geographical Network Condition Aware Zone Routing Protocol for MANET

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Abstract*: *The exponential rise in the demands for Quality of Service (QoS) centric wireless transmission systems has revitalized academia-industries to develop more efficient routing solutions to serve reliable communication. However, classical wireless communication protocols are confined due to static and resource constrained network scenarios. Up-surging mobile-communication demands require more scalable, reliable, QoS-centric routing even under dynamic topology conditions. For a large-scale wireless network, zone-based routing approaches that embody both reactive as well as proactive network management strategies have been found significant; however traditional routing decisions confines its efficacy for dynamic topology-based networking solutions such as Mobile Adhoc Networks (MANETs). MANET that often undergoes exceedingly high topological and network conditions changes requires optimal routing model with augmented network-awareness, multi-parameter assisted route decision etc to achieve QoS provision. With this motivation, in this paper a robust Cross-Layer Architecture Based Geographical Network Condition Aware Zone Routing Protocol (GC-ZRP) has been developed for QoS assurance over MANETs. Unlike classical ZRPs, GC-ZRP applies cross-layer architecture with, Network layer, Medium Access Control (MAC) layer and Physical layer to perform enhanced Service Differentiation and Fair Resource Scheduling (SDFRS), Proactive Network Management (PNM), Dynamic Link Quality Estimation, packet velocity estimation and congestion detection models, which are performed at the different layers of the standard IEEE 802.11a protocol stack. The multiple network parameters based best forwarding path formation enables GC-ZRP to exhibit optimal packet delivery ratio, minimum packet loss and deadline miss ratio for real-time data traffic while ensuring maximum possible performance for non-real time data traffic.

Index Terms*: *Cross Layer Architecture, MANET, Mission Critical Communication, Quality of Service, Zone Routing Protocol.

I. INTRODUCTION

The exponential rise in the demands of the data communication systems and allied wireless communication paradigms have motivated academia-industries to achieve more efficient and robust communication technologies to assure Quality of Service (QoS) provision. Wireless communication systems have been playing un-substitutable role to meet up surging data transmission and allied mobile communication demands. However, enabling reliable, resource-efficient and QoS centric service provision has always been the open research area for scientific community. This as a result has broadened the horizon for researchers to achieve more efficient communication or routing solution. Amongst major communication systems, Ad-hoc networks being decentralized, and infrastructure-less networking solution have gained immense attention. The rising mobile communication systems, especially the Machine to Machine Communication (M2M) systems too have been demanding more robust routing solution to assure reliable data transmission over uncertain network conditions. On the other hand, M2M communication being in exceedingly high dynamic topology undergoes network dynamism and numerous allied complexities such as increased link-vulnerability, data loss, retransmission, energy consumption, reduced network lifetime and unwanted resource consumption. These all factors degrade the efficacy of the routing protocols. Amongst major available communication techniques, Ad-hoc network is one of the most efficient routing protocols that employ two mechanisms, intra-zone and inter-zone transmissions to perform end-to-end communication. In practice, three predominant routing approaches reactive routing protocol, proactive protocol and hybrid routing protocol can be implemented to perform data transmission over wireless network; however, their efficacy often depends on the network-environment such as the nature of node placement, etc. Functionally, reactive routing protocol primarily relies on the local distance factor to perform routing decision; however, node mobility somewhere limits its efficacy for the applications like Vehicular Ad-hoc network (VANET) or Mobile-Ad-hoc Network (MANET) [1]. On contrary, classical proactive routing approaches operate well with mobile topology by performing dynamic node table management that helps in proactive routing decision. Unlike classical reactive or proactive routing approaches Zone-routing protocols exploits efficacy of the both to perform intra-zone and inter-zone transmission using reactive and Proactive Network Management (PNM) schemes, respectively. Undeniably, to ensure optimal routing decision, particularly for event-driven mission critical communication over MANETs, zone routing protocol requires augmenting PNM and allied optimal route formation to maintain optimal performance with minimum packet loss, energy-exhaustion and delay.

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MANETs with randomly deployed mobile node often impose significantly high topological variations, and hence increases link-vulnerability, packet-loss probability, end-to-end delay etc. and hence demands optimal routing decision to alleviate aforesaid issues. Functionally, MANET applies multihop transmission mechanism where each node embodies a routing scheme to forward data to the next hop nodes towards destination.

However, excessive hops often increase the likelihood of link-outage and data drop probability. Meanwhile, increase in hops results into compromised performance, especially in terms of delay, data drop and energy consumption. Noticeably, the major Internet of Things (IoT) centric applications demand MANET to ensure reliable and deadline sensitive communication [2-5]. To achieve these outcomes, developing a novel routing protocol with augmented PNM provision can be of utmost significance. This factor can be stated to be the decisive driving force behind the current study.

In practice, sophisticated communication systems accommodate both real-time data (RTD) as well as Non-Real-Time (NRT) data, where the first carries event-driven RTD information while later carries certain multimedia contents having relatively lower priorities. Assuring optimal delivery for RTD data while maintaining best possible transmission for NRT can be vital to achieve cumulative QoS provision. To achieve it, several researches have been made where the data type classification (i.e., RTD or NRT) has been performed so as to enable Service Differentiation (SD) and prioritization [6][7]. However, in majority of classical SD based routing protocols NRT data are dropped to accommodate RTD data under congestion situation. It degrades QoS provision and hence to alleviate this issue an enhanced SD model can be incorporated at the Application layer or Network layer of the standard IEEE 802.11a protocol stack so as to assist data-type classification and optimal QoS centric prioritization [3]. It can greatly augment Network and MAC layers to efficient resource allocation [3][8]. The lack of network dynamism and link-appropriateness or stability under mobility often leads link-outage that causes data drop and hence QoS violation. Such events could be greatly avoided by incorporating network awareness and PNM strategy armored with efficient network aware best forwarding node (BFN) selection or relay selection at the Network layer [8]. To provide delay resilient routing identifying a node with minimum holding period or maximum packet velocity can be significant that can further assist PHY layer to perform optimal Dynamic Power Management and link-adaptive transmission control [9]. Considering Zone-Routing Protocol (ZRP) assisted MANETs, there is often increased likelihood of congestion at the boundary region or in inter-zone transmission that gets increased manifold with mobility. In addition, mobility imposes link-outage probability significantly during inter-zone transmission, and therefore assessing dynamic congestion and link quality can help avoiding link-outage and data drop that eventually can achieve QoS centric communication over MANETs. These parameters can help MAC to select a node with optimal characteristics for assuring reliable data transmission over MANET. Estimating these different parameters (i.e., data types, congestion probability, dynamic link quality, and packet velocity) at the different layers of the standard IEEE 802.11a protocol stack and synchronizing across the layers can help in achieving optimal forwarding path selection for QoS provision over MANET. To achieve it, cross-layer architecture based routing protocol can be a potential solution [3][10-18]. Interestingly, majority of the existing cross-layer routing approaches have either focused on SD model, residual energy, or link quality to perform best forwarding relay selection; however dynamic topology and allied network conditions require protocol to be armored with multiple dynamic network parameters to make optimal routing decision. With this motivation, in this research paper a highly robust Network Condition aware Cross-layer Architecture based Geographical Zone Routing Protocol (GC-ZRP) has been developed for QoS assurance over MANETs. Unlike classical zone routing approaches our proposed GC-ZRP protocol performs enhanced service differentiation and fair resource scheduling (SDFRS), congestion detection, Proactive Network Management (PNM) at the Network layer, Adaptive link quality estimation and packet velocity estimation at the MAC layer, and PHY switching at the Physical layer of the IEEE 802.11a protocol stack. Estimating different network parameters such as adaptive link quality, cumulative congestion probability, packet velocity and residual energy of a node, GC-ZRP protocol performs BFN selection followed by BFR formation for QoS communication. These novelties strengthen GC-ZRP to achieve augmented PDR and deadline sensitive transmission along with the optimal tradeoff between RTD and NRT data transmission over MANET to meet mission critical communication demands. The MATLAB based simulation has exhibited that the proposed GC-ZRP routing protocol outperforms exiting classical cross-layer architecture-based routing approaches.

This manuscript is divided into six consecutive sections where Section II presents related work followed by problem formulation in Section III. Section IV presents system implementation. In Section V results obtained and respective inferences are discussed, which is followed by conclusion in Section VI. References used are mentioned at the end of manuscript.

II. RELATED WORK

To exploit efficacy of ZRP for wireless communication purposes different optimization efforts have been made. Chellathurai et al [19] developed an evolutionary ZRP (EZRP) model that retained inner zone part in ZRP as intact while the outer zone exploited evolutionary computing method for estimating optimal forwarding path. However, authors [1] could not address the issue of network dynamism and its impact on topological variations, link-vulnerability, congestion probability etc. SreeRangaRaju et al [20] focused on augmenting ZRP by reducing control packets overload while exploring best forwarding node. In addition, they applied a query control scheme for traffic control.

Primarily, it augments routing zone structure to perform overlapping query detection and avoidance. Their model enabled ZRP to establish routes to all connected nodes with minimum control traffic requirement as compared to classical proactive route discovery methods. Researchers like Malwe et al. [21], Minh et al [22] exploited location information to perform ZRP optimization. Considering network dynamism in Ad-hoc network, authors [21] at first implemented selective bordercast scheme to perform route estimation. The key novelty of this approach was that in this protocol route request was transmitted only by the peripheral nodes. Practically, all comprising nodes in a network can't be able to perform optimal route selection; it was executed only by certain specific peripheral nodes with better connectivity. It reduced storage complexity and memory required for proactive node table management. In [22], authors exploited ZRP concept to derive a geographical routing protocol for MANET that confined search space for route discovery [33]. Location-Aided Zone Routing Protocol (LAZRP) [22] applied node location to perform routing decision; however, could not address the key issues of dynamic topology and resulting link-vulnerability, congestion etc. Benni et al [23] focused on performance optimization by augmenting best forwarding route decision where they found distance based ZRP better than Intra Zone Routing Protocol (IARP) and Inter Zone Routing Protocol (IERP). In [24], Madasamy et al. applied Stochastic Dynamic Programming (SDP) scheme in conjunction with a geographic angular zone-based two-phase dynamic resource allocation scheme to perform routing over VANETs. Authors applied SDP model to achieve optimal resource allocation strategy while retaining optimal viability routing decisions. A similar effort was made in [25][26], where authors applied location information of node to perform best forwarding route selection. Authors exploited distance information to estimate a route that could accommodate all connected nodes to achieve higher packet delivery ratio. In [26] authors applied the concept of moving object modelling and indexing techniques to perform routing decision in VANETs. Considering routing overhead in ZRP Ghode et al [27] developed a node energy monitoring algorithm (NEMA) to perform zone head selection over MANET to achieve better performance. Authors derived Zone Head Selection Algorithm (ZHSA) to constitute different zones followed by zone head selection with maximum residual power. However, ignorance of link vulnerability, outage-probability, congestion condition etc in MANETs confines its suitability with real time applications. Jain et al [28] focused on resource management to achieve augmented performance in MANETs. Multi-zonal concept was applied in [29] to achieve reliable communication over heterogeneous WSNs. Authors applied triangle-zone based clustering concept to achieve increased lifetime. However, this approach could not deal with mobile topology conditions. To achieve route with minimal utilization of network resource like bandwidth, time, and energy Singh et al [30] applied linear regression concept with curve intersection point area to reduce request flooding (message) and energy-aware routing decision. Samarasinghe et al [31][32] developed a greedy ZRP (GZR) protocol that employed greedy coordinates to perform alternate routing path. In this model GZR allocates greedy coordinates to each zone, as oppose to individual nodes. In GZR messages are transmitted in two ways; greedy geographic routing in between zones and traditional tree-based routing within a zone. This method enabled tree to have manageable sizes due to confined depth by the zone-diameter. This approach could merely alleviate the issue of re-estimation of the coordinates of the network topology and hence reduces overheads. To deal with mobility in network Mafakheri et al [34] proposed a fuzzy clustering assisted mobility-adaptive routing model (MACP-FL) that incorporated mobility-adaptive clustering. In this model Fuzzy Clustering Mean (FCM) algorithm was applied to split network into multiple clusters, and parameters like residual energy, and membership function were used to perform CH selection to enable transmission. However, this approach could not address the issue of link-vulnerability and packet velocity to achieve deadline sensitive and reliable communication. To achieve QoS performance authors proposed a Virtual Base Station (VBS) selection model for MANET. Authors applied mobile node's Signal-to-Noise Ratio (SNR) parameter to select VBS for ZRP based MANET [35]. Similar to the [22] and [33], Shankar et al. [36] recommended geographic multicast routing to construct a virtual tree structure with node location information. However, the need of link repair model and outage probability confines optimal multicast tree formation. To alleviate this issue, authors [36] developed Zone based Geographical Multicast Routing (ZGMR) that employs stateless unicast routing protocol for data transmission over MANET. Authors applied link duration and distance as network parameter to perform BFN selection. Considering impact of the quality of link on BFN selection Yélémou et al [37] developed a Binary Error Rate (BER) based ZRP (BER-ZRP) routing protocol that enabled improved ZRP Packet Delivery Ratio performance. To achieve timely data communication authors applied velocity parameter to perform adaptive ZRP (OVBAZRP) for stable and better routing [38]. However, this approach mainly focused on achieving different zone radius (per node) moving at different speeds. OVBAZRP [20], redesigned intra-zone active routing protocol and bordercast resolution protocol of ZRP. Though OVBAZRP enabled reduced lookup overhead however could not address QoS centric communication that demands timely and reliable data transmission. Jun et al [39] developed a Hybrid Zone Based Multicast Routing (HZMAODV) protocol for MANET to achieve scalable and reliable communication. HZMAODV protocol applied zone division concept and the geographical routing scheme to achieve inter-zone transmission paths. A similar effort was made in [40] where authors developed Dynamic Zone Based Multicast Routing Protocol (DZBMP) for MANET. Undeniably, numerous efforts have been made to augment ZRPs; however, most of the existing approaches apply single network parameter to perform routing decision of inter-zone forwarding path selection, whose optimality is inevitable for MANETs. Employing multiple parameters from the different layers of the protocol stack, IEEE 802.11a can be significant to make optimal BFN selection, followed by BFR selection to achieve QoS centric transmission over MANETs.

With this motivation, Kusumamba et al [41] developed a cross-layer architecture-based routing scheme (CLRS); however, this research primarily focused on node lifetime optimization. In [42], a cross-layer routing model was developed, where once assigning application authors estimated cost of each path to perform inter-zone BFN and BFR selection. Authors [43] developed cross layer model while augmenting real time scheduling at the network layer with augmented Rate Monotonic Algorithm (RMA) and Earliest Deadline First (EDF) scheme. Gawas et al [44] developed cross layer architecture-based routing decision by using channel state awareness as the routing decision parameter. A cross layer routing protocol was developed in [45] where authors developed underlay model at the network layer of IEEE 802.11 standard. To alleviate signal flooding a cross-layered location based and energy efficient routing scheme was developed. Li et al [45] designed a cross layer routing model based on the IEEE standard 802.11 protocol stacks. To avoid signalling overheads a location restricted energy efficient routing scheme was developed. Their protocol achieved enhanced end-to-end delay. A cross-layer scheme was incorporated in between application and MAC and between MAC and transport layer [46] to achieve timely and reliable communication over MANETs. To achieve reliable data transmission Frias et al [47] designed a multipath DSR-based routing protocol, where a novel load balancing scheme was applied to reduce end-to-end delay and data drop probability. ViStA-XL [48] was developed to support real-time multimedia transmission. Authors [49] applied a real-time XL Optimizer (XLO) to collect node information and network information from the different layers of the protocol stack to make reliable transmission decision. DEL-CMAC was developed for distributed energy-adaptive location-based CMAC protocol named DEL-CMAC for MANET while in [50] a cross-layer design concept was developed. Authors [51] developed QoS centric routing model. A Hierarchical Cross Layer Optimization Protocol (HCLP) was developed in [51] that focused primarily on achieving high resource utilization, minimum delay and minimum jitter in MANET.

III. PROBLEM FORMULATION

Considering the inevitable need of the mobile wireless networks such as MANET, developing a reliable and time efficient routing protocol development is of great significance. Enabling QoS centric and reliable data transmission over MANET that itself undergoes significantly high topological variations require the allied routing protocol to be augmented with proactive routing strategies while embedding the features of dynamic network sensitiveness (i.e., channel condition awareness and node suitability) that eventually can help making optimal routing decision. In fact, under mobile topology, as is common in MANET the network parameters specially the congestion, link quality, etc. might vary over simulation time that eventually could lead link-outage and hence forcing network to undergo iterative node discovery and retransmission. It can cause significantly high energy exhaustion, resource consumption, and more significantly increased end-to-end delay which can't be recommended for event-driven mission critical communication. Avoiding such issues require optimal routing decision. As already stated, Zone-Routing Protocol (ZRP) with augmented proactive network management can be a vital solution to meet above stated demands. Being a hybrid type protocol ZRP comprises both reactive as well as proactive routing strategies; however, the significance of the later (i.e., proactive routing) becomes more vital when dealing with mobile network condition with exceedingly high topological variations. Augmenting proactive routing management with dynamic network awareness can help network model to avoid congestion, pre-mature link outage, data drop probability, high end-to-end delay etc. However, achieving this goal requires synchronized functional behavior across the layers of protocol stack (standard IEEE 802.11a) to make optimal routing decision. To achieve optimal proactive routing decision exploiting different network parameters from the different layers of the protocol stack can be vital to achieve Best Forwarding Node (BFN), followed by Best Forwarding Route (BFR) selection. With this motive, in this research work a robust network condition aware cross-layer routing protocol is developed that intend to exploit network-awareness features to enable optimal BFN/BFR selection to augment classical ZRP protocols.

To achieve it, in this paper a novel Network Condition Aware Zone based Geographical Routing Protocol for MANET (GC-ZRP) protocol is developed over standard IEEE 802.11a protocol stack. In conjunction with ZRP concept GC-ZRP protocol emphasizes on augmenting proactive routing with cross-layer features where it exploits dynamic network parameters from the different layers of the protocol stack to make QoS-centric optimal routing decision. Primarily our proposed GC-ZRP protocol exploits the key information from Application layer, Network Layer, and MAC layer. Here, it is assumed that each node is armored with the protocol comprising one hop-distant neighbor's information. In addition, the protocol contains node parameters from the different layers of the protocol stack. The awareness about node's key parameters such as congestion status, link-quality, channel information (i.e., buffer availability), and holding period (in other way, packet injection rate or packet velocity per node) can help making optimal BFN and/or BFR selection. Though, a few efforts have exploited classical features such as inter-node distance, and congestion probability as the node parameter to perform BFN selection; however, under exceedingly dynamic topology these limited parameters can't assure suitability of a node to retain QoS-centric communication over a long time. Therefore, our proposed GC-ZRP model exploits major possible node information or network features to perform BFN selection where dynamic link quality, packet velocity (say, packet injection rate), buffer availability and congestion probability have been applied to perform BFN and/or BFR selection. In addition, considering the role of optimal resource allocation for both event-driven Real-Time-Data (RTD) as well as Non-Real-Time (NRT) data GC-ZRP protocol applies a robust Service Differentiation and Fair Resource Allocation (SDFRS) model that achieve optimal QoS centric resource allocation.

To achieve these objectives, the node information from the different layers of the protocol has been collected from the different layers of the protocol stack. A snippet of the different layers under consideration and allied functions at the respective layers is given in Fig. 1.

Considering the key demand of event-driven mission critical communication over MANET, the proposed GC-ZRP protocol intends to accomplish maximum possible throughput with minimum data drop probability and deadline miss ratio. In addition, optimal resource allocation has also been targeted to be achieved to meet standard demands of major Long-Term-Evolution (LTE) assisted Device-to-Device (D2D) communication over IoT ecosystem.

IV. PROPOSED SYSTEM

This section primarily discusses the proposed GC-ZRP routing protocol for MANET.

A. GC-ZRP Protocol

GC-ZRP routing protocol exploits different dynamic network parameters from the different layers of the protocol stack to perform BFR selection. To achieve it, GC-ZRP protocol employs cross-layer routing model comprising application layer, network layer, MAC layer and PHY layer (Fig. 1). As depicted in Fig. 1, the application layer of the GC-ZRP protocol applies a novel SDFRS scheme that identifies type of data under communication to ensure QoS centric resource allocation. The employed Service Differentiation (SD) model helps in identifying RTD and NRT data types that in layer stage helps in optimal resource allocation. In major classical ZRP protocol the issue of congestion is prevalent at the outer layer (say, network boundary) and hence congestion awareness-based routing decision is must. With this intend GC-ZRP protocol performs congestion detection at the network layer that operates in conjunction with SDFRS model to perform optimal QoS-centric resource management. On the other hand, recognizing a node with sufficient resource can help PHY layer to induce multi-rate transmission and Dynamic Power Management (DPM) to achieve optimal resource utilization. in addition, identifying a neighbouring node with suitable link quality can help in achieving reliable data transmission even under varying topological conditions. GC-ZRP routing protocol performs this task at the MAC layer of the protocol stack. Similarly, unlike classical ZRP routing protocols, GC-ZRP explores a node for its packet injection rate capacity, also called packet velocity. Here, the prime intend is to select only that node having the highest packet injection rate capacity (with minimum holding period) for BFR selection to assure mission-critical communication. To achieve it GC-ZRP protocol implements a novel packet velocity estimation model at the MAC layer (Fig. 1). Being a cross-layer routing model GC-ZRP enables dynamic information sharing across the layers of the protocol stack so as to assure optimal routing decision and network management objectives. Summarily, our proposed GC-ZRP routing protocol performs Service Differentiation and Fair Resource Scheduling (SDFRS), Dynamic Congestion Detection (DCD) and Proactive Network/Node table management at the Network Layer, while MAC layer exhibits packet injection rate estimation and dynamic link quality estimation. Noticeably, SDFRS can be applies at the application layer as well based on network demands and machine suitability, while PHY layer can be armoured with DPM provision to enable multi-rate transmission control. The key functions by GC-ZRP routing protocol at the different layers of the protocol stack are:

1) *Proactive Network Table Management,*
2) *Service Differentiation and Fair Resource Scheduling,*
3) *Congestion Detection and Avoidance Model,*
4) *Dynamic Link Quality Measurement,*
5) *Packet Velocity Measurement,*
6) *Cumulative Rank Matrix Estimation and Best Forwarding Path Selection*

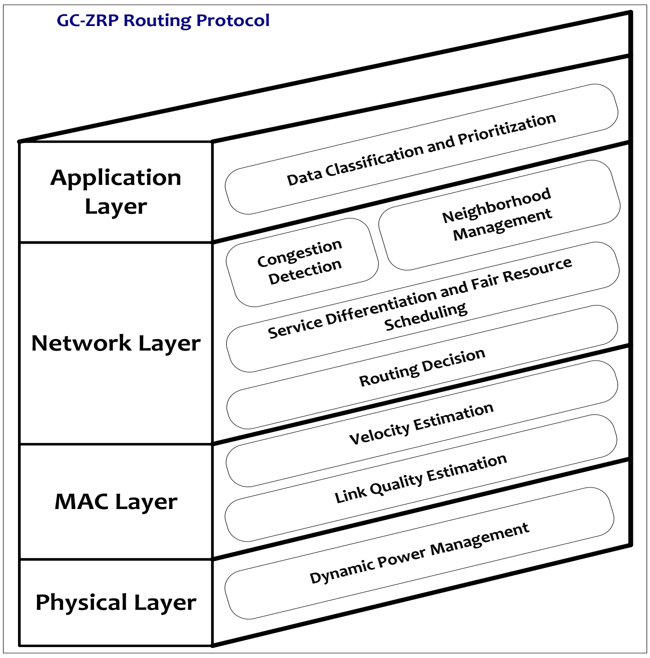

Fig. 1. Proposed Cross layer Architecture for QoS centric Routing Protocol for MANETs (GC-ZRP)

The detailed discussion of the proposed GC-ZRP routing protocol is presented in the subsequent sections.

1. Pro-active Network Table Management

Being a dynamic topology based wireless technology MANET often undergoes exceedingly high network parameter (link quality, inter-node distance, buffer availability, congestion, etc) variation. The topological changes might affect inter-node distance variation and hence affects link quality. Similarly, dynamic or mobile nature of nodes might force it to undergo congested network conditions affecting overall transmission efficiency. Increased resource demand can force a node to become memory (buffer) deficient and hence unsuitable to become BFN.

On the other hand, under dynamic network conditions, employing stale or outdated network information might cause link outage, thus forcing huge retransmission, delay and energy exhaustion. In such cases the use of Proactive Network Table Management (PNTM) can be a potential solution that even fits optimally for ZRP demands. The deal with these situations GC-ZRP model applies PNTM that updates network parameters dynamically to help optimal routing decision. Unlike reactive routing approaches PNTM enables dynamic network parameter update to help network-condition aware decision making. Noticeably, unlike classical proactive routing approaches, ZC-ZRP PNTM model alleviates the possibility of the iterative Node Discovery (ND) process that reduces signalling overheads significantly. In our proposed GC-ZRP protocol each participating node maintains information about one-hop distant neighbour node by means of a beacon message. The applied beacon message contains vital node information containing the NodeID, maximum buffer capacity, available buffer space, geographical node location, packet velocity, and link quality. Noticeably, in our proposed GC-ZRP protocol these parameters are obtained through the ACK of the beacon message that reduces unwanted iterative signalling overhead and control packet's caused energy exhaustion. Considering control packet configuration, we have considered each packet of 512 bytes possessing three distinct fields dedicated or node NodeID, Dynamic Node parameters and geographical position vector. Thus, transmitting a beacon message GC-ZRP protocol collects one-hop node information and updated node table to perform further BFR selection. In function, MANET might often undergo collision due to greedy nature of the nodes and competitive time-bounded transmission nature, and hence GC-ZRP enables a node to multicast beacon message only in conjunction with an offset timer decided based on a classical uniform distribution paradigm.

Receiving transmission request from a node, a receiving node resets its timer and hence avoids unwanted requests from other nodes. It helps in reducing congestion probability. In GC-ZRP PNTM model each node maintains a node table. Consider $\mathrm{N_j}$ be a one-hop distant neighbour and $\mathrm{BFN_i}$ be the optimal forwarding node in zone-based routing, and then the node table is updated as (1)

$$\mathrm{N}_{Table} = \{BFN_i \in \mathrm{N}_j \,|\, D_{Eucl\_d} - D_{Eucl\_F} \geq 0\} \qquad (1)$$

In equation (1), D_{Eucl_d} is the Euclidean distance between the source and nearest destination, and D_{Eucl_F} refers the distance between source and the nearest BFN.

2. Service Differentiation and Fair Resource Scheduling (SDFRS)

Undeniably, fulfilling QoS centric communication demands require optimal resource allocation; however, the different type of data and its respective significance makes resource-sensitive prioritization more tedious. For example, a network can have both RTD as well as NRT data for communication; however, it can have distinct priority to make optimal decision. In such cases sensing data types and allocating dynamic resource is a mammoth task to retain QoS provision under mission critical communication scenario. Identifying data types, GC-ZRP executes SDFRS to assure optimal resource allocation for RTD data while maintaining maximum possible resource for NRT. In our proposed routing model, each node possesses two distinct types of equi-capacity buffer. Being a RTD centric ZRP, once a node undergoes complete buffer consumption to assure QoS centric transmission, the supplementary buffer is provided from NRT buffer while assuring that it doesn't dumps all NRT data and retain QoS provision. To achieve it, GC-ZRP perform dual model prioritization where RTD buffer follows prioritized data store and allocation, while NRT buffer applies First-In-First-Out (FIFO) based allocation. In case during functional a node undergoes 100% resource exhaustion for RTD data transmission, it borrows supplementary buffer space from NRT buffer that to accommodate RTD drops some of the recently added NRT-data in queue. Unlike classical resource allocation approaches where NRT buffer is emptied completely to accommodate RTD data, our proposed SDFRS model drops only a few recently added packets in the NRT buffer queue. In this manner the packets waiting for long time and queued in NRT buffer remains in queue to preserve QoS provision. This, SDFRS model assures optimal resource allocation to the RTD data while maintaining maximum possible resource allocation to the NRT data. This mechanism assures optimal QoS trade-off for both RTD as well as NRT data and hence makes GC-ZRP suitable for major communication system demands.

3. Congestion Detection and Avoidance Model

As already stated in previous sections, the dynamic topology of MANET can force it to undergo congestion during communication. Node mobility on the other hand increases the probability of congestion that forces it to undergo data drop, retransmission and resource exhaustion. To alleviate such issues, GC-ZRP model implements a congestion detection method that exploits maximum buffer capacity and current buffer availability measurements to estimate congestion probability of a node. As already discussed in previous section, GC-ZRP applies an offset timer-based transmission control scheme that avoids unwanted transmission requests thus avoiding congestion probability. In addition, our proposed GC-ZRP model incorporates a novel Congestion Detection and Avoidance Model (CDAM) that measures buffer availability dynamically. Thus, with the estimated maximum buffer capacity and current available buffer CDAM estimates congestion probability of a node which further signifies suitability of that node to become BFN for optimal BFR selection. A node with enough resource availability and minimum congestion probability is considered as a BFN candidate. Being a cross-layer routing protocol GC-ZRP protocol operates in conjunction with SDFRS that assigns two distinct buffers for RTD and NRT data to avoid congestion probability. As stated, RTD-buffer stores data in prioritized queue manner while NRT buffer applies FIFO scheme to store data.

Since, in practice each data packet possesses certain defined lifetime and therefore needs to reach destination before deadline time to assist timely decision. One of the key contributions of the proposed GC-ZRP routing protocol is its deadline sensitive resource scheduling. To enable packet deadline sensitive resource allocation GC-ZRP protocol estimates distance between source and sink node. It helps in identifying data with the highest priority (2). Observing equation (2), retaining least $\mathcal{T}_{\mathrm{Ratio}}$ can be considered for prioritization.

$$\mathcal{T}_{Ratio} = \frac{RDT_i}{d_i^j} \quad (2)$$

In (2), RDT_i states for the residual deadline time (RDT), d_i^j is the Euclidian distance between the forwarding node i and the nearest sink j. In our proposed routing model RDT is estimated by assessing the arrival time of each packet and $\mathrm{RDT_i}$ is updated for each packet under transmission before transmitting. Similarly, the overall queue period is subtracted from $\mathrm{RDT_i}$. In GC-ZRP routing protocol the current buffer availability information is used to retrieve congestion probability at a node. Here, we derive a parameter called Congestion Degree Index (CDI) that signifies congestion probability at that node (3). Let the total number of neighbouring nodes be $\mathbb{S}_{\mathrm{n}}$. Then, the total congestion at certain node can be estimated as:

$$CDI_r = \frac{CDI_{NRTMem} + CDI_{RTDMem}}{CDI_{NRTMemMax} + CDI_{RTDMax}} + \sum_{i=1}^{N} CDI_{ri} \quad (3)$$

In (3), $\mathrm{CNI_{NRTMem}}$ refers the buffer available at NRT-buffer, while CDI_{RTDMem} states for the buffer available at RTD buffer. Similarly, in denominator the variables $\mathrm{CDI_{RTDMax}}$ and $\mathrm{CNI_{NRTMemMax}}$ present the maximum buffer capacity of the RTD-buffer and the NRT-buffer. Thus, once estimating the CDI of the neighboring node, a node can decide its suitability to become the BFN or the BFR node. In our proposed GC-ZRP routing protocol, a node with minimum CDI is selected as the (node) candidate for BFN selection.

4. Dynamic Link Quality Measurement

Undeniably, constituting BFR using the dynamic link information can be vital to assure reliable data transmission. Since, link quality often varies over distance and hence connecting a node with higher link quality can be vital for BFR selection. On the other hand, a higher fraction of correctly received data (say, throughput) signifies higher link quality which can be easily estimated at the MAC layer of the protocol stack. With this motive, in GC-ZRP routing model the received packet and the total transmitted packet information is applied to derive dynamic link quality of a node. Mathematically, we use equation (4) to estimate link quality.

$$\eta = \alpha * \eta + (1 - \alpha) * \left(\frac{\mathrm{N}_{rx}}{\mathrm{N}_{tx}}\right) \quad (4)$$

where, η states the dynamic link quality, $\mathrm{N_{rx}}$ and $\mathrm{N_{tx}}$ signify the total number of received and the transmitted packets, respectively. The parameter α, also called network coefficient remains in the range of 0 to 1. In GC-ZRP routing protocol, a node with the highest link quality is considered as the BFN candidate to constitute BFR.

5. Packet Velocity or Injection Rate

As already stated, being an event driven and QoS centric communication system in this research it is intended to enable timely data delivery for which identifying a node with maximum possible packet injection rate is must. Practically, there can be the node with sufficient buffer availability and link quality; however slow packet injection rate, which is related to its holding period can take significantly long time to complete transmission. This as a result might impose huge latency or end-to-end delay and hence can violate QoS demands. Considering it as a (node) decision parameter, in this paper packet velocity or injection rate of each node has been estimated. Here, we hypothesize that a node with high velocity can enable swift data transmission. In GC-ZRP routing protocol packet delay has been used to measure inter-node distance (i.e., distance between the neighboring node and the nearest sink). The two additional parameters; Euclidian distance, Mean Round Trip Time ($\mathrm{MRTT_{Ti}}$) have been applied to measure packet injection rate. Here, we estimated MRTT is estimated as the time-difference between the transmission and receiving of the ACK message (5).

$$MRTT_{Ti} = \frac{\sum_{i=0}^{N} R_{At}^{i} - S_{Pt}^{i}}{\mathcal{N}} \quad (5)$$

In above expression (5), $\mathrm{R_{At}^i}$ stated the time of ACK receiving, while $\mathrm{S_{pt}^i}$ denotes the packet transmission, and $\mathcal{N}$ presents the total packets transmitted. Additionally, the Euclidian distance between source and the nearest destination and the relative distance are also estimated between the neighboring node and the nearest sink. In this manner, employing these distance vectors and Mean Round Trip Time (MRTT), a speed factor $\mathbb{V}_\tau$ is obtained (6).

$$\mathbb{V}_\tau = \left(\frac{\mathbb{D}_{ESD}^{i} - \mathbb{D}_{ENS}^{i}}{MRTT_{Ti}}\right) \quad (6)$$

In (5), $\mathbb{D}_{ESD}^{i}$ states the Euclidean distance between the source i and the sink, while $\mathbb{D}_{\mathrm{ENS}}^{\mathrm{i}}$ refers the distance between the source and the (nearest) sink. To estimate the normalize factor called packet velocity ($\mathbb{V}_{\mathrm{packet}}$) at certain transmission power, we have applied the speed of radio signal in air ($\mathbb{R}_{MaxSpeed}$) (7).

$$\mathbb{V}_{\mathrm{PACKET}} = \left(\frac{\mathbb{V}_\tau}{\mathbb{R}_{MaxSpeed}}\right) \quad (7)$$

where $\mathbb{R}_{MaxSpeed} = 3 \times 10^{-8}\, m/s$.

Thus, once estimating the key network parameters (i.e., packet injection rate, dynamic link quality, congestion probability or congestion degree of a node), a parameter called Node Rank Index (NRI) has been estimated that classifies a node to become BFN for optimal BFR formation.

6. Node Rank Index (NRI) based BFR Selection

In GC-ZRP routing protocol, the above derived network parameters (i.e., packet injection rate, dynamic link quality, congestion probability or congestion degree of a node) have been exploited to estimated NRI value for each node. Here, we used equation (8) to estimate NRI for each node.

$$NRI_i = \omega_1 * \eta_i + \omega_2 * CDI_i + \omega_3 * V_{packet_i} \qquad (8)$$

In above expression, ω presents a weight parameter to be decided based on network preference or application demands. For example, in case of an application demanding maximum link quality or reliability (η) but with even relatively compromised packet velocity, ω_1 requires to be higher than ω_3. The selection of weight parameter follows the condition (9).

$$\sum_{i=1}^{3} \Omega_i = 1 \qquad (9)$$

In (9), NRI_i has been estimated for all neighbouring nodes and it has been updated to the PNTM in decreasing order. The algorithm applied to perform BFN selection in GC-ZRP protocol is given as follows:

Algorithm: Pseudo-Algorithm for GC-ZRP BFN Selection

```
Input: Total number of nodes, radio range, initial buffer
       capacity, one-hop distant node information.
Output: Node Rank Matrix, Best Forwarding Node, Initiate
       Node Score_Max (NRI) = -1;

foreach node i do
Estimate Current_Score i
  = ω1. ηi * One-hop Distant Node[i].η
       + ω2. CDI * One-hop Distant Node[i]. CDIi
       + ω3. VPacket i * One-hop Distant Node[i]. VPacket i ;

  If Score_Threshold_Max ≤ Current_Score i then
  Best Forwarding Node (BFN_ID) = i;
  end
end
```

Fig. 2. Pseudo-algorithm for GC-ZRP based BFN Selection

Unlike classical approaches where the node with maximum quality is used as BFN, GC-ZRP protocol considers a dual conditional approach to perform BFN selection. These are:

1. *Max-Feature Node Selection (MFNS)*
2. *Parallel-ND execution and MFNS.*
3. *Threshold based BFN Selection.*

In first case, once estimating NRI index for each node $NRI_{i \in totNodes}$, it updates PNTM in the decreasing order of NRI index. Thus, a node with maximum NRI value, also called Max-Feature is selected as BFN. However, considering dynamism in the network where a node can't be guaranteed to have stable NRI value for long time, there can be sudden change in node feature. Under such conditions, classical methods can impose huge signaling overhead to form alternate BFR. In addition, such behavior could cause link-outage and hence QoS violation. To form alternate BFR, node information available in PNTM can be exploited for time being, and in case of unavailability of a suitable BFN the proactive ND phase can be executed to perform BFN selection. However, being a proactive network management strategy applying second phase can't be justifiable. And hence, in our proposed GC-ZRP protocol, a threshold value is estimated which is compared with current NRI index value of a node. A node with NRI value more than threshold is selected as BFN that enabled optimal QoS-centric BFR selection.

The results obtained and their respective significances are discussed in Section IV.

V. RESULTS AND DISCUSSION

This research work primarily focused on developing an efficient Zone Routing Protocol (ZRP) with enhanced proactive routing strategies to be applicable for mobile wireless network solutions. ZRP being the combination of both reactive and proactive routing decision requires robust routing decision mechanism, especially at the outer layer. Reactive routing approaches exploits static node and/or network features to perform routing decision, on contrary proactive routing method requires dynamic network parameters updates to enable fault-resilient routing decision. Considering applications such as MANETs, enabling optimal routing decision with a robust proactive network management can be of utmost significance. Considering the current study where the emphasis was made on developing a novel ZRP model with augmented proactive network management, a Cross-Layer Architecture Based Geographical Network Condition Aware Zone Routing Protocol (GC-ZRP) has been developed. Unlike classical routing approaches where single network parameters such as inter-node distance or residual energy was used to perform routing decision, GC-ZRP model exploits cross-layer architecture that employs Application layer, Network layer, MAC layer and PHY layer. GC-ZRP was armoured with data classification, congestion detection, service differentiation and resource allocation, proactive network table management, routing decision at the network layer; dynamic link assessment and packet injection rate estimation for each node at the MAC layer and dynamic power management (DPM) at the PHY layer. However, this paper has not emphasized more on DPM. Thus, implementing proposed GC-ZRP routing protocol key network parameters such as dynamic link quality, congestion degree, and packet velocity (i.e., packet injection rate) of a node BFN selection has been done so as to constitute BFR for successful data transmission.

Unlike classical routing approaches where primarily residual energy or radio range were applied to select BFN; GC-ZRP has explored multiple QoS and reliability sensitive parameters to perform BFN selection that eventually assures optimal routing decision.

Exploiting dynamic link quality, congestion degree and packet velocity a single node characterizing parameter named Node Rank Index (NDI) was derived that assessed suitability of a node to become BFN. Noticeably, to assure optimal performance GC-ZRP employed deadline sensitive resource allocation and fair resource allocation that facilitated optimal resource provision for both RTD as well as NRT data. The overall proposed model was developed based on standard IEEE 802.11a protocol for which MATLAB simulation platform has been employed. Some of the key simulation parameters used is presented in Table I.

TABLE I. Experimental Setup

Parameter	Specification
OS	Windows 2010, 8GB RAM, Intel i5 processor.
Programming	Matlab Scripting
Simulation Tool	MATLAB 2010a
Physical	IEEE 802.11PHY
MAC	IEEE 802.11MAC
Mobile Nodes	10, 20, 30, 40, 50, 60
Protocol	GC-ZRP
Link-layer	CSMA-CD
Packet Size	512 Bytes
Radio Range	100, 150 meter
Packet Deadline time	8 Sec.
Traffic	CBR
Mobility	Athelete Circular Running Competition Scenaiton)
Weight parameters	$\omega_{1(LQE)} = 0.4$, $\omega_{2(Cong)} = 0.3$, $\omega_{3(P\ Vel)} = 0.3$
Simulation Period	600 Sec.
Payload	250, 500, 750, 1000, 1250, 1500, 1750, 2000, 2250, 2500, 2750, 3000.

Though, several ZRP routing protocols have been proposed so far; however, a very few efforts have been made on exploiting cross-layer concept to derive a hybrid routing decision. However, considering the need of performance assessment, in this research work a reference model [1-3] has been developed. Considering GC-ZRP to be applied for a mission critical communication scenario where enabling congestion free routing, fault-outage resilient transmission scheduling is must, in this paper the network normalizing factor (i.e. weight ω) has been assigned 0.4 for these parameters, while packer velocity is assigned 0.2.

In other words, $\omega_{1(LQE)} = 0.4$; $\omega_{2(Cong)} = 0.4$, and $\omega_{3(P\_Velocity)} = 0.2$ Though, to examine performance for mission critical communication $\omega_{3(P\_Velocity)} = 0.4$ was also applied and performance was examined; however, results remains near similar. Nevertheless, a researcher in future can apply these weight parameters based on its application specific demands and self-consciousness. The simulation outcomes were obtained for RTD as well as NRT data traffic where it was intended to achieve maximum possible or optimal Packet Delivery Ratio (PDR), low Packet Loss and Deadline Miss Ratio (DMR). Considering the existing systems and their efficacy to achieve QoS provision, in this research work two key works done in [35][36] are considered for performance assessment. Fahmy et al. [35] have developed a Virtual Base Station (VBS) selection scheme (VBS-ZRP) which exploits SNR information to perform BFN selection over ZRP based MANET. Noticeably, exploring their research it can be found that SNR information was exploited to examine suitability of a node to become BFN so as to achieve a virtual base node towards the destination. However, this approach exploits merely the SNR information to perform routing decision. Similarly, Shankar et al. [36] developed Zone based Geographical Multicast Routing (ZGMR) protocol that exploited distance and link duration to select the data forwarding nodes. A similar work was done by Yélémou et al [37]. The overall performance of the considered protocols has been assessed in terms of PDR, PLR and DMR; which are the dominant QoS signifier. The performance of the considered algorithms has been done in terms of packet delivery ratio (PDR) of the RTD data and NRT data traffic, Packet Loss Ratio (PLR) of the RTD and NRT data traffic and cumulative deadline miss ratio. The following results (Fig. 3 to Fig. 7) presents the results obtained. In general, during mobile topology a node might undergo varying payload conditions. Such abrupt payload pile-up could even give rise to the congestion of contention. In such cases the efficacy of better resource or buffer management as well as link adaptive routing often play decisive role. As stated, authors [35] had exploited link feature to route the data to the virtual sink, while in [36] inter-node distance and link quality was considered to perform link adaptive resource allocation and allied transmission (routing). Now, observing result (Fig. 3), it can be easily found that the proposed GC-ZRP routing protocol outperforms other state-of-art techniques (ZGMR and VBS-ZRP) in terms of higher PDR performance. Noticeably, the maximum data delivery for RTD, which is a prioritized data traffic type to retain QoS provision, GC-ZRP protocol exhibits approximate 97.92% PDR, which is more than other approaches (i.e., ZGMR (88.9%) and VBS-ZRP (82.0%)). Since, both the classical approaches, ZGMR and VBS-ZRP don't have any sophisticated multiple buffer provision and allied resource scheduling, and therefore it has resulted into inferior PDR performance. On contrary, the inclusion of a highly robust buffer management strategy in conjunction with congestion resilient transmission decision has strengthened our proposed GC-ZRP protocol to exhibit better PDR performance. PLR being reciprocal of PDR is depicted in Fig. 4. Here, it can easily be visualized that the augmented proactive routing decision and resource allocation model of GC-ZRP has enabled it to exhibit better Inter-Zone Best Forwarding Node Selection (BFN). This as a result has helped in reducing unwanted link outage or packet retransmission which is the major reason for increased packet loss. Thus, in relation to these facts our proposed GC-ZRP model has exhibited minimum packet loss than other approaches. Undeniably, the data sensitive resource allocation (here, RTD traffic is assigned prioritized buffer allocation while NRT is assigned FIFO resource allocation), enabled GC-ZRP to exhibit maximum possible successful data delivery and hence minimum PLR.

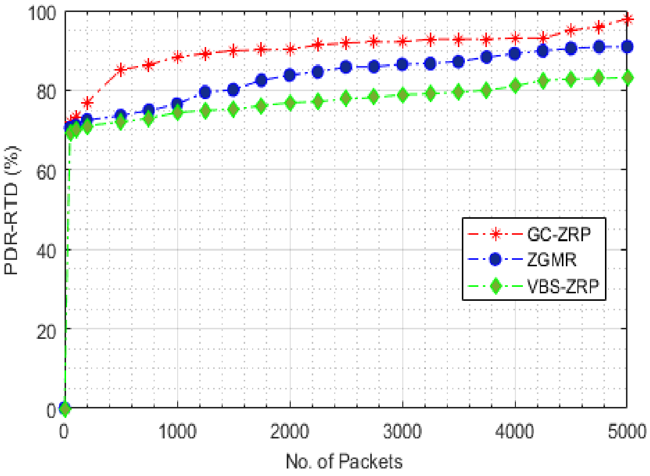

Fig. 3. PDR performance for RTD traffic

Considering major applications including LTE supported D2D communication there are often NRT traffic along with RTD data transmission. These NRT data can be the multimedia data or certain log (activity) contents required to be processed in future. Undeniably, such data used to be having relatively lower priority as compared to event-driven RTD data traffic. However, its significance can't be ignored, especially when NRT data communication is most communicated data in handheld devices. Considering this fact, in this paper it was hypothesized that NRT traffic too has equal significance to meet QoS demands. With this motivation, in this paper GC-ZRP protocol was developed in such manner that it assures maximum buffer for RTD traffic while ensuring maximum possible resource allocation for NRT traffic. Its significance can be easily visualized in Fig. 5, where the proposed GC-ZRP protocol has exhibited better NRT PDR than other state-of-art reference routing protocols, especially designed for ZRP based communication.

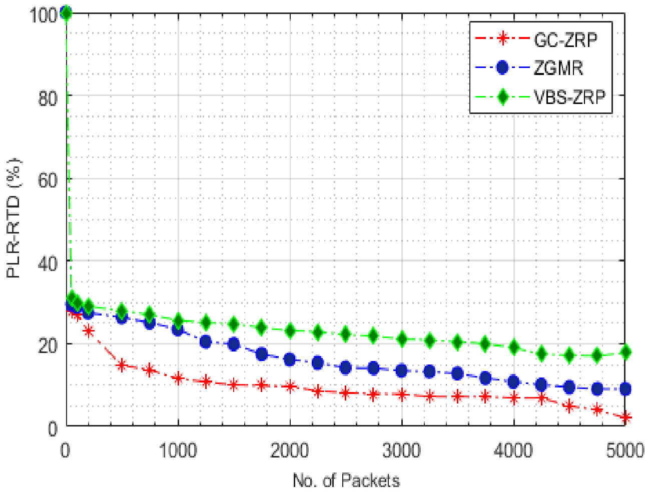

Fig. 4. PLR performance for RTD traffic

Exploring in depth, it can be found that ZGMR which itself is a geographical routing protocol could not accompany fair resource provision for NRT traffic underwent more data loss. Our proposed GC-ZRP routing protocol exhibited maximum 92.01% of PDR, while ZGMR could achieve maximum of 89%. On contrary, VBS-ZRP could achieve merely 82% of PDR for NRT traffic. Though, a few works have been done by exploiting cross-layer concept to assess channel condition for selecting best relay node between source and destination over MANET communication; however, their efficacy is still inferior to our proposed GC-ZRP routing protocol. Though Adaptive Cross Layered Cooperative Routing Algorithm (ACCA) was a novel effort to exploit network channel condition for routing decision; however key node-features like packet velocity and cumulative congestion probability during movement could not be addressed. Even the possibility of contention and traffic sensitive resource allocation could not be done. These all limitations are alleviated in our proposed GC-ZRP protocol. These all features have augmented GC-ZRP to exhibit traffic sensitive resource allocation along with network condition aware routing decision. The robustness incorporated with GC-ZRP protocol have accomplished better performance than existing state-of-art techniques. Though, a few more efforts such as "Two-tiered service differentiation and data rate adjustment scheme for Wireless Multimedia Sensor Network (WMSN) cross layer MAC" [7][6] were made to enable traffic sensitive resource allocation for QoS achievement; however, these approaches focused mainly on delay centric communication. On contrary, GC-ZRP embodied enhanced SDFRS along with multiple network parameters based (dynamic) relaying strategies that cumulatively enables it to exhibit more reliable transmission in addition to the reduced deadline miss (Fig. 7). Fig. 6 exhibits the PLR performance for the NRT data traffic. Here, it can be observed that our proposed GC-ZRP protocol exhibits better PLR as compared to other routing protocols. The maximum drop observed for the NRT traffic is approximately 8%, 11% and 18% respectively by GC-ZRP, ZGMR and VBS-ZRP routing protocols respectively.

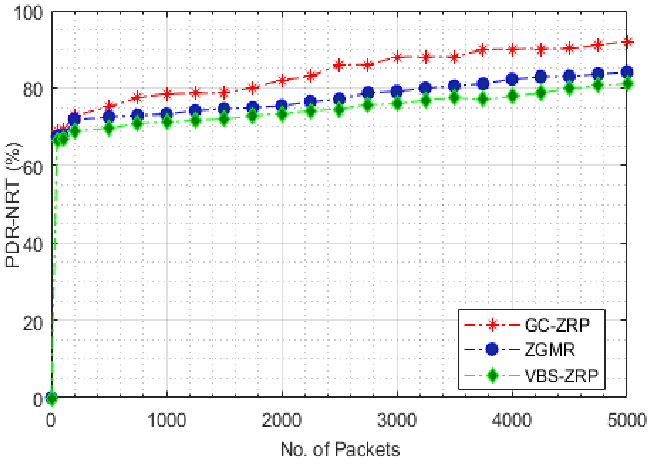

Fig. 5. PDR performance for NTD traffic

Assuring deadline sensitive communication by preserving minimum delay is of paramount significance for wireless communication systems. Even, it becomes inevitable for event driven MCC communication. As already stated, numerous efforts have been made to achieve higher QoS centric communication with low delay or latency. However, major existing works primarily focus on augmenting PDR by either efficient resource allocation measure of by avoiding link-outage probability.

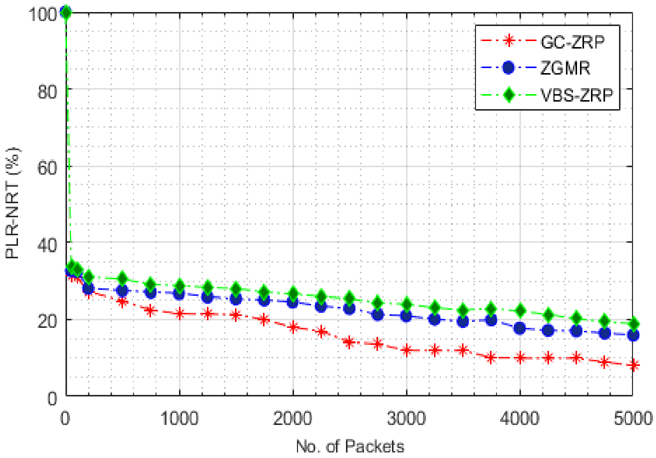

Fig. 6. PLR performance for NTD traffic

As per our knowledge not many efforts have been done to assess the suitability of a node for its maximum possible packet injection rate that could help enabling deadline sensitive transmission over MANET. Our proposed GC-ZRP routing protocol was armored with a novel packet injection rate or velocity estimation measure. A node with higher packet velocity was considered suitable as a relay or BFN that further helped in forming BFR to achieve QoS delivery. Such novel inclusion enabled our proposed GC-ZRP model to exhibit better deadline sensitive transmission. Fig. 7 reveals that the proposed GC-ZRP model performs minimum deadline miss performance than the other routing protocols.

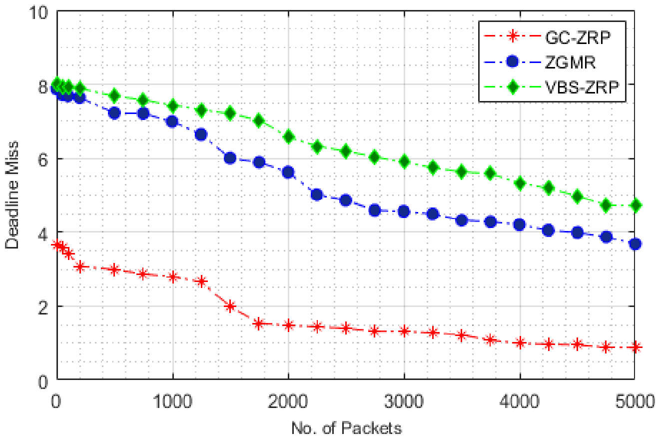

Fig. 7.Deadline Miss ratio performance

The above retrieved results do affirm that our proposed routing protocol achieves more reliable data transmission for both RTD as well as NRT traffic, which affirms its suitability for real-time communication demands. In addition, the deadline sensitive delivery too applauds GC-ZRP to be used in event driven communication purposes. The overall results obtained do signify suitability of the proposed GC-ZRP model to be used for Inter-Zone BFN or relay node selection method to achieve QoS centric communication over MANETs.

TABLE II. Comparison of the different existing approaches

Algorithm / References	Distance (Location)	Delay	Deadline	Velocity/Injection rate	LQE	(SD) Prioritizati	BW	Energy
LA-ZRP [22], [25]; MoZo [26], Greedy[31-33]; ZGMR[36]	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥
NEMA [27]	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟩
Resource Management[28][44]	🟥	🟥	🟥	🟥	🟥	🟥	🟩	🟥
VBS-ZRP [35]; ZGMR [36]	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥
ZGMR [36]	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥
OVBA-ZRP[38]	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟥
RMA/EDF[43]	🟥	🟥	🟩	🟥	🟥	🟥	🟥	🟥
Delay Sensitive[52]	🟥	🟩	🟥	🟥	🟥	🟥	🟩	🟥
Resource Management[53]	🟥	🟥	🟥	🟥	🟩	🟩	🟥	🟥
QoS [54]	🟥	🟥	🟥	🟥	🟥	🟩	🟩	🟥
Two- Tier SD [55]	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥
Energy Efficient Routing Protocol [56]	🟩	🟩	🟥	🟥	🟥	🟥	🟥	🟥
* GC-ZRP	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Notation	Yes	🟩				No	🟥	

Table II presents a snippet of the different existing protocols developed for zone-based routing as well as cross layer concept-based routing. Observing above comparison chart, it can be found that majority of the existing approaches has used single network parameter, or a few have applied two parameters to perform BFN selection or further routing decision. On contrary, our proposed GC-ZRP routing protocol has applied multiple network parameters to perform routing decision. It signifies robustness of the proposed routing approach over other state-of-art existing approaches. Summarily, the proposed routing model outperforms other approaches in terms of efficacy as well as robustness to meet QoS demands over MANETs. The research conclusion and allied future scopes are discussed in the sub-sequent section.

VI. CONCLUSION

Zone routing protocol being a hybrid routing approach requires highly efficient proactive network management capacity, especially for mobile networking solutions such as MANET. In such case developing a robust proactive network management strategy with (dynamic) network awareness capacity can be vital to assure reliable and QoS centric communication. The dynamic topology of a network can impose huge network parameter variations such as congestion probability, inter-node distance, link quality, residual energy, packet transmission rate of a node etc. Such variations might force network to undergo outage condition or data drop. Such events are often realized in ZRP based routing approaches, especially in inter-network communication.

To alleviate such problems in this paper a highly robust and novel Cross-Layer Architecture Based Geographical Network Condition Aware Zone Routing Protocol (GC-ZRP) was developed that exploited the features of the cross-layer network design and parameter sharing to perform optimal best forwarding node selection. Being a cross layer routing approaches GC-ZRP performed congestion detection and proactive node table management, service differentiation and fair resource scheduling at the network layer, packet velocity estimation and link quality estimation at the MAC layer that cumulatively performed to estimate best forwarding node so as to enable QoS centric communication over MANET. The deadline sensitive resource allocation features and multiple key parameters based BFN selection enabled optimal forwarding route selection for both real-time data as well as the non-real time data.

The simulation results revealed that the proposed GC-ZRP routing protocol achieves maximum packet delivery ratio of 98% for RTD data while maintaining approximate 92% of packet delivery ratio for non-real-time data. It signifies the robustness of the proposed multiple-network constraints based BFR selection and fair resource allocation strategies. The overall results affirm suitability of the proposed system for major real-time communication needs including Long-Term-Evolution (LTE) assisted D2D communication. Since, the current model focused on system level optimization with network, MAC and Application layers, in future a hybrid cross layer model can be developed to perform dynamic power control or management to achieve optimal resource allocation and energy efficiency.

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