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Beaconless Traffic-Aware Geographical Routing Protocol for Intelligent Transportation System

SADIA DIN[1], KASHIF NASEER QURESHI[2], M. SHEHERYAR AFSAR[2], JOEL J. P. C. RODRIGUES[3,4], (Fellow, IEEE), AWAIS AHMAD[5], AND GYU SANG CHOI[1], (Member, IEEE)

[1]Department of Information and Communication Engineering, Yeungnam University, Gyeongsan 38541, South Korea
[2]Department of Computer Science, Bahria University, Islamabad 44000, Pakistan
[3]PPGEE, Federal University of Piauí (UFPI), Teresina 64049-550, Brazil
[4]Instituto de Telecomunicações, 1049-001 Lisbon, Portugal
[5]Department of Computer Science, Air University Islamabad, Islamabad 44000, Pakistan

Corresponding author: Gyu Sang Choi (castchoi@ynu.ac.kr)

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ABSTRACT Intelligent Transportation System (ITS) in sustainable smart cities are taking advantage of moving vehicle nodes for data communication. VANETs support many applications related to safety, infotainment, and accident detection. The routing protocols are using for data communication in the presence of high mobility nodes and dynamic topologies. Due to high mobility and unpredictable topologies, the data communication becomes unreliable which causes data loss, delay, and link disconnections among vehicle nodes. To address these routing limitations, various types of routing protocols have developed. In all existing routing protocols types, geographic routing protocols are one of the efficient types due to its low overhead processes. Geographical routing protocols are able to handle vehicular environment constraints. However, with many advantages, geographic routing protocols are not considering many constraints of the vehicular environment. Geographical routing protocols should have well-defined routing metrics to deal with high mobility and other data loss and link disconnection issues. This research designs a Beaconless Traffic-Aware Geographical Routing Protocol (BTA-GRP) by considering traffic density, distance and direction for next forwarder node and route selection. The protocol is feasible for urban dense and sparse traffic conditions and addresses delay, disconnection and packet dropping issues. The proposed protocol has simulated with state of the art routing protocols. The simulation results indicated that the proposed protocol has higher performance in VANETs.

INDEX TERMS VANET, geographical routing, mobility, distance, ITS.

I. INTRODUCTION

Vehicular Ad hoc Network (VANET), enables the communication between vehicles with or without using any infrastructure which enables drivers to drive safely [1]. VANET has gained popularity among researchers because of its various different types of safety and infotainment applications. Designing of routing protocol that can accommodate high mobility environment is still a challenge. Due to high mobility and dynamic topologies, information becomes outdated which results in disconnection and packet dropping issues among vehicle nodes. These issues have been addressed by different routing protocols. Routing protocols have been characterized into different types such as table-driven or topology and geographic-based routing [2]. In topology-based routing, the information stores in routing tables. These protocols face data communication and delay issues. This type of routing is categorized into two types proactive and reactive. The proactive type has low delay because routes are known before the packets need to be forward. Proactive protocols have high overhead due to many rout e update requests. On the other hand,a reac-

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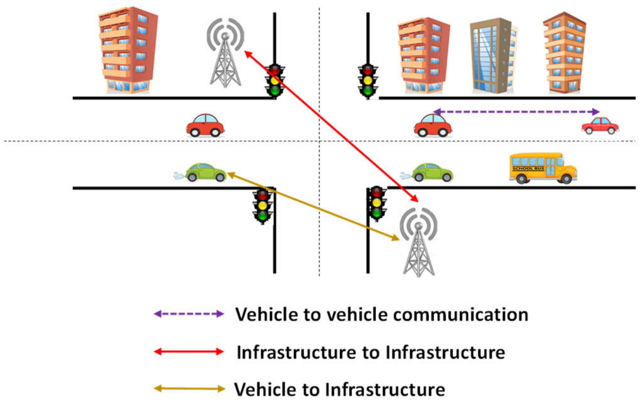

FIGURE 1. Vehicular ad hoc network overview.

tive protocols have high delay because the routes have to be discovered when the source node initiates the route request. Reactive protocols determine routes when there is data to send. Figure 1 shows the Vehicle-t-Vehicle, Vehicle-to-infrastructure and Infrastructure-to-Infrastructure communication.

Geographical routing protocols use neighbor nodes information only which are in its transmission range. Data forwarding in these types of protocols depends on node location information for data forwarding decisions. Hello, messages are used to find the position information of neighbor node in the beacon-based geographic routing protocol. The beaconless geographical routing protocol is based on modified control packets. Geographical routing protocols use Global Positioning System (GPS) information [3] for the exact information about the vehicle position. For dynamic topologies, geographic routing protocols are considered to be more feasible and efficient [2], [4], [5]. The basic idea of geographical type is evolved from GPRS (Greedy Perimeter Stateless Routing) [6]. GPSR uses two models particularly, the greedy and perimeter mode. When a data packet is delivered to the node which is closest to the destination it is called greedy mode. On the other hand, when greedy mode fails then protocols use perimeter mode. Various routing issues occur when the source node is near to the destination and its neighbors are far away from the destination. In such cases the protocol switches to the perimeter mode which uses the right-hand rule. All nodes send information to the neighbor's clockwise when they send the information in anti-clockwise, this mechanism is called the right-hand rule. The GPSR suffers from face routing issues and protocols are not working well in uneven traffic distribution. The GPSR only takes distance metric and does not consider direction metrics, which leads to wrong packet forwarding decision and increase packet loss.

Geographic source routing (GSR) [7], utilizes a limited way to forward the data towards the destination by using a digital map and not efficient due to the static map strategy. It does not take real-time traffic information while planning the path to the destination. GSR works well in a highly dense area due to its shortest path algorithm but the protocol does not work well in light traffic area. Improved Greedy Traffic-Aware geographic Routing (GyTAR) [8], uses speed, direction plus density as routing metrics for routing decisions. There are two modes of operations in this protocol: routing at the intersection and routing at the road segment. At road segment protocol reactively selects the neighbor intersection, when there is a the change in traffic density or distance to destination. GyTAR does not consider changes in the length of road segment in urban environment. This protocol uses traffic density as metric which is very costly in terms of bandwidth when beacon messages are exchanged. GyTAR stores the vehicle nodes information in routing tables.

Some intersection routing protocols like TARGET [9], selects the junction based on the destination junction position. If the packet is not delivered to the junction due to a link break between two junctions, then the packet came back to the source junction which causes computational complexity. IG [10], uses distance and link quality between vehicle nodes to transfer the data packets. IG also does not take direction metric which causes the face routing and protocol to suffer from low packet delivery ratio. CAIR [11], uses link quality, the direction of nodes, and traffic density as routing metrics. The greedy approach is used for data forwarding. When these metrics are taken in CAIR, the protocol leads to packet drop issues. For solving the aforementioned routing issues, geographical routing uses more appropriate routing metrics including vehicle direction, vehicle speed, road segment, traffic density, distance and intersections [12], [13]. With many advantages of geographical routing protocols, still protocols have packet delay, disconnectivity and throughput issues. To overcome these issues, we conduct this study to design a beaconless geographical protocol to handle the high mobility of vehicle nodes and changing the topologies of VANET. To achieve the main aim of this research by designing a new beaconless geographical routing protocol, the following are the main research objectives:

To design a geographical routing to improve the disconnectivity issues for an urban area, with low delay and high throughput.

To design a lightweight geographical routing protocol by considering more feasible routing metrics.

The rest of the paper is organized as follows: Section 2 presents the related work with discussion. Section 3 illustrates the proposed protocol design. Section 4 presents the experiment setup and results. The last section concluded the paper with a future direction.

II. MATERIALS AND METHODS

Various geographical protocols have designed which majority of those protocols are trying to achieve a minimum packet delivery ratio. The proposed protocols also target to attain low network overhead, low end to end overhead. This section presents a detailed overview of the protocols and discusses their issues or challenges.

Greedy Perimeter Stateless Routing (GPSR) [6], is a geographical based protocol developed originally for MANETs (Mobile ad hoc Networks). GPSR utilizes position data of one-hop neighbors and exchange beacons to make greedy forwarding towards the destination position. GPSR requires one-hop topology information and destination location to make a local forwarding decision. This protocol uses a greedy forwarding strategy to select the next forwarder as the progressively closest immediate neighbor to the final destination. Whenever the greedy method does not work then GPSR switches to recovery mode around the perimeter of the failing region. Like many other geographic routing protocols, GPSR does not specify a location service to obtain the destination position. GPSR performs well in high mobility networks like VANET and not required full path finding or maintaining operations. However, greedy routing in the VANETs causes multiple local minimum events where GPSR uses perimeter mode for recovery, in which a packet crosses from the planner subgraph of connected VANET until success a node that is near to destination than the position that the perimeter mode started at, where greedy forwarding is resumed. This causes a major increase in the number of intermediate forwarders and, accordingly, the end-to-end packet delivery delay.

GyTAR [8], takes real-time road traffic variation which includes vehicle speeds and directions plus intersection. GyTAR uses road segments and junctions as a road map. In GyTAR each cell is based on equal size. The protocol uses cell density packets (CDP) when a vehicle leaves the road. CDP is forwarded to another intersection through the anchors known as call centers. GyTAR works with two modules, routing at the junction and between two junctions. For junction selection, the source node determines the destination position and give the score to each junction in the network by considering the traffic density. Then the high score junction will be the forwarding junction. In GyTAR, every vehicle stores the neighboring table in which direction, position, and velocity information are stored. When beacon messages are exchanged, vehicle nodes update the information about vehicles in the neighboring table. In GyTAR, every node position is determined by receiving hello packets, thus node predicts the node distance toward the destination and selects the next-hop neighbor. The protocol uses to carry and forward strategy when the node is in local optimum issue. Each node carries the data packet until the node enters its transmission range. This protocol forwards the data packets from an adjacent intersection to the final destination. The protocol considers only adjacent intersections when forwarding decision is made at each intersection. This limited vision can cause routing of packets from unoptimized routes or causes of packets bounced back.

In order to address the node level routing challenge in the highly dynamic topology of VANETs, GSR [7] uses source position-based routing. By utilizing map information and planning the routes by the means of consecutive junctions, GSR overcomes the problem of traversing high intermediate forwarders presented in GPSR. GSR uses Dijkstra's algorithm to finds the shortest path between the source node and the destination node. The graph is extracted from the city road map with bidirectional edges representing roads, and graph-nodes representing road intersections. Data packets are transmitted between nodes which has complete route information from source to the destination node. Intermediate forwarders use greedy routing to select the next-forwarder in order to deliver the data packets independently to the next-junction indicated in their routes. Although GSR is using the shortest path algorithm, the connectivity of these paths is not ensured. GSR does not use statistical or real-time traffic information to rate the map while planning the path, which affects its performance. In dense networks and limited data traffic streams, GSR performs well and shows low delivery latency. However, in light traffic areas, GSR fails to discover connected routes and shows low packet delivery ratios. Moreover, as GSR applies static routing, it can easily cause data traffic congestions on some road segments.

As proposed in [9], traffic-aware geographic routing (TARGET), divides the nodes into two categories: junction node and ordinary node. Each junction has its own monitoring method which is responsible for communication with other nodes and shares traffic information with them. The number of vehicle nodes is calculated when two monitor nodes exchange detective packets. Data packets also store the forwarding node position information and count the number of nodes existing between two junctions. In TARGET, junctions are selected dynamically. Source node junction selection is selected on the basis of the source code. Whenever the source node is not located then it finds the shortest path using Dijkstra and selects the junction which is near to the destination. If the source node is at the junction, then the source node looks for the junction which is closer to the destination. If the monitor node does not receive any data packet from the neighboring junction in a specific time frame, the monitor node considers the link is broken and exclude the junction from the list.

Monitor nodes check if there is at least one junction which is closer to the destination among all other junctions, monitor node enters the greedy approach. If there is no junction closed to the destination node, then the protocol enters the perimeter mode. When junction has been selected then the packets are transferred greedily between the junctions. If data is not delivered to the junction, then the packet comes back to the last junction and monitor node marks that the junction unconnected. TARGET protocol has better data delivery because GPSR does not take traffic into account.

The first version of intersection based connectivity aware routing protocol (iCAR) is presented in [14]. The iCAR addresses the real-time packet delivery delay and traffic density and for each road. The iCAR combines real-time traffic information and static map for better performance in the city environment. iCAR sends control packets (CP) to calculate real-time traffic. The iCAR uses control packets to collect traffic density and connectivity. The iCAR is based on unicast routing and maintain connectivity by generating control packets at every intersection. In iCAR, when a node reaches the intersection, then the next road with high traffic density is selected which makes it suitable for urban areas. The iCAR has fewer data delivery delay issues because high traffic density results in a maximum number of hops.

Control packets (CP) are used in iCAR which uses for maintaining connectivity information at each intersection. The score has been assigned to each road segment and is exchanged between vehicles in the beacon message. CP is used to determine the vehicle information when it is traversed along the road and determine connectivity among the vehicle nodes. iCAR uses a greedy approach for data forwarding between two junctions. The nodes position is determined by the exchange of beacon messages, however, nodes can move out of each other transmission range which causes retransmission. This problem can be escaped by using the available forwarders node of the last report based on speed and position. If there is no forwarder node found, the protocol uses a store and forward approach to forward the data packets. The first version of connectivity aware routing protocol has the routing problem, the second version of connectivity aware routing protocol (iCARII) [15], addresses the routing problem by increasing delivery delay. Nodes in iCARII update their locations periodically. The protocol uses node to node beacon messages. Nodes use the roadside units and board units to access the internet.

Junction-based routing is proposed in [16], which exploits the junction nodes. The protocol uses the greedy forward approach for the junction nodes which are located near the destination. Nodes located at junctions are coordinator nodes and the nodes placed between the roads are simple nodes. The protocol broadcasts hello packets by every node in which coordinates of nodes are present. If the packet is not transmitted after some time then the entry for the node will be deleted and if a hello message is received after some time then the entry for the node in the neighbor's list will be updated. The selectively greedy method forwards the data packet by selecting the node which is farthest from the source node. If a packet has to be forwarded by a simple node then the node searches the neighbor list closer to the destination and divides the nodes into coordinator and simple node. If there are available coordinator nodes then they are queued priority wise. The protocol uses a distance metric to select the next-hop closets to the destination. When there is not any coordinator node then a simple node will forward the packet. The protocol suffers from packet delay issue because traffic density has not been considered as a metric which causes a maximum number of hops in the network.

RTS/CTS (request-to-send/clear-to-send) [17], is a four-way handshake method for session data transmission and designed based on CSMA/CA (DCF Carrier Sense Multiple Access/Collision Avoidance) based IEEE 802.11 protocol. The basic purpose of RTS/CTS frames to address the hidden terminal issue in VANETs. The hidden terminal issue refers to the area where more than one node is located to receive the packets and collision occurs. The control frames address the hidden terminal issue where the source node locates the communication channel for a specific time period and selects a random bakeoff timer. After receiving the packet, the receiver node acknowledges by CTS packets to all its neighbors. Afterward, the neighbor of the source node updates NAC (Network Allocation Vector) for the time interval. In this time interval, the neighbor nodes defer data until transmission session completion. After receiving CTS packets, the data transmission initiates. Last, the acknowledgment frame has completed the data transmission between the source and receiver nodes in the network.

As proposed in [18], intelligent beaconless geographical routing (IB) is infrastructure less protocol. Data packets are sent using a beaconless strategy. To forward the data packet, IB makes data forwarding decisions between or at an intersection. At the intersection, the packet carrier node sends RTS to all its neighbor's nodes to decide about data forwarding. The forwarding decision is based on three metrics: distance, signal strength, and direction. When the best intersection has been selected, the forwarder node tries to catches the channel between the intersections using direction and signal strength, the packet is being forward to the candidate node. When the best node accesses the channel, other nodes cancel their transmission. IB protocol suffers from variation in traffic density. In high traffic density, IB suffers from delays by increasing the number of vehicle nodes. If traffic density is low IB suffers from disconnectivity ratio and low packet delivery ratio.

In [11], CAIR is presented which is based on lower delay, the higher probability of connectivity, and uneven distribution of vehicles. The protocol uses topology, traffic, geographic and localization information. In CAIR, each node broadcasts a hello message, each node maintains its neighbor list and know its neighbor position. By exchange of neighbor list, every node may aware about it is a known intersection node or not. At the intersection, the node will broadcast a hello packet to update its neighbors. Based on the vehicle speed location information extracted from beacon messages, the forwarder node predicts its future location of its neighbors and takes the node greedily by considering the distance metric for data forwarding. CAIR uses the routing recovery method when there is no neighbor node near with destination. This is called the local maximum issue. The protocol uses a store-carry-forward policy to overcome this issue. Store-carry-forward method work in a way that node carries the packet along the road and forwards the packet when another node enters its transmission range.

Improved geographical routing protocol [10], establishes communication between vehicles. IG works in two modes; between the intersection and at the intersection. The protocol exchange beacon messages to know the position of the nodes. After the exchange of beacon messages, the relay node checks its location at the intersection or not. If it is between the intersections, then the source node computes the forwarding progress (FP). FP measures through computing the distance of source node and intermediate node towards the destination.

If an intermediate node has a higher value of forwarding progress, then the source node will select the intermediate node which is closer to the destination node. After computing FP, the source node computes the Beacon Reception Rate (BRR). BRR is used to determine link quality between two vehicles. It is measured by how many packets have been received and transmitted at some interval by the vehicle. Packet carrier node gives high value to the vehicles that move in a similar way. IG link quality, destination and link stability before sending the packet to an intermediate node. When the forwarder node reaches the intersection then distance and traffic are used for data forwarding. Distance and direction are taken as routing metrics when the node is at the intersection to forward the data packet. IG uses different metrics when a single metric is not useful in a harsh vehicular environment for packet forwarding.

VDLA [19], is based on a geographic routing protocol. Mostly geographic routing protocols forward the packet along the road and make routing decisions when the packet reaches the destination. The protocol makes routing decisions before a packet reaches the junction. VDLA also considers traffic density and load. By considering traffic density and network traffic load, VDLA prefers the path with low density and selects the path with the higher network connectivity. VDLA reduces the transmission delay by maintaining the network load along the paths. All the routing decisions are made before the junction in VDLA. The protocol decreases congestion by avoiding disconnected roads. VDLA uses Network Information Collection Packet (NICP) and transmits it from one node to another. NICP consists of a number of nodes, the entire length of the buffer queue, and total neighbors. NICP provides the shortest route in the network by calculating the weighting score for every adjacent road section vehicle node which reduces the network load if two nodes enter at the junction at the same time. To address the local maximum issue in VDLA, the protocol provide the optimal route in a network by recalculating traffic density in a network. Recalculation of traffic density has low data delivery. To overcome the overhead issue, the route lifetime and timer is necessary for VDLA.

As proposed in [20], a reliable beaconless routing protocol (RBRP) presents a self-adaptive scheme to forward the data packet. RBRP uses a beaconless routing strategy for data forwarding. To forward the data packet, the protocol takes distance, link quality, and a load of a node as metrics. The distance metric makes use of the normalization method used in VIRTUS [21]. The protocol uses link quality and distance as routing metrics. When link quality is not good, then the source will not send data to the candidate node and the protocol initiates the whole process again to forward the data packet. The protocol also takes the direction metric in which all nodes moving towards the destinations are considered and nodes moving in the opposite direction are discarded. The protocol does not take traffic density in to account which leads to increase the maximum number of nodes and increases network delay.

RSBR [22], aims to forwards the data from source to destination. The protocol predicts the network gap in a path earlier to increase system performance. The protocol selects the best route at the junction towards the next junction. Each road has ratings, which helps to find the best road between the junctions. The protocol assumes that every node has a routing table using GPS service to know their own location and forwards data to that vehicle which has the same direction as the destination. The protocol selects the road with the best road rating which helps to solve the network gap problem. TRSBR uses less number of nodes for data forwarding to the destination. The protocol initiates to start a short route using the Dijkstra algorithm. Then the source vehicle forwards the data to the nearest node. The protocol activates the Multihop communication when the source node reaches the junction and forwards the data to the static vehicle on the junction. As a static vehicle receives the data and forwards it by calculating road ratings. Road rating is calculated using the number of vehicle nodes and junction information. The road with fewer vehicles and low connectivity will have a high road rating and roads with more vehicles and strong connectivity will have low road ratings. The protocol selects the road with the low road rating.

The protocol uses a recovery phase to save the system from the network gap which is created between the junctions. A network gap can be generated in any direction. The road with the low road rating uses a network gap to forward the data in the same direction. The protocol presents a speed adjustment method for recovery to solve the gap issue. The protocol assumes that a vehicle moves with the constant speed between the junctions until some situation occurs, whenever the vehicle increases or reduces their speed. The sufferer vehicle forwards the data to the backward or forward vehicle when the vehicle has a greater speed than the sufferer vehicle. The protocol can be evaluated by calculating three metrics including delay, and network gap. The number of nodes is also used to decrease the network gap, the number of vehicles in the path increases then the network gap will be zero, with the increase of distance network gap will also increase. When the number of vehicle nodes increases the delay increases. The delay depends on the density of vehicle nodes and less number of vehicles can also generate network gaps.

As proposed in [23], the Greedy probability-based routing protocol for incompletely predictable vehicular ad hoc network (IPN) is a beacon-based protocol and take node speed and traffic density as parameters. IPN is not suitable due to an unpredictable vehicular environment. The networks in which node movements are limited and have known trajectories are called incompletely predictable VANET. So to route, the packet anti pheromone and the greedy algorithm is required in a vehicular network. In anti-pheromone, if route lengths remain constant and the source needs to send the data packet to different neighbors, then anti pheromone would choose the node which is less used. IPN has APh information added to ACK which indicates, how many times the node has been used to send the packet. Node with less APh is selected. IPN uses a selective greedy approach to select the next forwarder and take node density and distance into an account to forward the packet. IPN uses beacon messages to share nodes' information. IPN does not take direction into account so these types of protocol suffer from looping issues.

In [24] Beaconless Packet Forwarding strategy (BPF), was presented as a protocol that aims to modify handshake messages for better performance. The protocol takes distance and link quality as routing metrics. To update the node's location, beacon messages are exchanged in a network. In beaconless protocols, RTS/CTS has been modified for data forwarding. The protocol sends the source and destination address with RTS in its transmission range. The candidate node calculates the routing metrics: distance and link quality to forward the packet. The protocol prefers to select the border node which has better link quality as a forwarder node. When the relay node has been selected, then the relay node sends CTS to the source to sends the data packet. When the packet reaches to the relay node, the relay node initiates the same process to forward the data packet. BPF protocol does not take traffic density and direction as a routing metrics due to which BPF suffers from looping issue and disconnectivity issue as there will be two-way traffic and protocol suffers from packet delay issue. Traffic density should be considered in BPF so that protocol does not suffer from disconnectivity issues and the maximum number of hops due to minimum and maximum number of hops respectively.

In [25] Opportunistic Beaconless Packet Forwarding strategy (OBPF), was presented as a protocol that aims to packet delay and data delivery ratio. The protocol takes distance, direction, and link quality as metrics. OBPF is designed for intercommunication between vehicles and does not use and road infrastructure to communicate between the vehicles. OBPF takes routing decisions at or between intersections. OBPF modifies the RTS message with source and destination nodes address and add a flag which determines the position of the nodes at or between intersections. If the node is at the border or located near the destination and has the good link quality and its moving direction towards the destination node, then it will be selected for the relay node. If no node satisfies the criteria, then it will be selected as a relay node. OBPF suffers from a disconnection issue if nodes are very far or located at the border as the protocol does not take traffic density metrics. The protocol also suffers from a maximum number of hops issues as there will be an area where a large number of nodes exist so the number of hops required to forward the data packet will increase which will result in an increase of packet delay.

In [26], CISRP is presented which uses distance, traffic density, and vehicle speed to forward the data packet. This protocol calculates the average distance between nodes and a closer distance node is selected. CISRP computes the average velocity of all the vehicle nodes in its communication range and takes its average. The node which has its velocity closer to the average velocity will be selected. CISRP takes traffic density into account, neither at nor between intersections. The negligence of this metric cause the maximum number of hops issue and link failure issue which affects the packet delay and the packet delivery ratio. CISRP also suffers from the face routing issue due to two-way traffic as a distance metric is not considered.

A. DISCUSSION

Various geographical protocols have been presented as it is delineated in Table 1, and they are using different metrics to evaluate their performance. Due to the dynamic topology, geographical routing metrics should have well-defined routing metrics to handle high mobility and disconnection issues. Three important metrics for geographical routing are traffic density, direction, and distance. The protocols which do not consider distance suffer from outdated information and link failure as node go out of the reach when communication starts. The direction metric is very useful in evaluating geographical routing protocols as nodes which do not consider direction face looping issue. The protocols which are not considering traffic density metric, they suffer from a maximum number of hop issue due to dense network and link failure issue when there is sparse traffic in the network.

III. BEACONLESS TRAFFIC-AWARE GEOGRAPHICAL ROUTING PROTOCOL FOR ITS

The proposed Beaconless Traffic-Aware Geographical Routing Protocol (BTA-GRP) addresses the staleness issue of geographical routing protocols in VANETs. This chapter presents the complete design of the proposed protocol using RTS/CTS control packets. The RTS/CTS packets have been modified based on appropriate routing metrics for the selection of the next node in the network. BTA-GRP uses RTS/CTS modified frames to perform data routing in the urban VANETs environment. We have some assumptions to test the proposed protocol in simulation such as all the vehicle nodes are equipped with GPS systems and vehicle nodes also aware of the digital map. In the digital map, the vehicle nodes position, coordinates of intersections, and road segments. The proposed routing protocol is based on three metrics, distance, direction and traffic density in the networks.

A. DISTANCE

Distance has considered one of the important metrics for design a geographical routing protocol. In this type of routing, the packet carrier node routes the data using source and destination position information. This type of method is also called greedy packet forwarding. The greedy forwarding is based on the distance metric in which nodes that are located at the border is selected within its communication range. If, there is no node available on the border then, this type of protocol faces delay or disconnection issues. The proposed BTA-GRP uses distance as one of the metrics because distance has less or more among vehicle nodes. By distance, the proposed protocol measures the distance of nodes which are not very far or not very near. This is a well-known fact that when the distance is short between vehicle nodes then the number of

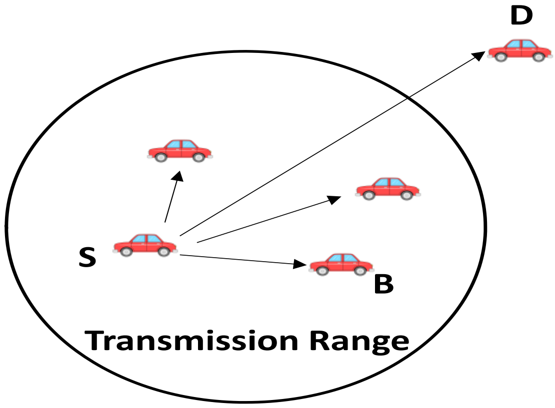

FIGURE 2. Distance calculation.

hops will increase. When the distance is more than the link failure probability increase. In order to address this issue, the proposed protocol selects the node which is located with maximum distance. This matric increases the reliability of packet forwarding in VANET. The position of vehicle nodes is known through GPS services. For distance calculation, the Pythagoras theorem is used as shown in Figure 2.

In Figure 2, the distance is calculated where node A denotes as a source, and node D denotes the destination in the network. After the distance calculation, the node B is selected with maximum range vehicle node for data forwarding. The distance evaluates and prefers maximum distance vehicle node within the source communication range. The distance metric is calculated in Equation 2.

$$Distance = max\left[\log\left(\frac{SD}{SN}\right)\right] \quad (1)$$

In Equation 2, the Distance calculated and the maximum distance evaluates between the source node to Destination (SD) and Source node to Neighbour Nodes (SN).

B. DIRECTION

After distance calculation, the second metric is direction. Without direction metric, the protocols face looping issues because traffic is multidirectional in VANET. The direction is a more suitable routing metric for stable and reliable routing. The direction of the vehicle node is constrained by the roads. In a straight highway environment, the vehicles move in the same or opposite direction. The BTA-GRP selects the direction of the source node to the destination because, in VANET, all vehicle nodes are aware of its own and neighbor nodes' direction. So the proposed protocol first checks the distance of the neighbor node and selects the maximum distance node then selects then checks the direction of the selected node and sends a data packet to the node which is moving towards the destination. The direction based method of the proposed protocol shows in Figure 3, where the line shows the direction of nodes towards the destination. At the first stage, the source vehicle node calculates the angle O = DSA which is made between the vectors of neighbor nodes vector SD and AD. After the angle of neighbor calculation, the vehicle node which has the smallest angle towards the destination is selected for data forwarding. This process will continue until the data packets will reach the destination in the network.

The direction is calculated in Equation 4, where the direction weight value factor is calculated with travel vehicle direction $(\overrightarrow{Direction_n})$ and direction of packet transmission $(\overrightarrow{Direction_{packettransmission}})$.

$$Direction_{WeightValue} = \left[(\overrightarrow{Direction_n}, \overrightarrow{Direction_{packettransmission}})\right] \quad (2)$$

Forwarder Vehicle Node Address	Next Forwarder Vehicle Node Address
Traffic Density ($T_{Density}$)	Duration timeline ($D_{Timeline}$)
Number of hops	
Original flag	Time stamp

FIGURE 3. CP packet structure.

C. TRAFFIC DENSITY

The traffic density metric is initiated when the source node reaches to intersection area, then the source node collects the traffic status and then forwards the data to the destination or next intersection. At intersections, the Road Side Unit (RSU) is used to update the traffic status and broadcast Collector Packet (CP) within the range of intersection using a digital map for traffic density information.

CP packet uses for traffic and network status and contains some information or fields as shown in Figure 3. The first field has to hold the forwarder node address. The second field has the next forwarder address at the intersection which is assigned by RSU for forwarding the data further. The next field is about vehicular density information Traffic density (density) which has an accumulative number of vehicles located on the roads or moving on roads. The proposed protocol uses direction metric that's why the source node neglected the opposite direction vehicle nodes. RSU already has all the road IDs through the digital map in the network.

The CP also has a Duration Timeline (DTimeline) which refers to a duration that remains until the next update. This time is set based on the estimated period of time where a network disconnection is expected to occur. CP packet also has a number of hops section, original flag section which makes differentiate with normal beacon and CP message. The last field is the time stamp for registration the generation time of CP.

After receiving the CP packet from RSU, the candidate vehicle node calculates the traffic density to select the next forwarder node towards the destination. The candidate node initiates the received values from CP and calculates the road density using Equation 3.

$$\mathrm{TD_{Value}} = \frac{2 * \mathrm{T_{Density}}}{3 * No.of\ vehicle\ nodes * N_{con}} \quad (3)$$

$$TDV = \left\{ \begin{array}{c} \frac{1}{\mathrm{TD_{Value}}} \mathrm{TD_{Value}} > 1 \\ otherwise \end{array} \right\} \quad (4)$$

The candidate node selects the higher density road because it has a high data delivery ratio and less delay as discussed in [27]. Therefore the proposed protocol selects a higher weighting factor which is equal to $\frac{2}{3}$ given for $\mathbf{T_{Density}}$. Equation 4 shows that roads with higher traffic density and $\boldsymbol{N_{con}}$ shows a constant connectivity degree. Based on Equation 5, if the $\mathbf{TD_{Value}}$ is higher than requirthe ed density the Traffic Density Value (***TDV***) parameter scaled to 1, otherwise TDV is in the range 0.0, 10.0 based on Equation 4.

D. SCORE FUNCTION FOR ROUTING DECISION

After an explanation of the routing metric, this section presents the score function for the routing decision. The candidate (Source) node calculates the distance and direction between two intersections by calculating the score function. The first metric is the distance, where the maximum distance vehicle node is selected as a next forwarder. The progressive distance toward the destination is one of the significant routing metrics in the geographical routing protocol. The next routing metric is the direction towards the destination where the next forwarder select only which is moving towards the destination to avoid looping issues. Equation 5shows the distance and direction weighting factor score, respectively.

$$Next\ Forwarder\ Score = \alpha_1 + \alpha_2 \quad (5)$$

In above Equation 6, the weighting factors for distance and direction indicators and the factors must be equal and the calculated next forwarder vehicle score is 1, 0, and all values in this range. This value is calculated and send through the CTS control packet to the source node. Then the source node selects the next forwarder on the basis of this scope.

When the source node reaches an intersection, then it receives the CP packet. The CP packet is calculated as showed in Equation 3 and 4. Then select the next road towards the destination and again the first metrics (Distance and Direction) calculation initiated.

E. ROUTING PROCESS

The proposed routing protocol BTA-GRP adopts RTS/CTS control packets for the nodes which are located at or between intersections. When the node reaches the intersection then from RSU, the source node again determines the traffic density and selects the road with maximum vehicle nodes towards the destination. For the first process, the source vehicle node calculates the distance of neighbor nodes that are in its transmission range and selects the node which has more time to leave the transmission range and address the greedy forwarding issues in the network. The second routing metric is the direction that is used to avoid looping problems due to bi-directional vehicle nodes traffic in urban areas. By direction metric, the source node neglects the opposite direction vehicles and selects the vehicle as a next forwarder which direction towards the destination node. These routing metrics support the source node between two intersections. An intersection is an area where different roads are linked to different destinations. At the intersection, another important route decision is needed to avoid the packet dropping due to more traffic and fewer traffic situations. In urban areas, the RSU is available at intersections to update the traffic conditions based on the map segmentation method, where they count the vehicle nodes and this information is broadcasted through short messages to the intersection area vehicle nodes. The proposed protocol adopts this method and selects the next road which has maximum vehicle nodes and improves packet throughput and delivery. Basically, the proposed protocol overcomes the beaconing by using RTS/CTS control packets and improve data delivery and decrease the network overhead. Through traffic density updating, the proposed protocol improves data delivery and delay issues. The next section illustrates the proposed protocol flowchart and algorithm. In the CTS packet, the metric score function value is added to imitate the routing decision in the network.

F. PROPOSED PROTOCOL FLOWCHART AND ALGORITHM

The below Figure 4 shows the flowchart of the proposed protocol routing process at or between intersections. The dotted rectangles show the proposed protocol process at the intersection and between two intersections.

Algorithm 1 shows the process line by line where line 1 indicates that the source node broadcasts the RTS frame instead of beacon messages. After RTS the protocol checks the source node position by intersection flag and if it is 1 then initiated the further process. Upon receiving the RTS packets by neighbor nodes of the source node the distance and direction have calculated as shown in line no 4, 5, and call the score function and weight the values to select the next forwarder. When the source node is at the intersection area, then it will check the traffic density updates through RSU as shows in line no 8, 9. In the last protocol broadcast the CTS packet and start data forwarding in the network.

IV. PERFORMANCE EVALUATION

The selection of simulation is a very important factor to analyze and validate the research objectives. In this study, the NS-2.34 is used with a mobility generator (MOVE). The NS-2.34 was developed in 1981 as an event-driven an open-source simulator. The simulator supports network and MAC layer operations. It provides the user executable TCL scripts as an argument. A simulator trace file is generated after the execution of the TCL file, and it is used to plot graphs for animations. Further, the simulator provides a tool called NAM (Network Animator) to execute animation files having an extension NAM file. NS-2.34 working with two languages OTcl (Object-oriented Tool Command Language) and C++. C++ provides a user facility to define internal

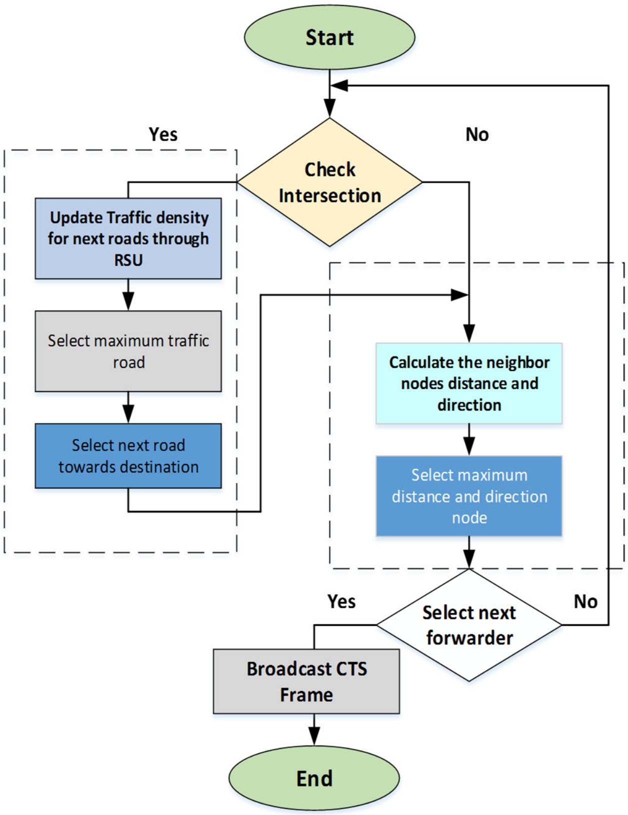

FIGURE 4. Flow chart.

Algorithm 1 Routing process of BTA-GRP

Broadcast RTS frame to neighbor nodes
If RTS received then
If*Intersection check=1* **then**
    determine Distance
    determine Direction
    Call score function
Else
    Receive traffic density update from RSU
    Calculate the maximum traffic density
end if
    Broadcast CTS frame
end if
end if

working mechanisms (executed at the backend) of the simulations objects, while OTcl provides facility to setup simulation scripts and configurations of objects (executed at the front end), and discrete events [28].

A. SIMULATION SETUP OF PROPOSED PROTOCOL

In this section, the simulation setup-in is presented to evaluate the proposal Beaconless traffic-aware geographical routing protocol (BTA-GRP). The simulation parameters are as following:

- Physical Layer: The simulation setup of the physical layer is based on the Nakagami radio propagation model to determine the fading features of wireless channels among vehicles (Nakagami, 1960). According to [29], this data is more realistic for data output and feasible for real-time vehicular communication. Furthermore, all vehicles are communicating with a default radio coverage of 300 meters.
- Mobility and Traffic Model: The speed of vehicle nodes is set to 40-70 km/h with a rectangular area 3,968 * 1251 m. Washington DC, USA, a map is used with 370 road segments and 124 intersections [30]. The Constant Bit Rate (CBR) is a source of simulation [31]. The vehicular density varies from 100 to 350 vehicle nodes and beaconing is set with 0.5-second intervals.
- Network and Media Access Control Layers: The radio range is set with 300 m and packet size 512 bytes, 2MB/s data rate [32], [33]. IEEE 802.11 is used for the MAC layer with 3 Mbps channel bandwidth [34]. Furthermore, in the simulation, the process of packet forwarding continues until the packet reaches a destination or pass over 10 hops (TTL = 10 hops)
- Simulation Time: The time for simulation is set at 500s for each round, where the settling time is set at 40 seconds to avoid the transmit behaviors from the results. The confidence interval is set 95%.

The BTA-GRP is evaluated with two routing protocols Intelligent Beaconless protocol (IB) and Incompletely Predictable Vehicular Ad hoc Network (IPN) for evaluated the protocol performance. The detail of metrics are as following:

- Packet Delivery Ratio (PDR) shows the ability to successfully transmitting data packets between the source and destination.

Network delay presents the complete time of data transmission from source to the destination node. Table 1 delineates simulation parameters.

B. NUMBER OF NODES ANALYSIS

The first experiment is with a number of vehicle nodes to analyze the data delivery ratio of the proposed routing protocol and compared the results with one beaconless Intelligent Beaconless (IB) [18] protocol and one beacon-based Greedy Probability-Based Routing Protocol for Incompletely Predictable Vehicular Ad-hoc Network (IPNs)... [23]. The IB protocol is beaconless but only considers distance, direction, and signal strength and neglected the traffic density metric, which is one of the important metrics for the nodes located at the intersection. On the other hand, the IPNs protocol is prediction based protocol and due to the unpredictable VANET environment and not suitable for VANETs.

Figure 5 shows the Packet Delivery Ratio (PDR) in accordance with a different number of vehicle nodes in the network. The figure shows the trend that BTA-GRP has increased data delivery consistently due to increasing connectivity probability with more vehicles in dense networks.

TABLE 1. Simulation parameters.

Parameters	Values	Parameters	Values
Traffic Type	CBR	Simulation Time	500s (each round)
MAC protocol	IEEE802.11 p	Mobility model	MOVE
No of Vehicle Nodes	100 to 350	Vehicle speed	40-70 km/h
Packet Size	512 bytes	Antenna Model	Omnidirection al
Transmissi on Range	300 m	Intersectio ns	10
The total area of simulation	3500 × 3500 m2	Propagatio n model	Nakagami radio propagation model

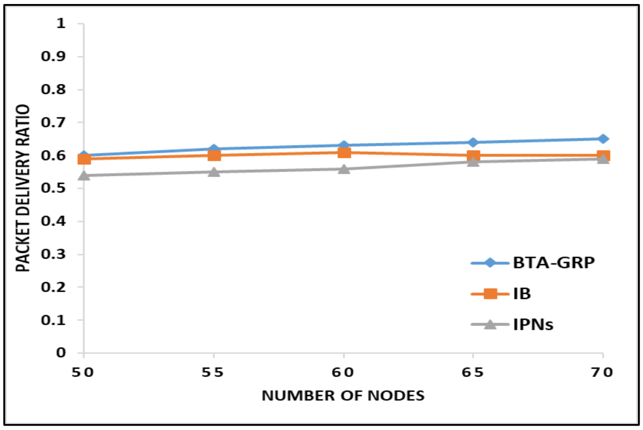

FIGURE 5. Packet delivery ratio with the number of nodes.

In addition, when the number of nodes reaches 60, the proposed protocol trend becomes flat due to RTS/CTS handshaking method. The existing beaconless routing protocol IB has better results than IPN because of the RTS/CTS mechanism. The IPNs protocol is based on greedy forwarding and prediction mechanism which is not suitable for VANET. This is the main reason that IPN is behind IB and BTA-GRP.

Figure 6 illustrates data delivery with more number of nodes. The results indicate the better results of the proposed protocol compared to existing beaconless and beacon-based routing protocols. The proposed BTA-GRP protocol data delivery ratio has increased more due to increasing connectivity probability with more traffic density in the urban environment. In addition, when the number of nodes reaches 80 and 85 the PDR has increased. These results are because of controlling the handshaking mechanism (RTS/CTS), the trend of existing beaconless protocol IB also has better results compared to IPNs due to its beaconless strategy. The IPNs protocol has a minor difference compared to IB due to its mechanism support in more traffic density where protocol predicts easily to find the next forwarder in the network.

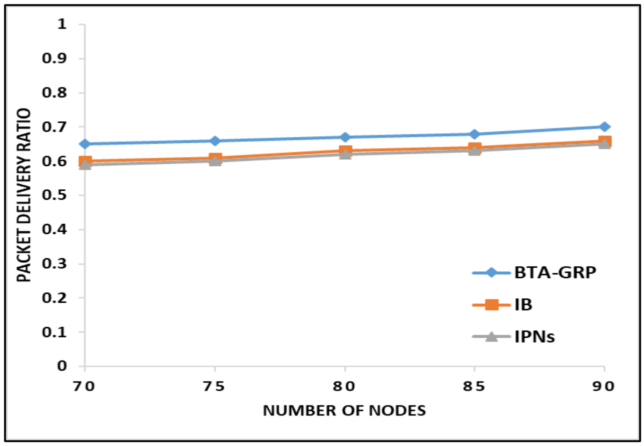

FIGURE 6. Packet delivery ratio with the number of nodes.

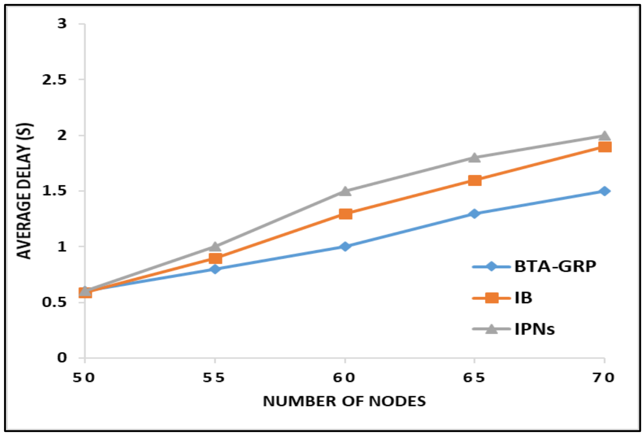

FIGURE 7. Average delay with the number of nodes.

Another performance metric has been analyzed that is an average delay as shown in Figure 7. The average delay of proposed protocol BTA-GRP consistently increased due to its routing metrics calculations and waiting time of CTS packets. However, the existing protocols have more delay compared to the proposed protocol. This result also indicated that both the beaconless protocol has less delay compared to beacon-based protocol because more traffic has more beacon overhead and the next forwarder selection is difficult. The IB protocol steeply increased the delay because at the intersection, this protocol initiates the decision based on distance, direction, and signal strength. Although, sometimes the more congested road nodes have strong signal strengths but have more delay due to the number of vehicle nodes. The proposed protocol address this issue by selecting the maximum traffic density road at the intersection.

Figure 8 shows the average delay analysis with more number of nodes. These results indicate that the proposed beaconless BTA-GRP protocol has better results compared to IB and IPN protocols. Whenever the traffic density is high in the network the delay is more due to various nodes. Compared to beacons based IPNs protocol, the beaconless IB and BTA-GRP have less delay because more traffic has

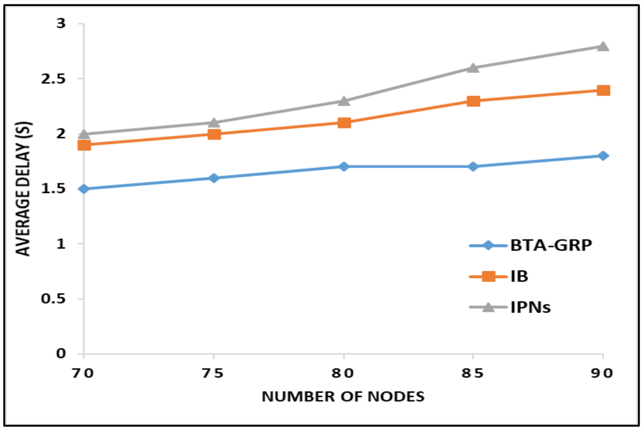

FIGURE 8. Average delay with the number of nodes.

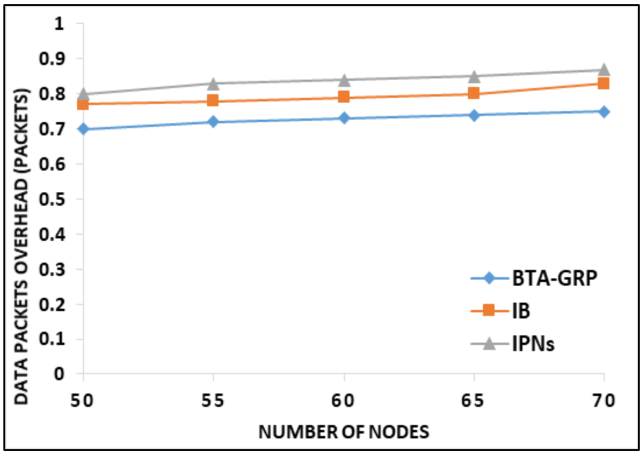

FIGURE 9. Data Overhead with the number of nodes.

more beacon overhead and the next forwarder selection is difficult. The IB protocol steeply increased the delay because, at the intersection, this protocol initiates the decision based on distance, direction and signal strength. Although, sometimes the more congested road nodes have strong signal strengths but have more delay due to the number of vehicle nodes. The proposed protocol address this issue by selecting the maximum traffic density road at the intersection.

Figure 9 shows the data overhead analysis with more number of nodes. These results indicate that the proposed beaconless BTA-GRP protocol has better results compared to IB and IPN protocols and has less overhead. Whenever the traffic density is high in the network the overhead is more due to various nodes. Compared to beacons based IPNs protocol, the beaconless IB and BTA-GRP have less overhead because more traffic has more beacon overhead and the next forwarder selection is difficult. The IB protocol steeply increased the overhead because, at the intersection, this protocol initiates the decision based on distance, direction and signal strength. Although, sometimes the more congested road nodes have strong signal strengths but have more overhead due to the number of vehicle nodes. The proposed protocol address this issue by selecting the maximum traffic density road at the intersection.

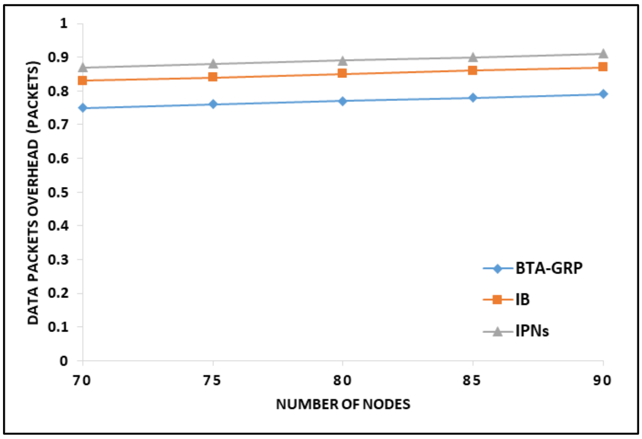

FIGURE 10. Data Overhead with the number of nodes.

Figure 10 shows the data overhead analysis with more number of nodes. These results indicate that the proposed beaconless BTA-GRP protocol has better results compared to IB and IPN protocols and has less overhead. Whenever the traffic density is high in the network the overhead is more due to various nodes. Compared to beacons based IPNs protocol, the beaconless IB and BTA-GRP have less overhead because more traffic has more beacon overhead and the next forwarder selection is difficult. The IB protocol steeply increased the overhead because, at the intersection, this protocol initiates the decision based on distance, direction and signal strength. Although, sometimes the more congested road nodes have strong signal strengths but have more overhead due to the number of vehicle nodes. The proposed protocol address this issue by selecting the maximum traffic density road at the intersection.

C. VEHICLE SPEED ANALYSIS

This section shows the results based on vehicle node velocity in terms of packet delivery ratio and the average delay in the network. Figure 11 shows the data delivery ratio of the BTA-GRP, IB, and IPNs routing protocols. A prompt result is that the vehicle speed cause of low PDR in the network. However, the proposed BTA-GRP has better results due to the removal of beacon messages and add RTS/CTS handshaking method for routing decision. This mechanism also helps to reduce the consumption of bandwidth and less memory to store the neighbor node information. In addition, the multi-metric protocol supports the protocol to select the appropriate next forwarder node for data delivery towards the destination. On the other hand, the IB protocol has one mechanism where this protocol determines the distance, direction and signal strength between two intersections and at the intersection. In addition, the IPNs protocol uses prediction which leads to packet dropping issues. The high speed also causes of staleness of neighbor node information. The result shows that the proposed protocol even has a better packet delivery ratio when the vehicle nodes speed set to 35 and 40 respectively.

Figure 12 shows the PDR analysis in the presence of different vehicle speeds. As per the previous graph, again the

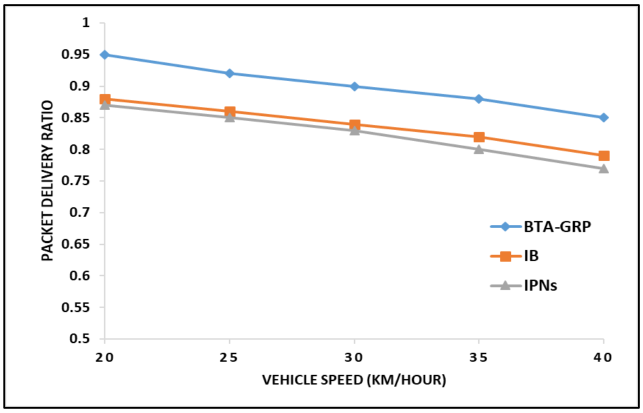

FIGURE 11. Packet delivery ratio with vehicle speed.

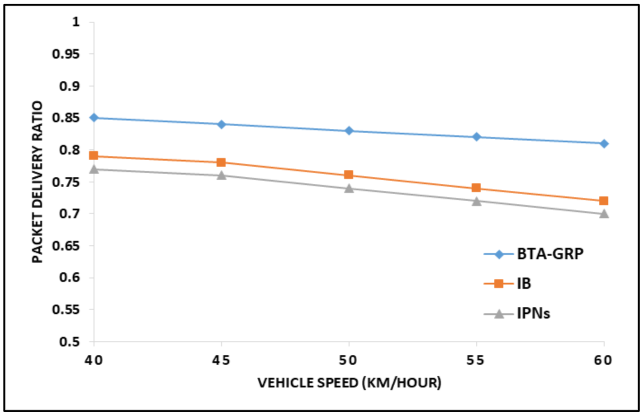

FIGURE 12. Packet delivery ratio with vehicle speed.

proposed protocol BTA-GRP has better results compared to IB and IPNs protocols even when the vehicle velocity reached 55 and 60 km/hour. Basically, the PDR decreasing trend indicates that the vehicle speed cause of low data delivery in the network but BTA-GRP still has better results due to the removal of beacon messages for next forwarder node selection. The beaconless strategy supports to consume less bandwidth compared to beacon-based routing protocols. The IB protocol also has fewer packet drops compared to IPNs due to its multi-metric and beaconless strategy. In addition, the IPNs protocol uses prediction which leads to packet dropping issues and that's why the graphs show when the vehicle speed reaches 55 and 60, the protocol suffers from packet delivery ratio. In addition, the high speed also causes of staleness of neighbor node information. The result shows that BTA-GRP has better results when the vehicle nodes speed set between 40 to 60 in the network.

Figure 13 shows the average delay results with vehicle speed analysis. The results indicate that the proposed beaconless BTA-GRP protocol has less delay compared to IB and IPNs. Whenever the vehicle speed reaches 35 and 40 the delay is more due to the high velocity of nodes where the information is outdated and the next forwarder selection is difficult. Compared to beacons based IPNs protocol, the beaconless IB and BTA-GRP have less delay. The high velocity

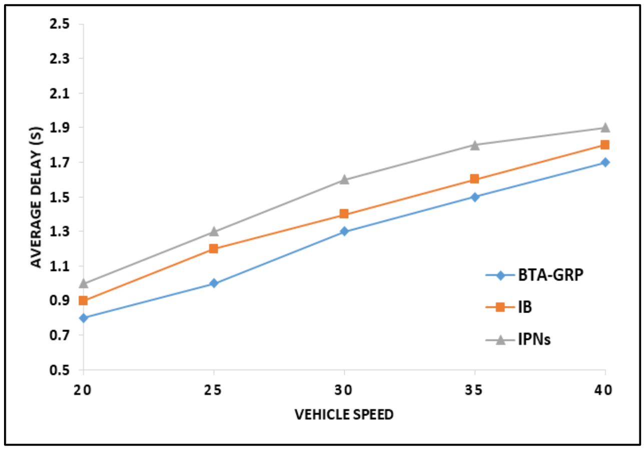

FIGURE 13. Average delay with vehicle speed.

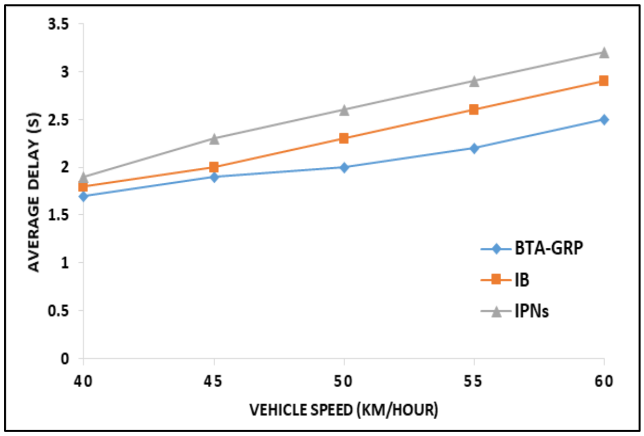

FIGURE 14. Average delay with vehicle speed.

has more chances for packet dropping. On the other hand, the IB protocol steeply increased the delay because, at the intersection, this protocol initiates the decision based on distance, direction and signal strength. Although, sometimes the more congested road nodes have strong signal strengths but have more delays due to high speed. The proposed protocol address this issue by selecting the maximum traffic density road at the intersection.

The graph Figure 14 shows the delay trend with more vehicle velocity in the urban environment. The proposed routing protocol BTA-GRP has better results in terms of delay compared to IB and IPNs even though the vehicle speed is set at 40 to 60 km/hour. The proposed protocol is the best option for urban areas where the vehicle speed at a normal level. On the contrary, the existing protocols have suffered when the vehicle speed increases in the network. The beaconless protocols (IB and BTA-GRP) have less delay compared to IPNs because the high speed of vehicle nodes leads to packet dropping and protocols again check the neighbor node information to initiates the routing decision. On the other hand, the IB protocol steeply increased the delay because, at the intersection, this protocol initiates the decision based on distance, direction and signal strength. Although, sometimes

TABLE 2. Results comparison of BTA-GRP, IB, and IPNs.

Packet Delivery Ratio				Average Delay				Network Overhead			
No of Sensor Nodes	BTA-GRP	IB	IPNs	No of Sensor Nodes	BTA-GRP	IB	IPNs	No of Sensor Nodes	BTA-GRP	IB	IPNs
50	0.6	0.59	0.54	50	0.6	0.59	0.6	50	0.7	0.77	0.8
55	0.62	0.6	0.55	55	0.8	0.9	1	55	0.72	0.78	0.83
60	0.63	0.61	0.56	60	1	1.3	1.5	60	0.73	0.79	0.84
65	0.64	0.6	0.58	65	1.3	1.6	1.8	65	0.74	0.8	0.85
70	0.65	0.6	0.59	70	1.5	1.9	2	70	0.76	0.83	0.87
75	0.66	0.61	0.6	75	1.6	2	2.1	75	0.77	0.84	0.88
80	0.67	0.63	0.62	80	1.7	2.1	2.3	80	0.78	0.85	0.89
85	0.68	0.64	0.63	85	1.7	2.3	2.6	85	0.79	0.86	0.9
90	0.7	0.66	0.65	90	1.8	2.4	2.8	90	0.76	0.87	0.91
Vehicle Velocity	BTA-GRP	IB	IPNs	Vehicle Velocity	BTA-GRP	IB	IPNs	Vehicle Velocity	BTA-GRP	IB	IPNs
20	0.8	0.9	1	20	0.6	0.59	0.6	20	0.7	0.77	0.81
25	1	1.2	1.3	25	0.8	0.9	1	25	0.71	0.78	0.82
30	1.3	1.4	1.6	30	1	1.3	1.5	30	0.72	0.79	0.83
35	1.5	1.6	1.8	35	1.3	1.6	1.8	35	0.73	0.8	0.84
40	1.7	1.8	1.9	40	1.5	1.9	2	40	0.74	0.81	0.85
45	1.9	2	2.3	45	0.6	0.59	0.6	45	0.75	0.82	0.86
50	2	2.3	2.6	50	1.6	2	2.1	50	0.76	0.83	0.86
55	2.2	2.6	2.9	55	1.7	2.1	2.3	55	0.77	0.84	0.87
60	2.5	2.9	3.2	60	1.7	2.3	2.6	60	0.78	0.85	0.88

the more congested road nodes have strong signal strengths but have more delays due to channel congestion.

After evaluating the proposed protocol BTA-GRP with state of the art existing routing protocols, Table 2 presents the difference of results and protocols comparison.

Figure 15 shows the data packets' overhead trend with more vehicle velocity in the urban environment. The BTA-GRP has better results in terms of network overhead compared to IB and IPNs even though the vehicle speed is set at 40 to 60 km/hour. The proposed protocol is the best option for urban areas where the vehicle speed at a normal level. On the contrary, the existing protocols have suffered when the vehicle speed increases in the network. The beaconless protocols (IB and BTA-GRP) have less overhead compared to IPNs because of their RTS/CTS mechanism. The IB protocol steeply increased the overhead because at the intersection, this protocol initiates the decision based on distance, direction and signal strength. Although, sometimes the more congested road nodes have strong signal strengths but have more delays due to channel congestion.

The last graph Figure 16 shows the data packets' overhead trend with more vehicle velocity in the urban environment. The BTA-GRP has better results in terms of network overhead compared to IB and IPNs even though the vehicle speed is set at 40 to 60 km/hour. The proposed protocol is the best option for urban areas where the vehicle speed at a normal level.

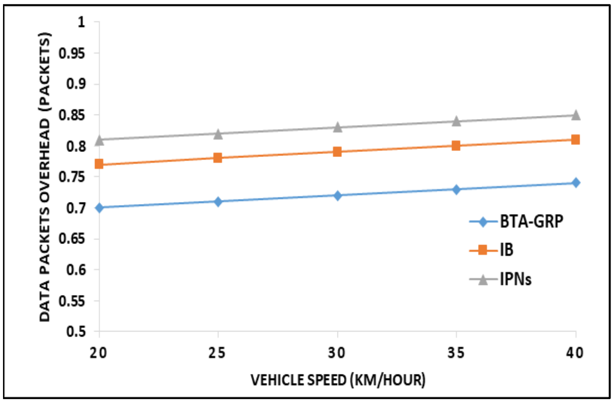

FIGURE 15. Data packets overhead with vehicle speed.

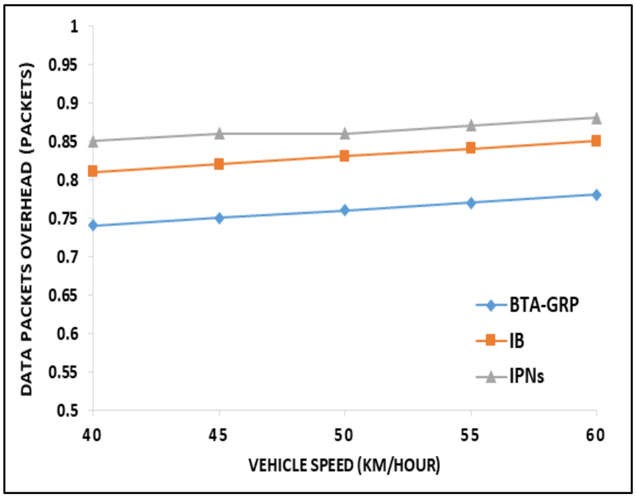

FIGURE 16. Data packets overhead with vehicle speed.

On the contrary, the existing protocols have suffered when the vehicle speed increases in the network. The beaconless protocols (IB and BTA-GRP) have less overhead compared to IPNs because of their RTS/CTS mechanism in the network.

After evaluating the proposed protocol BTA-GRP with state of the art existing routing protocols, Table 2 presents the difference of results and protocols comparison.

V. CONCLUSION

In this work, an efficient routing protocol has been presented for VANETs with minimum overhead. The main challenges involved in designing efficient, stable, robust routing protocol has been addressed and resolved. An extensive study of existing routing protocol has been done in terms of their operation, framework and limitation. Modifications in the existing routing techniques have been made and new routing protocol has been developed with an objective to resolve the following limitations: Disconnectivity issue for urban areas due to dynamic topology, minimize delay in the geographical routing protocol, Improve data throughput in the geographical routing protocol. A critical examination of these limitations led to the designing of a beaconless traffic-aware geographical routing protocol. BTA-GRP has been simulated using the NS-2.34 simulator and the performance of the protocol has been compared with existing beaconless and beacon-based geographical routing protocol. Simulation results show that BTA-GRP has a high data delivery ratio in terms of the total number of nodes and nodes speed. The research work has been carried out in this thesis, in order to find solutions to the problems which are discussed in the literature review. It has been found that the research regarding beaconless geographical routing protocol is still to go a long way. For future work, compare the proposed protocol by adding more parameters and also compare other beacon-based and beacon less geographical routing protocols with the proposed one.

REFERENCES

[1] M. J. Piran, G. R. Murthy, and G. P. Babu, "Vehicular ad hoc and sensor networks; principles and challenges," 2011, *arXiv:1108.2776*. [Online]. Available: http://arxiv.org/abs/1108.2776

[2] K. N. Qureshi, A. H. Abdullah, and R. Yusof, "Position-based routing protocols of vehicular ad hoc networks & applicability in typical road situation," *Life Sci. J.*, vol. 10, no. 4, pp. 905–913, 2013.

[3] S. M. Bilal, C. J. Bernardos, and C. Guerrero, "Position-based routing in vehicular networks: A survey," *J. Netw. Comput. Appl.*, vol. 36, no. 2, pp. 685–697, Mar. 2013.

[4] A. Fonseca and T. Vazão, "Applicability of position-based routing for VANET in highways and urban environment," *J. Netw. Comput. Appl.*, vol. 36, no. 3, pp. 961–973, May 2013.

[5] A. Bazzi and A. Zanella, "Position based routing in crowd sensing vehicular networks," *Ad Hoc Netw.*, vol. 36, pp. 409–424, Jan. 2016.

[6] B. Karp and H.-T. Kung, "GPSR: Greedy perimeter stateless routing for wireless networks," in *Proc. 6th Annu. Int. Conf. Mobile Comput. Netw.*, 2000, pp. 243–254.

[7] L. Liu, Z. Wang, and W.-K. Jehng, "A geographic source routing protocol for traffic sensing in urban environment," in *Proc. IEEE Int. Conf. Autom. Sci. Eng.*, Aug. 2008, pp. 347–352.

[8] M. Jerbi, R. Meraihi, S.-M. Senouci, and Y. Ghamri-Doudane, "GyTAR: Improved greedy traffic aware routing protocol for vehicular ad hoc networks in city environments," in *Proc. 3rd Int. Workshop Veh. Ad Hoc Netw. (VANET)*, 2006, pp. 88–89.

[9] K. N. Qureshi, A. H. Abdullah, J. Lloret, and A. Altameem, "Road-aware routing strategies for vehicular ad hoc networks: Characteristics and comparisons," *Int. J. Distrib. Sensor Netw.*, vol. 12, no. 3, Mar. 2016.

[10] K. Z. Ghafoor, J. Lloret, A. S. Sadiq, and M. A. Mohammed, "Improved geographical routing in vehicular ad hoc networks," *Wireless Pers. Commun.*, vol. 80, no. 2, pp. 785–804, Jan. 2015.

[11] C. Chen, Y. Jin, Q. Pei, and N. Zhang, "A connectivity-aware intersection-based routing in VANETs," *EURASIP J. Wireless Commun. Netw.*, vol. 2014, no. 1, p. 42, Dec. 2014.

[12] L. Da Xu, W. He, and S. Li, "Internet of Things in industries: A survey," *IEEE Trans. Ind. Informat.*, vol. 10, no. 4, pp. 2233–2243, Nov. 2014.

[13] S. Parvin, M. A. Sarram, G. Mirjalily, and F. Adibnia, "A survey on void handling techniques for geographic routing in VANET network," *Int. J. Grid Distrib. Comput.*, vol. 8, no. 2, pp. 101–114, Apr. 2015.

[14] N. Alsharif, S. Cespedes, and X. S. Shen, "ICAR: Intersection-based connectivity aware routing in vehicular ad hoc networks," in *Proc. IEEE Int. Conf. Commun. (ICC)*, Jun. 2013, pp. 1736–1741.

[15] N. Alsharif and X. S. Shen, "ICARII: Intersection-based connectivity aware routing in vehicular networks," in *Proc. IEEE Int. Conf. Commun. (ICC)*, Jun. 2014, pp. 2731–2735.

[16] S. Tsiachris, G. Koltsidas, and F.-N. Pavlidou, "Junction-based geographic routing algorithm for vehicular ad hoc networks," *Wireless Pers. Commun.*, vol. 71, no. 2, pp. 955–973, Jul. 2013.

[17] A. Yadav, S. Y. N. Smieee, and R. Singh, "Cross layer design for power control and link availability in mobile adhoc networks," *Int. J. Comput. Netw. Commun.*, vol. 7, no. 3, pp. 127–143, May 2015.

[18] K. Z. Ghafoor, K. A. Bakar, J. Lloret, R. H. Khokhar, and K. C. Lee, "Intelligent beaconless geographical forwarding for urban vehicular environments," *Wireless Netw.*, vol. 19, no. 3, pp. 345–362, Apr. 2013.

[19] C. Zhao, C. Li, L. Zhu, H. Lin, and J. Li, "A vehicle density and load aware routing protocol for VANETs in city scenarios," in *Proc. Int. Conf. Wireless Commun. Signal Process. (WCSP)*, Oct. 2012, pp. 1–6.
[20] Y. Chen, C. Li, X. Han, M. Gao, and L. Zhu, "A reliable beaconless routing protocol for VANETs," in *Proc. IEEE Int. Conf. Comput. Inf. Technol.*, Sep. 2014, pp. 94–99.
[21] C. Rezende, H. S. Ramos, R. W. Pazzi, A. Boukerche, A. C. Frery, and A. A. F. Loureiro, "VIRTUS: A resilient location-aware video unicast scheme for vehicular networks," in *Proc. IEEE Int. Conf. Commun. (ICC)*, Jun. 2012, pp. 698–702.
[22] S. K. Bhoi and P. M. Khilar, "A road selection based routing protocol for vehicular ad hoc network," *Wireless Pers. Commun.*, vol. 83, no. 4, pp. 2463–2483, Aug. 2015.
[23] J. Shen, C. Wang, A. Castiglione, D. Liu, and C. Esposito, "Greedy probability-based routing protocol for incompletely predictable vehicular ad-hoc network," in *Proc. Int. Conf. Secur., Privacy Anonymity Comput., Commun. Storage*, 2016, pp. 208–217.
[24] K. N. Qureshi, A. H. Abdullah, and F. Ullah, "Beaconless packet forwarding approach for vehicular urban environment," *Bull. Electr. Eng. Informat.*, vol. 5, no. 2, pp. 253–262, Jun. 2016.
[25] K. N. Qureshi, A. H. Abdullah, J. Lloret, and A. Altameem, "OBPF: Opportunistic beaconless packet forwarding strategy for vehicular ad hoc networks," *KSII Trans. Internet Inf. Syst.*, vol. 10, no. 5, pp. 1–22, 2016.
[26] D. K. N. Venkatramana, S. B. Srikantaiah, and J. Moodabidri, "CISRP: Connectivity-aware intersection-based shortest path routing protocol for VANETs in urban environments," *IET Netw.*, vol. 7, no. 3, pp. 152–161, May 2018.
[27] M. Jerbi, S.-M. Senouci, R. Meraihi, and Y. Ghamri-Doudane, "An improved vehicular ad hoc routing protocol for city environments," in *Proc. IEEE Int. Conf. Commun.*, Jun. 2007, pp. 3972–3979.
[28] M. Behrisch, L. Bieker, J. Erdmann, and D. Krajzewicz, "Sumo-simulation of urban mobility," in *Proc. 3rd Int. Conf. Adv. Syst. Simulation (SIMUL)*, Barcelona, Spain, 2011, pp. 1–6.
[29] J. Alme, Y. Andres, H. Appelshäuser, S. Bablok, N. Bialas, R. Bolgen, U. Bonnes, R. Bramm, P. Braun-Munzinger, R. Campagnolo, and P. Christiansen, "The ALICE TPC, a large 3-dimensional tracking device with fast readout for ultra-high multiplicity events," *Nucl. Instrum. Methods Phys. Res. A, Accel. Spectrom. Detect. Assoc. Equip.*, vol. 622, no. 1, pp. 316–367, Oct. 2010.
[30] K.-C. Lan and C.-M. Chou, "Realistic mobility models for vehicular ad hoc network (VANET) simulations," in *Proc. 8th Int. Conf. ITS Telecommun.*, Oct. 2008, pp. 362–366.
[31] Y. Chen, S. Y. M. Lee, S. Li, and C.-R. Huang, "Emotion cause detection with linguistic constructions," in *Proc. 23rd Int. Conf. Comput. Linguistics*, 2010, pp. 179–187.
[32] M. Torrent-Moreno, J. Mittag, P. Santi, and H. Hartenstein, "Vehicle-to-vehicle communication: Fair transmit power control for safety-critical information," *IEEE Trans. Veh. Technol.*, vol. 58, no. 7, pp. 3684–3703, Sep. 2009.
[33] J. Nzouonta, N. Rajgure, G. Wang, and C. Borcea, "VANET routing on city roads using real-time vehicular traffic information," *IEEE Trans. Veh. Technol.*, vol. 58, no. 7, pp. 3609–3626, Sep. 2009.
[34] B. Aubert, Y. Karyotakis, J. P. Lees, V. Poireau, E. Prencipe, X. Prudent, V. Tisserand, J. G. Tico, E. Grauges, M. Martinelli, and A. Palano, "Observation of the $\chi c2(2P)$ meson in the reaction $\gamma\gamma \longrightarrow D\bar{D}$ at BABAR," *Phys. Rev. D*, vol. 81, May 2010, Art. no. 092003.

SADIA DIN received the master's degree in computer science from Abasyn University, Islamabad, Pakistan, in 2015, and the Ph.D. degree in data science from Kyungpook National University, South Korea, in 2020. She has worked as a Postdoctoral Researcher with Kyungpook National University, from March 2020 to August 2020. In 2015, she was a Visiting Researcher with the CCMP Laboratory, Kyungpook National University, where she worked on big data and the Internet of Things. She is currently working as an Assistant Professor with the Department of Information and Communication Engineering, Yeungnam University, South Korea. During her Ph.D. degree, she has worked on various projects, including artificial learning, machine/deep learning, the Internet of Things, and big data analytics. Her research interests include big data, 5G, the IoT, and data science. She has published few highly reputed conferences, such as IEEE LCN, ACM SAC, ICC, Globecom, and some SCIE journal at the beginning of her research career. She was also the Chair of IEEE International Conference on Local Computer Networks (LCN 2018). In IEEE LCN 2017, Singapore, she has chaired couple of sessions. She has been serving as a Guest Editor in journal of Wiley.

KASHIF NASEER QURESHI is currently working as an Assistant Professor with the Department of Computer Science, Bahria University, Islamabad. His research interests include network and wireless communication, and the Internet of Things.

M. SHEHERYAR AFSAR is currently pursuing the master's degree in computer science with Bahria University, Islamabad, Pakistan. His research interest includes wireless communication.

JOEL J. P. C. RODRIGUES (Fellow, IEEE) is currently a Professor with the Federal University of Piauí, Brazil; a Senior Researcher with the Instituto de Telecomunicações, Portugal; and a Collaborator of the Post-Graduation Program on teleinformatics engineering with the Federal University of Ceará (UFC), Brazil. He has authored or coauthored over 900 papers in refereed international journals and conferences, three books, two patents, and one ITU-T Recommendation. He is a member of the Internet Society and a Senior Member of ACM. He is also the Leader of the Next Generation Networks and Applications (NetGNA) Research Group (CNPq), an IEEE Distinguished Lecturer, a Member Representative of the IEEE Communications Society on the IEEE Biometrics Council, and the President of the Scientific Council at ParkUrbis–Covilhã Science and Technology Park. He had been awarded several Outstanding Leadership and Outstanding Service Awards by IEEE Communications Society and several Best Papers Awards. He was the Director of Conference Development–IEEE ComSoc Board of Governors, the Technical Activities Committee Chair of the IEEE ComSoc Latin America Region Board, the Past-Chair of the IEEE ComSoc Technical Committee on e-Health and the IEEE ComSoc Technical Committee on Communications Software, a Steering Committee Member of the IEEE Life Sciences Technical Community, and the Publications Co-Chair. He has been the General Chair and the TPC Chair of many international conferences, including IEEE ICC, IEEE GLOBECOM, IEEE HEALTHCOM, and IEEE LatinCom. He is also the Editor-in-Chief of the *International Journal of E-Health and Medical Communications* and an Editorial Board Member of several high-reputed journals.

AWAIS AHMAD received the Ph.D. degree in computer science and engineering from Kyungpook National University, Daegu, South Korea, and the master's degree in telecommunication from Bahria University, Islamabad, Pakistan. He is currently working as an Assistant Professor with the Department of Computer Science, Air University, Islamabad. He is also working as a Senior Research Scientist at University degli Studi di Milano, Italy. Previously, he was working as an Assistant Professor with the Department of Information and Communication Engineering, Yeungnam University. In 2014, he was also a Visiting Researcher with INTEL-NTU, National Taiwan University, Taiwan, where he was working on Wukong Project (Smart Home). Since 2013, he has published more than 140 international journals (Cumulative Impact Factor: 150+)/Conferences/Book Chapters in various reputed IEEE Transactions, *IEEE Magazines*, *ACM Transactions*, Elsevier, and Springer Journals, whereas in leading conferences, such as IEEE GLOBECOM, IEEE INFOCOM, IEEE LCN, and IEEE ICC, respectively. His research interests include deep learning, machine learning, artificial intelligence, denoising and demosacking, big data analytics, sensor and adhoc networks, and the Internet of Things. He is also serving as a Guest Editor in various Elsevier and Springer journals. Moreover, he is serving as a TPC member or reviewer in 20+ International Conferences and workshops in including IEEE GLOBECOM, IEEE ICC, IEEE Infocom, ACM SAC, and much more. He was a recipient of four prestigious awards: IEEE Best Research Paper Award: International Workshop on Ubiquitous Sensor Systems (UWSS 2015), in conjunction with the Smart World Congress (SWC 2015), Beijing, China, August, Research Award from President of Bahria University Islamabad, Pakistan in 2011, Best Paper Nomination Award in WCECS 2011 at UCLA, USA, and Best Paper Award in 1st Symposium on CS&E, Moju Resort, South Korea, in 2013. He was also serving as a Lab Admin of CCMP Labs from 2013 to 2017. He was also awarded as Best Outgoing Researcher of CCMP labs. Furthermore, he is an invited reviewer in various journals, including IEEE Communication Letters, IEEE Transactions on Wireless Communications, IEEE Transactions on Intelligent Transportation System, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, *Ad-Hoc Networks* (Elsevier), *Computer Network* (Elsevier), and *IEEE Communications Magazine*.

GYU SANG CHOI (Member, IEEE) received the Ph.D. degree in computer science and engineering from Pennsylvania State University. He was a Research Staff Member with the Samsung Advanced Institute of Technology (SAIT), Samsung Electronics Company Ltd., from 2006 to 2009. Since 2009, he has been with Yeungnam University, where he is currently a Professor. His prior research interest includes improving the performance of clusters. His research interests include data mining, deep learning, and parallel computing. He is also a member of ACM.