Enhancing Geographical Routing Protocol Using Swarm Intelligence

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Abstract: A MANET (Mobile Ad hoc Network) which ensures wireless connections between cars/vehicles is called Vehicular Ad Hoc Network (VANET). Though geographic routing in VANETs was recently the cynosure, developing multi-hop communication in such networks is challenging due to changing topology and network disconnections resulting in failures/inefficiency in traditional MANET routing protocols. As GPS (Global Position System) use increases, progress on self-configuring localization mechanisms and VANETs geographic routing provides message delivery solutions. The need to study VANETs routing protocols is linked to data exchange expansion in vehicles which aims to provide dedicated applications for Intelligent Transportation Systems (ITS). This paper proposes the use of Particle swarm Optimization (PSO) to improve Geographical Routing Protocol (GRP) efficiency. Simulation results demonstrate that the proposed modified GRP using PSO, effectively improves the packet delivery ratio, and reduces the end to end delay.
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1. Introduction

MANETs are self-configuring, self-organizing multi-hop wireless networks, consisting of mobile nodes in a network which transmits packets among nodes. Routing functionalities ensure efficient/robust procedures in MANETs for mobile nodes. For example, unicast routing generates a multi-hop forwarding path for source/destination nodes beyond wireless communication range. Routing protocols also maintain connectivity when path links break because of radio propagation, node movement, or wireless interference.

MANET mobile node's velocity is likely to be equal to that of a walking person. If mobile nodes are considered vehicles, then networks are Vehicular Ad Hoc Networks (VANETs). VANET vehicle velocity is higher when compared to MANETs as vehicles move faster when compared to walking [1]. The aim of studying VANET routing protocols is linked to data exchange expansion among vehicles providing applications for Intelligent Transportation Systems (ITS) which include on-board active safety systems, provision of communications in and between nearby vehicles and between vehicles and roadside infrastructure. But several challenges, usually connected to node mobility, dynamic scenarios and scalability for many were identified, in adopting VANET on a large scale. Hence, development of a routing protocol providing quality inter nodal communication is a must.

Topological and geographic routing are two VANETs routing protocols. The former, uses mobile nodes with topological information to manage routing tables/search routes directly where as in the latter each node knowing its position makes routing decisions based on destination position and that of local neighbours [2]. Geographic routing in VANET has received attention to provide message delivery solutions because of increased GPS use and progress of self-configuring localization mechanisms.

2. Geographic Routing Protocol (GRP)

2.1 Introduction

Though geographic routing research is the latest when compared to topological routing, the latter gained attention due to improvement in routing produced geographic information. Geographic routing is stateless routing, where a node need not perform maintenance functions for topological information beyond a one-hop neighbour [3]. So, geographic routing is practical for large-scale networks when compared to topological routing as the latter needs network-wide control message dissemination.

Geographic routing also needs lower node memory through maintaining information locally. Generally, geographic routing includes location service and geographic forwarding process. The former determines packet destination position to improve routing process and to create a path with source node using intermediary nodes. So packet position destination is added to packet headers so that hops know packet destination [4].

Similarly, geographic forwarding is performed in geographic greedy-forwarding and void-handling modes1. The former defines next-hop node to forward packets considering current node positions and that of neighbouring and destination nodes. A node gets its position through GPS receiver/localization algorithms. Neighbouring nodes positions is acquired either from a node's centralized neighbourhood table or through a distributed method via neighbouring nodes' contentions [5]. Finally, packet headers have destination node's position from the source node. But if an intermediate node has a more accurate destination position, it is updated in the packet header before being forwarded.

Geographic routing protocols are advantageous over conventional ad hoc routing strategies. First, a geographic forwarding process allows path adaptation through next hop selection, when an intermediate node used earlier, is unavailable. Due to lack of a route creation process, path selection needs no table maintenance procedure excepting intermediate neighbours and control packet propagation. Other advantages are capacity to utilize weight additional metrics for the next hop selection and route alteration on node basis considering neighbour related QoS like bandwidth and delay [6]. But some geographic routing challenges still await investigation. [7].

- Difficulty in controlling overhead needed for distributed location database service of geographic routing protocols.
- Irregular vehicle distribution in urban centres ensures difficult route selection.
- High signal interference in communication due to large buildings voiding physical network topology.

In summary, best routes computation to forward packets in VANETs is tough because of high node mobility and presence of unstable wireless links. Many solutions were created to improve geographic routing protocols performance. This paper presents an overview of geographic routing's main techniques, addressing the main challenge of using geographic routing in VANET optimization through Particle Swarm Optimization (PSO) use.

2.2 Geographic Routing in Vehicular Ad Hoc Networks

Ad hoc routing protocols provide routing procedures to select best routes to forward packets from source nodes to destination nodes through multi hops. Similarly, geographic routing protocols use location services to improve such processes. Figure 1 show VANET geographic routing's general architecture.

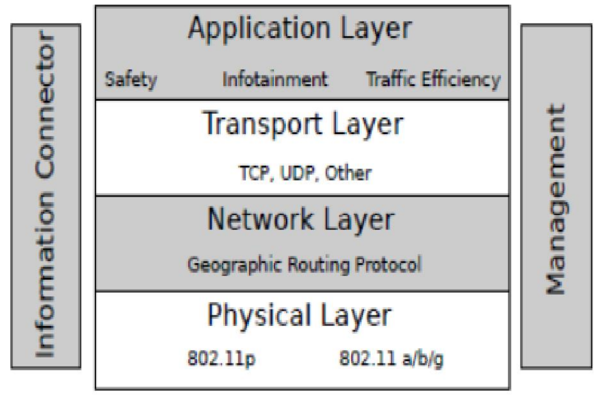

Figure 1: Geographic routing architecture for vehicular ad hoc networks.

The architecture is a top-down approach with:

- Application Layer: The first layer having VANET applications like interfaces between users and communication layers.
- Transport Layer: Operates with conventional transport protocols (i.e. TP or UDP) and also a specific VANET transport protocol.
- Network Layer: Geographic routing protocol provides services and procedures like location services and forwarding procedures.
- Physical Layer: Operates with both conventional wireless communication protocols/VANET wireless communication protocols.
- Additionally, modules are vertically added to architecture's left or right including Information Connector and Management.

2.2.1 Geographic Forwarding

Geographic forwarding algorithms work in both greedy and void-handling modes, the difference ensuring a situation where each mode is used conveniently. Though greedy forwarding mode is used when possible, void-handling mode is applicable only in places where greedy forwarding mode is not possible.

2.2.2 Greedy Forwarding

Greedy forwarding algorithms perform varied optimization techniques to choose the next-hop node near a destination node. Face routing [8] is a fundamental algorithm to route packets using compass routing on geometric networks. The idea is best path selection along faces intersected by source and destination line segments. The original network's planar graph is needed to avoid face routing.

Source nodes send messages to destination nodes in greedy forwarding mode. When location service detects node positions a greedy routing algorithm selects the next-hop adjacent to the destination. For example, node A selects the next-hop using similar selection rules till the message reaches the destination node. When a next hop is unable to be located by a node, it uses void-handling mode [4] where a node decides to route packets around a void due to the existence of a valid path from source to the destination node.

Communications voids are serious issues for a geographic routing protocol and, so it is important to learn to handle them properly. It is also tough to predict when/where a void occurs due to the unpredictability of node deployment pattern. A simple void-handling strategy is to flood a network from source to neighbouring nodes. When every node does likewise, this enables packets to reach Destination node after least path location. Though effective, this is inefficient as regards resource utilization, as every node forwards packets and destination nodes could receive copies of same data packet from different paths.

VANET environments have many prerequisites on position information availability like position awareness of each participating vehicle, e.g., a GPS receiver installed in vehicles. Assumption of using position systems is possible due to GPS increase and improved progress on self-configuring localization mechanisms in urban scenarios. Thus, it is important that each vehicle be aware of a neighbour's position. Forwarding beacon messages is a way to perform position updates indicating current vehicle position.

The Greedy Perimeter Stateless Routing (GPSR) protocol is an algorithm which demonstrates basic geographic routing concepts in vehicular ad hoc networks. Proposals using GPSR models to provide new geographic protocols in VANET scenarios include [9] and [10]. In summary, GPSR is a local decision strategy requiring no route setup/maintenance. Forwarding hops are determined 'on the fly' casually, instead [2]. This is applicable to both greedy forwarding to send packets using position information and a void-handling technique through a perimeter mode as a recover strategy. Position information points in the right direction without being correlated with available destination paths in such scenarios.

3. Related Works

Füßler et al., [11] examined ad-hoc routing algorithms applications on data exchange among vehicles. This includes two important aspects: 1) vehicles created unique ad-hoc network features, and 2) use of existing ad-hoc routing approaches to networks displaying such features. A realistic highway traffic vehicular movement pattern employing an accurate, validated traffic simulation tool addresses both aspects. On the basis of patterns, it is seen that VANET characteristics are diverse from the usual random waypoint model. A reactive ad-hoc routing protocol (DSR) performance and that of a position-based scheme (greedy forwarding as done in GPSR) together with a basic reactive location service are evaluated. Vehicular networks where communication spans are greater than 2 or 3 hops position-based ad-hoc routing has many advantages on reactive non-position-based schemes both in successful packet delivery quantity and in routing overhead, as seen from the analysis.

Routing protocols and other methods should be modified for VANETs vehicular-specific capabilities and requirements. It is seen form prior work that the availability/stability of wireless links is highly dependent for routing performance as it is a parameter which cannot be disregarded in VANETs to achieve specific performance measurements. Though routing protocols are analysed and compared comparisons and simulations also consider random motions. Hence, in realistic urban scenarios, Haerri et al., [12] evaluated AODV and OLSR performance. The protocols are examined under differing metrics like node mobility and vehicle density and with differing traffic rates. Effects on evaluation/performance metrics due to clustering effects formed by cars aggregating at intersections are illustrated. The idea is facilitation of a qualitative protocol implementation assessment in various vehicular scenarios.

Internet facilitates researchers to produce different mobile applications different from commercial services and entertainment to safety and diagnostic tools. A challenge in seamless access to a wireless network resource is in mobility management. To overcome issues in mobility management in vehicular ad hoc networks, Huang, et al., [13] proposed a new link enhancement mechanism. Particle swarm optimization and fuzzy logic systems are machine learning methods integrated into the proposed technique to improve prediction precision of link break and congestion occurrence. The proposed method's feasibility and efficiency are demonstrated through experiments.

Transient communications links are due to a node's velocity in a VANET that degrades a developed protocol's performance. Most accomplished routes develop into an invalid state leading to an incurring delay, which is interrupted resulting in more overhead in existing communication flows. Minh et al., [14] measured end-to-end VANET delay to develop route metric aimed at reducing route discovery time. Hybrid routing protocol deploys a route model mainly to shrink route overhead, improve route convergence speed and improve each node's routing table quality.

The proposed model's characteristics are demonstrated through simulation.

The problem to locate a shortest tour of least length on a completely connected graph is the city routing issue. Several nature inspired algorithms were proposed for this issue. Hadia et al., [15] proposed an application of Particle Swarm Optimization for this issue including the concept of Swap Operator and Sequence of Swap. The proposed algorithm performs efficiently in the minimum number of cities. This algorithm can be advanced to work in many cities as a future VANET routing issue.

4. Methodology

4.1. Particle swarm Optimization (PSO)

Maximizing/minimizing a cost function by searching for a variable set is called optimization. "Swarm intelligence" is used for optimization, where many components decentralized controls and self-organization are coordinated to create a study of collective system behaviour. The focus is on collective behaviour adaptation observed in natural systems and reverse engineering which tries to design efficient algorithms for distributed optimization. The desirable properties of adaptability, scalability and robustness are revealed by these algorithms as being the same as their natural systems of inspiration. In a network routing context and specially of routing in wireless sensor networks these are important characteristics. Many routing protocols are developed according to swarm intelligence for wireless sensor networks. The inspiration is mainly from ant/bees foraging behaviour or the social behaviour of bird flocking and fish schooling.

Particle swarm Optimization (PSO) offers quality solutions converging quickly compared to other population-based optimization algorithms like GA [16, 17]. PSO is based on the social behaviour of birds flocking where cooperation among entities achieves goals efficiently. The entities/PSO particles have two properties - position and velocity. A candidate solution as an objective function is represented in them. With a position as input, objective function establishes particles fitness value in each iteration. Entity velocities are dynamically adjusted as they flit through the search space. A particle's present best position is computed using information of its own (pbest) best position and that of a global best position (gbest) searched by the swarm. The particle modifies velocity accordingly and arrives at its new position.

The particles position can be mathematically given as:

$$V_i^{k+1} = wV_i^k + c_1 rand_1(\dots) * \left(pbest_i - s_i^k\right)$$
$$+ c_2 rand_2(\dots) * \left(gbest_i - s_i^k\right)$$

where, v_{ik} is the velocity of agent i at iteration k, w: weighting function, c_j: weighting factor, rand: uniformly distributed random number between 0 and 1, s_i^k : current position of agent i at iteration k, pbesti : pbest of agent i, gbest: gbest of the group.

The flowchart of the proposed method is shown in the Figure 2.

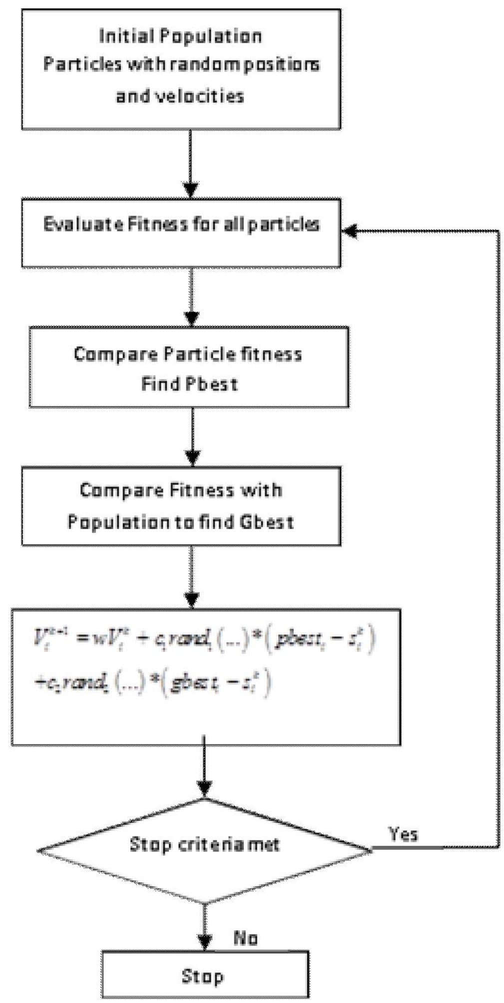

Figure 2: Flowchart of the Proposed Method

5. Experimental Setup and Results

A simulation testbed of 20 nodes is considered to evaluate the proposed method. The nodes have random trajectory and are spread a 2000 m by 2000 m area. The data rate of each node is 11 Mbps with a transmit power of 0.005 watts. Simulations are run for 400 sec. Figures 3 to 5 show end to end delay, jitter and packet delivery ratio simulation results respectively.

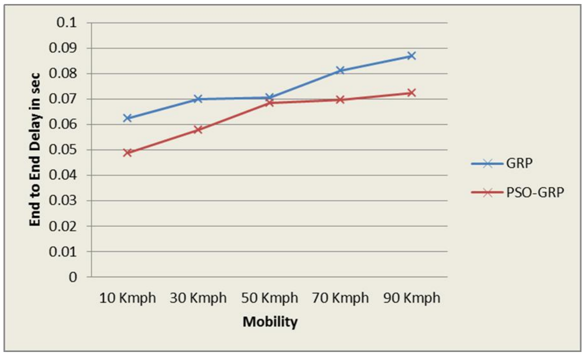

Figure 3: End to End Delay for GRP and the proposed PSO based GRP

It is seen from the Fig. 2 that the performance in terms of end to end delay decreases significantly with the use of proposed optimization.

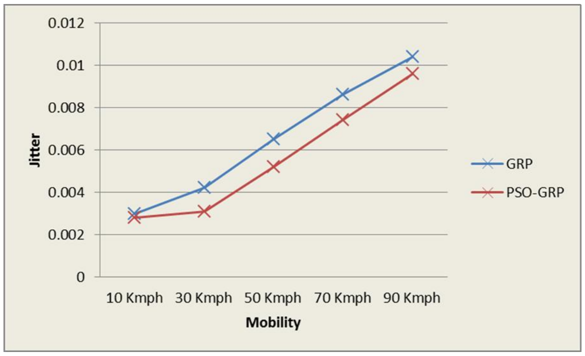

Figure 4: Jitter in seconds for GRP and the proposed PSO based GRP

The average jitter is shown in Fig. 3 for GRP and optimized GRP. It can be seen that the proposed modified protocol reduces the jitter when compared to the existing GRP.

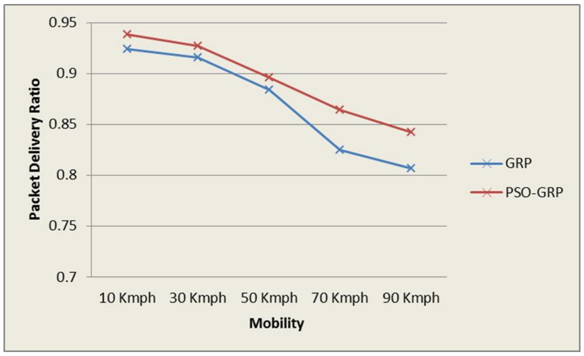

Figure 5: Packet Delivery Ratio for GRP and the proposed PSO based GRP

It is observed from Figure 4 that the packet delivery ratio for the proposed PSO-GRP is better due to optimization especially when the mobility of the nodes is higher. It is seen that packet delivery ratio improves by more than 4% when the mobility is above 70 kmph.

6. Conclusion

Any motivation to study VANETs routing protocols is related to data exchange expansion among vehicles to provide applications for Intelligent Transportation Systems (ITS). This paper proposes the use of Particle swarm Optimization (PSO) to improve geographical routing protocol (GRP) efficiency. GRP Optimization reduces end to end delay and improves network packet delivery ratio. Simulation results demonstrate that the modified GRP using PSO, effectively improved packet delivery ratio and reduced jitter and end to end delay.

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