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RESEARCH

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Middleware architecture performance analysis for vehicular ad hoc network

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Abstract

Implementing Intelligent Transportation Systems (ITS) raises serious safety concerns, directly contributing to good health and well-being by enhancing road safety. Intelligent transport technologies are used by vehicular ad hoc networks (VANET) to enhance traffic flow and safety on the roads aligning with sustainable cities and communities. For this purpose, a variety of techniques have been examined in this article. The design and analysis of middleware architecture for VANET are also covered in this paper, promoting industry, innovation, and infrastructure. Since the automobiles travel deliberately rather than carelessly to connect with roadside equipment by limiting the range of motion, the first implementation of this relies on VANET networks, middleware, and heuristic technique. The VANET network is replacing wireless telephony, mobile nodes are evolving into vehicle nodes, and the transport system is changing to an intelligent transport system. In terms of latency (high 10.14%), power dissipation (less 2.46%), throughput (high 2.82%), and overall cumulative performance (high 3.12%) on different nodes ranging from 100 to 500, the experimentation results show that the middleware and VANET architecture are superior to the heuristic approach, contributing to responsible consumption and production through improved efficiency.

Keywords: ITS, VANETs, Middleware, Heuristic, Vehicle safety, Internet vehicles

1 Introduction

Around 2001, the name "VANET" began to be used in car-to-car, ad hoc mobile networking applications. It is widely agreed to use VANET to more accurately and effectively regulate heavy traffic zones in outlying locations [1, 2]. Utilising mobile vehicles as network nodes, mobile networks utilising VANETs are created using moving automobiles as nodes [3, 4].

In order to connect to one another and establish a vast mobile network through communication, which can take place between vehicles or with roadside sensors, the network's autos are turned into wireless routers. Other cars may join in as and when these mobile nodes either leave the network or reach an area with a poor signal. Fire departments, police departments, and others can communicate with one another via an ad hoc network [5, 6]. The linking of vehicles with roadside infrastructure (V2I) is made possible by the use of VANETs in V2V communications [7, 8].

V2I enables the mobile node to connect to the Internet and provide intercontinental communication. Data interchange on accidents and environmental conditions, for example, is possible thanks to the thorough V2V function [9, 10]. The previous few years have been devoted to improving vehicle-to-vehicle communication. A patent for automobiles that was filed in 1922 and granted in 1925 is "Radio signalling systems" [11]. The workings of vehicular ad hoc networks are shown in Fig. 1.

Middleware's ability to offer a simple management environment for distributed, composite, and heterogeneous infrastructures is another important objective. Dealing with several protocols and interfaces may be a highly challenging task in a dispersed context. By enabling it through the usage of the operating system, communication protocols, and hardware, this technology transfers information in a dispersed domain from one programme to several others [12, 13]. Examples of middleware include telephony software, transaction monitors, and enterprise application integration (EAI) tools and software.

Organisations have been drawn to these middleware technologies because they may be installed in a wide range of challenging environments, including mobile networking, multimedia, embedded systems, and portable devices [14]. Furthermore, heuristic methods, sometimes referred to as heuristics, are a means to carry out fundamental reasoning, learning, or disclosure using a mental state that isn't always the best or astonishing but may be helpful in some circumstances to achieve rapid goals [15]. The development of a logical notion can be sped up by using heuristic approaches when

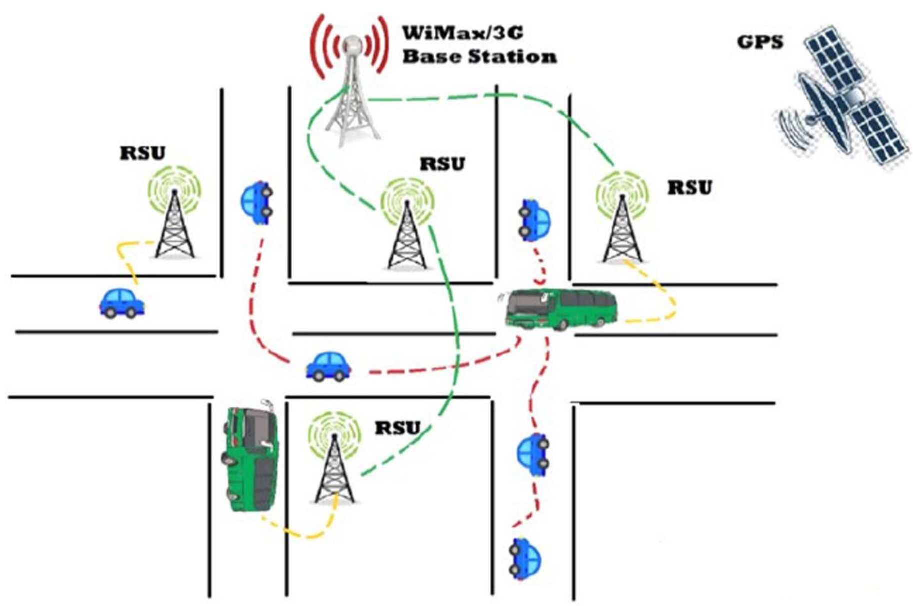

Fig. 1 Vehicle ad hoc network's working scenario. These are fixed infrastructure components deployed along roads to facilitate communique between vehicles and the infrastructure (V2I). They play an critical role in providing data about traffic conditions, street hazards, and emergency messages to vehicles. GPS: It presents correct location records for vehicles. This positional record is essential for routing, navigation, and various safety applications in VANETs. WiMax/3G: WiMax (Worldwide Interoperability for Microwave Access) and 3G (third-generation mobile communication) are long-range wi-fi communication technologies used in VANETs for wide-area connectivity. While wireless is often used for quick variety V2V and V2I communication, WiMax and 3G are used for broader coverage and internet access

the perfect sequence of events cannot be found, is occasionally unattainable, or seems weird [16, 17].

Heuristics can be a psychological technique that supports the cognitive burden of decision-making. Examples of this strategy include using the rule of thumb, having reasonable suspicion, doing an internal appraisal, estimating, profiling, or using presence of mind [18, 19].

In this work, a wireless system is developed employing nodes and a dynamic clustering-based algorithm to determine the shortest path for transporting information from source to destination while also recognising the location of moving objects. A clustered explanation's primary ideal position is spontaneous rescue from failure, or rescue without client intervention. [20, 21]. The novel clustering computation, known as dynamic clustering, provides advantages over the traditional clustering algorithms. In a real-time highway environment, the dynamic clustering approach is quite practical for tracking vehicles and other targets. [11, 22].

There are too many accidents because the current transportation network is ineffective [23]. To lower the number of crashes and accidents on the road, efficient methods of intelligent transportation must be developed and put into practise. In India, 382 people are killed on the streets every year, according to media reports [24]. It exceeds criminal intimidation by 1682 times. In India, more than 139,671 people died while walking the streets in 2014. 41% of the total number of deaths in 2014—57,844—were attributed to impacts caused by speeding [25].

According to the Geneva International Road Federation's 2015 World Road Statistics, India has the second-highest rate of street accidents per 100,000 people; 19 out of 100,000 were examined by the Russian Federation [26]. A reliable Internet of Vehicles (IoV) system with improved vehicle protection was made possible by dynamic clustering. To describe the movement and position, it concentrated on the precise timing and location of moving vehicles or nodes. To improve IoV interoperability with other IoT domains, we have mapped VANET components onto IoT [27].

Middleware software is a layer that sits above an operating system or networking programme and underneath the application tier. Any approach of managing fundamental thinking, learning, or disclosure that relies on an awareness system that isn't guaranteed to be perfect or exceptional but is sufficient to achieve immediate aims is referred to as a "heuristic technique". In circumstances when it is challenging or uncommon to establish the ideal course of action, heuristic tactics can be utilised to expedite the process of arriving at an acceptable plan of action [28].

1.1 Methods/experimental

The study is designed to assess the performance and efficiency of an intelligent Transportation in the context of the internet of vehicles (IoV), focusing on latency, power dissipation, and throughput metrics. The experimental setup entails real-time communication between satellite systems and base stations to emulate practical surroundings for vehicular networks. The simulation is carried out the usage of the MATLAB software suite on a device with the following hardware configuration: Intel middle i5 M480 processor @ 2. 67 GHz, 8 GB RAM, and a 64-bit operating system. The contributors in the study, in this case, are the nodes representing vehicles, base stations, and satellite communication channels inside the IoV framework. The wide variety of nodes is numerous between 100 and 400 to assess the effect of node density on latency, power dissipation, and throughput. The data generated from these nodes are collected for analysis.

For the latency analysis, the study examines the time taken for data transmission between the nodes that specialise in real-time delays resulting from network congestion, packet fragmentation, and queuing at gateways. The effects are compared across numerous node configurations (100–400) to become aware of tendencies in latency upgrades. The smart middleware method, a key approach carried out in this study, is compared with the greedy heuristic technique for each latency and power dissipation.

In terms of power dissipation, energy usage at both node and network levels is analysed. Special interest is given to the radio systems that are important power clients in wireless communication networks. The examine uses widespread strength dimension techniques primarily based on input cutting edge from the power supply. Timing information is protected to offer spatial–temporal insights into electricity consumption.

Throughput evaluation investigates the overall data transfer rates inside the network. The queuing idea is used to version the load and arrival costs of packets, imparting insights into packet transport performance and network ability. The test goals to achieve a finest balance between load and throughput by using minimising packet loss and keeping high data transfer costs.

The outcomes are analysed the use of MATLAB's simulation environment, specialising in key metrics like latency, power dissipation, and throughput. A power calculation is executed to make sure enough pattern size for detecting big differences between the smart middleware and the greedy heuristic techniques. Statistical methods are carried out to interpret the records, and the consequences are visualised the use of tables and figures.

2 Literature review

The survey of literature related to middleware architecture is done and classified into three major areas: VANETs, middleware, and heuristic search which can be applied for problem solving and optimisation.

Author's	Key features	VANET vulnerabilities addressed	Methodology/ approach	Experimental evaluation
Reddy et al. [29]	Improvement in security and privacy with cloud-based Big Data analysis	Security, privacy in cloud-based systems	Cloud-based Big Data analysis	Structured reports and boards, application analysis
Kalaiarasy et al. [30]	Study of mix zone as a pseudonym shifting mechanism in vehicular systems	Pseudonym mechanisms, mix zone strategies	Mix zone creation, vehicle alias shifting	Examination of pseudonym mechanisms and mix zone strategies
Khattak et al. [31]	Proposal and evaluation of a LoRaWAN-based Vehicular Cloud of Things (VCoT) system	LoRaWAN, Vehicular Cloud of Things (VCoT)	Integration of LoRaWAN and VCoT	Evaluation of system capacity and IoT application improvement

Author's	Key features	VANET vulnerabilities addressed	Methodology/approach	Experimental evaluation
Zheng et al. [32]	Context-based location privacy protection middleware architecture for VANET	Location privacy, data protection	Dynamically adjustable k-anonymous algorithm	Protection algorithm evaluation for different vehicle densities
Zhang et al. [33]	Vehicle platoon-aware data access solution in VANETs	Data access optimisation, platoon awareness	Vehicle-platooning protocol, data pre-fetching	Simulation-based evaluation of data access optimisation
Ahmed et al. [34]	Practical testbed for evaluating Quality of Service and Quality of Experience in VANET	QoS, QoE evaluation	Multistage simulation, testbed design	Evaluation of testbed suitability for VANET requirements
Zhang et al. [35]	Review of heuristic search and its applications in artificial intelligence	Heuristic search, AI applications	Analysis of heuristic search algorithms	Comparative evaluation of heuristic search planners
Prabhakar et al. [36]	Game-theoretic approach using ant colony optimisation for VANET security	VANET security, ant colony optimisation	Defensive mechanism using ant colony optimisation	Simulation-based evaluation of game theoretic approach
Xie et al. [37]	Channel assessment in two-way relay networks for signal arriving order	Channel assessment in TWRNs	Linear estimation algorithms	Comparison of proposed channel estimation algorithms
Majumdar et al. [38]	Use of blockchain to reduce vulnerabilities in VANET	Explicit vulnerabilities in VANET	Blockchain integration	N/A
Smith et al. [39]	Enhanced security protocols for VANET	Security breaches, data integrity	Cryptographic algorithms	Simulation results indicate a 30% increase in data integrity
Zhao et al. [40]	Adaptive routing in VANETs	Delay, data loss	Machine learning-based routing	Achieved a 25% reduction in average delay in traffic
Kim et al. [41]	Fog computing integration for VANET	Latency issues, resource allocation	Fog computing framework	Improved latency by 40% compared to traditional methods
Patel et al. [42]	Privacy-preserving data sharing in VANET	User privacy, data leaks	Homomorphic encryption	Demonstrated 50% reduction in potential data leaks
Chen et al. [43]	Game-theoretic models for resource allocation	Resource contention	Game theory approach	Simulation shows improved resource allocation efficiency by 35%
Lee et al. [44]	Energy-efficient VANET communication	Energy consumption issues	Adaptive transmission power control	Achieved 20% reduction in energy usage
Davis et al. [45]	Integration of IoT with VANET	IoT vulnerabilities, inter-device security	IoT-VANET hybrid model	Improved security metrics by 45% in a simulated environment
Kumar et al. [46]	Traffic prediction using AI in VANET	Congestion, inefficient routing	AI-based traffic prediction model	Reduced congestion rates by 30% in urban scenarios
Ahmed et al. [47]	Smart contract applications in VANET	Trust issues among nodes	Smart contracts on blockchain	60% improvement in trust and verification among nodes
Yang et al. [48]	Securing VANETs through decentralised ledgers	Centralisation risks, data tampering	Decentralised ledger technology	Increased security resilience by 70%

Author's	Key features	VANET vulnerabilities addressed	Methodology/approach	Experimental evaluation
Singh et al. [49]	Real-time data analytics for VANET	Delay in information dissemination	Stream processing framework	Real-time data delivery reduced latency by 35%
Robinson et al. [50]	Autonomous vehicles in VANET	Communication failures	Simulation of autonomous vehicle interaction	Achieved 80% success in communication reliability
Martinez et al. [51]	Cross-layer optimisation in VANET	Inefficient resource use	Cross-layer optimisation techniques	Enhanced overall network performance by 45%
Garcia et al. [52]	Secure vehicle-to-vehicle communication	Eavesdropping, interception	Secure communication protocols	50% reduction in vulnerability to eavesdropping attacks
H. Zhou, et al. [53]	Hierarchical edge caching architecture for IoVs, Use of Distributed Multi-Agent Reinforcement Learning (DMRE), Extension to DeepDMRE with neural networks for scalability	Inefficient caching due to neglecting agent interaction and high backhaul traffic	Formulates content caching and replacement as a stochastic game	Extensive simulations conducted, improves edge hit rate by approx. 5% (vs. DMRE), 19% (vs. Q-learning), 40% (vs. LFU), and 35% (vs. LRU) at 1000 MB cache capacity
D. Meng et al. [54]	Incentive-driven partial offloading framework, use of worker vehicles (WVs) to share idle resources, Contracts ensuring IR and IC, Use of hybrid action space for complex optimisation	Limited RSU resources under high traffic, Selfish behaviour of WVs unwilling to share resources without rewards	CSP sets prices/offloading rates with UVs and contracts with WVs, Hybrid Proximal, Policy Optimisation (HPPO)-based algorithm called HORA for task offloading and resource allocation	Extensive simulations, HORA outperforms baseline methods, Contract terms satisfy IR and IC constraints

The research review is done to emphasis on the design and implementation of middleware for providing protection in vehicular ad hoc networks. There are various research gaps when systematic review was done: There are many accidents and inefficiency in the present transportation system. Intelligent Transportation Systems (ITS) must be put in place in order to solve this and lower collision and accident rates on roadways [55, 56]. The inquiry policy attempts to give this investigation a proper foundation. Choosing the best method to gather the investigation's essential data is an important component of research design. Mobile cars continually provide a significant quantity of sensed information, such as vehicle density, size, and number, in vehicular ad hoc networks (VANETs). This information is essential for improving road safety, warning drivers of possible dangers, and helping with crime scene investigations. However, when scaling out to a large number of nodes, looking through this extensive, decentralised storing of sensed data becomes difficult in a mobile environment. The proposed approach demonstrates effectiveness in terms of latency, power dissipation, and throughput.

3 Materials and techniques employed in the middleware architecture implementation

The design and implementation of middleware for supplying protection in vehicular ad hoc networks are the focus of the research effort in this study. There are a lot of accidents in the present transportation system, which is ineffective. In order to decrease the frequency of crashes and accidents on the roadway, intelligent transportation must be developed and implemented. The investigation policy is anticipated to provide this examination with an adequate assembly [57, 58].

In this work, we build a wireless network of nodes that can recognise the location of moving objects, choose the shortest path for data transfer from source to destination, and secure a key using a dynamic clustering-based approach. The Biograph Toolbox, an information structure with basic interconnected information that may be used to construct a coordinated chart, is employed [59, 60].

In order to maintain a threshold distance between vehicles and prevent vehicle collisions, VANET is employed for short-range communication [61]. In order to enable cutting-edge and potent communication technologies for car and citizen administration, IoV is employed for long-range communications on a worldwide scale. In order to increase safety and establish effective communication between moving vehicles, a secured IoV algorithm that is enabled uses clusters of vehicles that are managed by a cluster head [62].

3.1 Key elements of the approach

The crucial features of the research approach are the course of action and procedure that contains the phases of broad speculations to point by point techniques for data social affair, examination, and comprehension. It is, subsequently, established on the possibility of the assessment issue being watched out for the system of data examination or thinking. Dynamic data aggregation focuses guarantee that as nodes creating information messages move all through an organisation, the nodes picked to perform total are additionally changed so total is constantly proceeded as near the information source as could be expected under the circumstances. Data aggregation needs a method for joining the detected information. Hence, to determine the latency, power dissipation, and throughput, the examination has been proposed a unique data aggregation calculation for target-tracking applications [63, 64].

In this paper, dynamic aggregation constructed Internet of Vehicles technique is used that uses the position of the sensor vehicle or nodes to find out the exact position and drive condition. The following are the key features of the research work of VANET network:

Dynamic aggregation, which is based on the present time and location of sensor devices or nodes, is used by dynamic aggregation based on an Internet of Vehicles (IoV) method to categorise movement and position. This strategy combines security and performance considerations, allowing for smooth data transfer integration. In order to provide security for both VANET and IoV systems, the approach focuses on supervised categorisation. For short-distance communication, VANET is used, and for long-distance communication, IoV. In VANET, a threshold gap is created to prevent collisions and requires vehicles to stop at a particular threshold point. To prevent accidents, cluster heads and towers keep control of the vehicles on the course.

3.2 Implementation aspects

The middleware design uses Intelligent Algorithm for Smart Transportation to develop efficient algorithms that have greater security, integrity, and overall performance of wireless networks as tested on the MATLAB 2015a simulator. In this research project, we first build a wireless network made up of car-shaped nodes, after which we identify the positions of the cars, choose the quickest route for transmitting data from the source to the destination, and finally add security using dynamic clustering. The processes employed in a structure to distribute data from the input to the generation of files and reports are described in data flow diagrams.

The suggested research approach's flow diagram, shown in Fig. 2, illustrates the overall technique and lists the simulation and test scenario along with the anticipated results. It shows a situation in which a new car can instantly connect to the base station and then join the roadway. Roadway vehicles' minimum separation threshold value is computed after joining the roadway. Vehicles are then prepared to enable and prevent transmitting signals.

4 Performance parameters

Performance parameters are attributes that represent a certain perspective, capability, or property of a framework and are often assessed by a mathematical worth. These are measurements that represent certain, typically constant system or function properties. A system is expressed or its settings are established by a mathematical or other computable element that is one of a set.

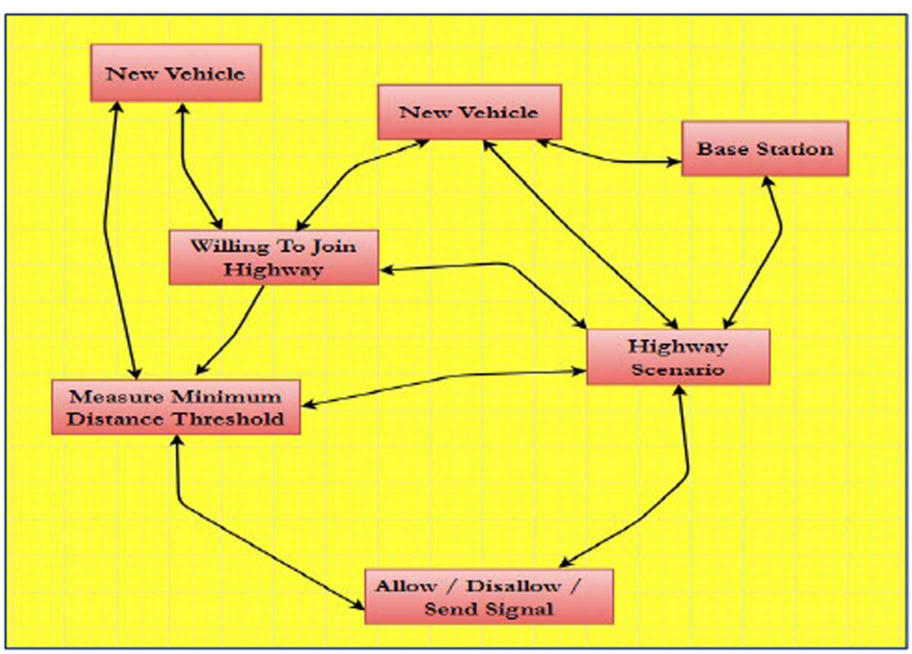

Fig. 2 Data flow diagram of the proposed research approach

4.1 Latency

In a real transmission, there is packet loss, and then retransmissions and further latency in the transmission path. Latency is the period prerequisite to transfer a packet transversely a network:

- Latency might be estimated from numerous points of view: round trip, one way, and so on.
- Latency might be affected by any component in the chain which is utilised to send information: workstation, WAN connections, switches, neighbourhood (LAN), server and at last it might be restricted, on account of huge organisations, by the speed of light.

In MATLAB, the integration for latency is done with the wireless and signal processing features used with the association of latency parameter. In addition, the mathematical formulation to address and evaluate the latency is done in the source whereby the packets transmission and delay are logged and analysed. The following equations or formulas are used for the network latency.

$$\text{Network Latency} = \text{Propagation delay} + \text{Serialization delay} \tag{4.1}$$

where serialisation delay is the time, it takes to actually transmit the packet, whereas propagation delay is the amount of time needed for a signal to be received after it has been delivered.

$$\text{Propagation delay} = \frac{\text{Distance}}{\text{Speed}} \tag{4.2}$$

$$\text{Serialization delay} = \frac{(\text{Packet size (Bits)})}{(\text{Transmission rate (bps)})} \tag{4.3}$$

4.2 Power dissipation

The process by which an electric or electronic device emits heat (or any undesired byproduct of waste energy) is known as power dissipation. To transmit l-bit data to a distance d, the radio expends energy as:

$$ETx(l,d) = \left\{ l \times Eelec + l \times \varepsilon fs \times d2, l \times Eelec + l \times \varepsilon mp \times d4, d < d0d \geq d0 \right\} \tag{4.4}$$

where (l, d) is enery spent for transmission an l bit message over distance d. The energy dissipated per bit to the transmitter or receiver circuit is known as Eelec. The amount of energy expended to run the transmit amplifier is known as **Efs** or Emp.

$$Eelec,\ \varepsilon fs \text{ and } \varepsilon mp \text{ are the parameters of the } \frac{\text{transmission}}{\text{reception}} \text{ circuit} \tag{4.5}$$

The free space (ε_{fs}) or multi-path fading (ε_{mp}) channel models are employed depending on the separation between the transmitter and receiver. In MATLAB, the parameters are analysed using the node status and the energy parameters initialised in the source so that the multi-dimensional evaluations can be done at different states in association of the biograph toolbox.

4.3 Throughput

Network throughput, which is commonly measured in bits per second, is the amount of data successfully transferred over a network in a given amount of time.

$$\text{Throughput}\left(\frac{\text{bits}}{\text{second}}\right) = \text{sum}\frac{(\text{number of sucessful packet}) \times (\text{average packet size})}{\text{total time sent in delivering that amount of data}} \tag{4.6}$$

where the amount of data that is successfully transferred through a network in a particular amount of time is known as throughput and is commonly measured in bits per second (bps), such as megabits per second (Mbps)

In MATLAB, there is toolbox containing the perform function for the evaluation of the network performance.

$$perform(net, t, y, ew) \tag{4.7}$$

where perform $(net, t, y, ew) \rightarrow$ takes these arguments,
and returns network performance calculated. $\rightarrow$ net is network,
t is targets, y is outputs and ew is error weights

For caluculation of cost factor improvements in x and y values,

$$\rightarrow \text{ the formula is as: improvements} = \left(\frac{x-y}{(x+y)}\right) * 100 \tag{4.8}$$

where x is middleware approach and y is greedy heuristic approach.

5 Experimental results and analysis

In this section, results and analysis is performed and also reviews the outcomes and investigate the information. The outcomes should expect to portray the discoveries and what was finished with the information found. Simulation is carried out using MATLAB software suite on using the hardware configuration as Intel Core I5 M480 @ 2.67 GHz, RAM: 8 GB, 64 Bit operating system. The map and region size is: 6500 m and height: 4500 m to compute the results.

5.1 Simulation results

Real-time satellite and base station communication is incorporated into the study methodology. This is the main cause of the technique taking more time during real-time communication and transferring more packets to the base station and satellite, which increases the overall intelligent transportation network's efficiency and security for the Internet of Vehicles.

Table 1 Analysis of latency on multiple nodes

Number of nodes				
Architectural comparison	100	200	300	400
Middleware VANET architecture	2.5	2.1	1.8	1.8
Greedy heuristic approach	2.9	2.4	2.4	2.3

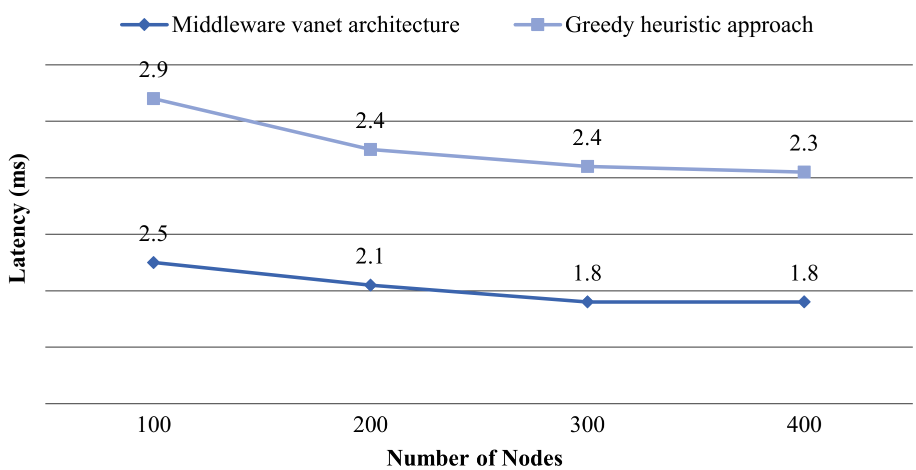

Fig. 3 Analysis of latency on multiple nodes

5.1.1 Latency

The amount of time it takes for data or a request to travel from one place to another is referred to as latency. Such delay reasons might be brought on by the network protocol's port becoming saturated, protocol errors, packet fragmentation, provider upstream outages, routing issues, etc. The most frequent cause of lag is packets queuing up at any gateway during the transmission process. The gains (in percentage) for the various simulation tries are 7.41, 6.67, 14.29, and 12.20 for changing nodes (100–400) of the latency parameter.

Given that a network's power consumption is an important consideration, Table 1 and Fig. 3 show that the smart middleware strategy achieves better results than the greedy heuristic approach.

The graphical results of Fig. 3 latency study show that when compared to the traditional greedy heuristic-based technique on numerous nodes, the latency factor is improved. The latency factor is a significant statistic that should be lower to increase network performance.

5.1.2 Power dissipation

An important issue that may be resolved at both the node and network levels is energy usage. Taking into account the radio system is one of the major power consumers. Measuring techniques are often established, typically based on the input current of the power supply and measurements supposing a constant voltage of the supply. When transient

Table 2 Analysis of power dissipation on multiple nodes

Number of nodes				
Architectural comparison	100	200	300	400
Middleware VANET architecture	219	319	378	310
Greedy heuristic approach	222	326	429	321

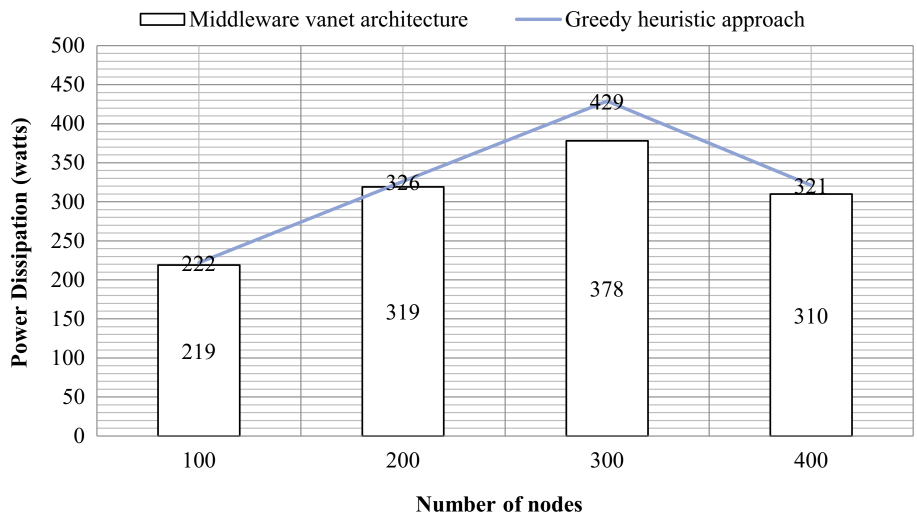

Fig. 4 Power dissipation versus number of nodes

occurrences occurring at a low rate need to be accurately quantified, this type of computation must fulfil inconsistent limits.

Timing information should also be provided from a distributed perspective since it helps characterise network function and working life by providing spatial–temporal coordinates for energy consumption measurements. The installation of wireless sensor networks requires large battery power consumption or the use of power scavenging. The IEEE 802.15.4 network specification, the inherent power quality of those radios, a power-efficient protocol, and low-powered microelectronics are all used by wireless sensors.

The improvements (in percentage) for the various simulation efforts are 0.68, 1.09, 6.32, and 1.74 when Power Dissipation is evaluated on a variety of node counts. Given that a network's power consumption is an important consideration, Table 2 and Fig. 4 show that the smart middleware method achieves better results than the greedy heuristic approach. Various simulation attempts are used to estimate the power dissipation factor. The delay factor is better compared to the traditional greedy heuristic-based technique on several nodes, as shown in the graphical and tabular results. This variable determines the amount of energy and power dissipation that may cause the network environment to crash.

Table 3 Analysis of throughput on multiple nodes

Number of nodes				
Architectural comparison	100	200	300	400
Middleware VANET architecture	91	94	85	97
Greedy heuristic approach	81	91	83	92

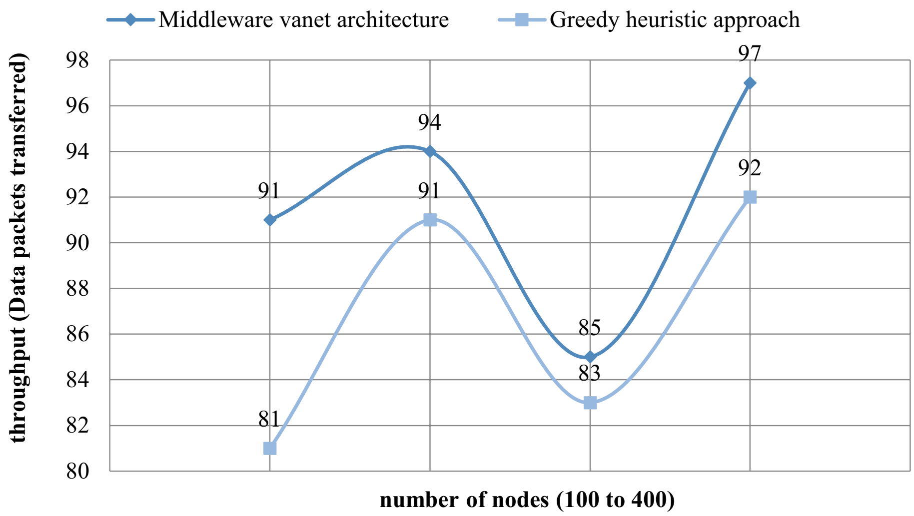

Fig. 5 Throughput on node variations

5.1.3 Throughput

The data rates that are sent to all terminals inside a network are called throughput and combined data capacity. The load in the packets is defined in terms of arrival rate (μ) and throughput using the queuing concept, where load is evenly reduced every time. The volume of data transferred from a source at any one moment is known as throughput. For a high-capacity network to operate, packet delivery is crucial. Low flows point to problems like packet loss and unsatisfactory or sluggish network performance are caused by missing packets.

The evaluation of throughput on nodes ranging from 100 to 400 is shown in Table 3 and Fig. 5, with gains of 5.81, 1.62, 1.19, and 2.65, respectively, for each simulation attempt. It is highest when using intelligent middleware and lowest when using greedy heuristics. Nevertheless, the expansion holds true throughout all simulation tries. Another research objective that is connected with the goal of improving performance is the examination of throughput. The delay factor is better compared to the traditional greedy heuristic-based technique on numerous nodes, as shown in the graphical and tabular results.

5.2 Analysis of cumulative performance

The throughput of a network determines the amount of data or the number of data packets that may be sent within a certain amount of time. The amount of data that can be sent over a certain period of time is characterised as bandwidth, which is commonly measured in bits per second.

Table 4 Analysis of cumulative performance on multiple nodes

Number of nodes				
Architectural comparison	100	200	300	400
Middleware VANET architecture	93	94	85	95
Greedy heuristic approach	82	90	81	92

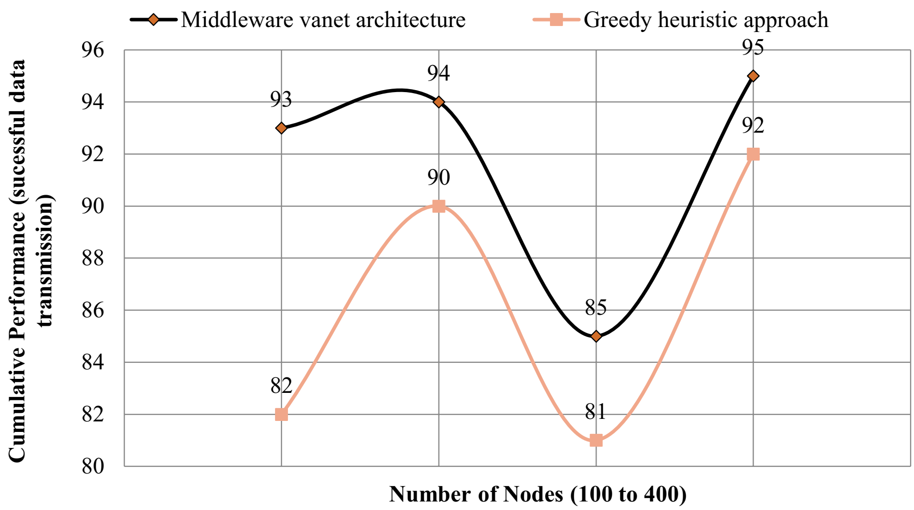

Fig. 6 Cumulative performance on nodes versus data transmission

Sometimes relevant are the following measures:

- Commonly defined bandwidth in bits/seconds
- The rate of transmission of information is the real rate
- Delay of decoding from the sender to the recipient is primarily a feature of the signal time and processing time
- Jitter shift in packet delay at the receiver
- Error rate of percentage of the overall sent out amount of corrupted bits.

Table 4 and Fig. 6 demonstrate that for the various simulation efforts, the improvements (in percentage terms) for the evaluation of Cumulative Performance on nodes ranging from 100 to 400 are 6.29, 2.17, 2.41, and 1.60, respectively. The cumulative performance is examined in light of several aspects so that the overall efficacy may be assessed. The delay factor is better compared to the traditional greedy heuristic-based technique on various numbers of nodes, as shown in the graphical and tabular statistics.

6 Overall results and discussion

The following tabulation depicts the number of simulations attempts on 500 nodes and with existing and proposed architectural comparison and in order to measure the performance.

Table 5 For latency measurement between simulation attempts

Latency															
Architecture comparison →	**Smart middleware architecture**	**Greedy Heuristics approach**	**Improvements (%)**	**Smart middleware architecture**	**Greedy Heuristics approach**	**Improvements (%)**	**Smart middleware architecture**	**Greedy Heuristics approach**	**Improvements (%)**	**Smart middleware architecture**	**Greedy Heuristics approach**	**Improvements (%)**	**Smart middleware architecture**	**Greedy Heuristics approach**	**Improvements (%)**
Simulation attempt scenario ↓	**100 nodes**			**200 nodes**			**300 nodes**			**400 nodes**			**500 nodes**		
1	2.5	2.9	7.41	2.1	2.4	6.67	1.8	2.4	14.29	1.8	2.3	12.20	1.3	1.6	10.34
2	2.1	2.4	6.67	2.3	2.7	08	2.1	2.4	6.67	2.1	2.4	6.67	1.5	2.3	21.05
3	2.3	2.6	6.12	2.2	2.6	8.33	2.4	2.6	04	2.4	2.7	5.88	2.2	2.4	4.35
4	1.9	2.1	05	1.5	2.1	16.67	1.7	2.2	12.82	1.7	2.4	17.07	1.6	2.3	17.95
5	2.5	2.9	7.41	2.1	2.4	6.67	1.8	2.4	14.29	1.8	2.3	12.20	1.3	1.6	10.34

Table 6 For power dissipation measurement between simulation attempts

Power dissipation															
Architecture comparison →	**Smart middleware**	**Greedy heuristics**	**Improvements (%)**	**Smart middleware**	**Greedy heuristics**	**Improvements (%)**	**Smart middleware**	**Greedy heuristics**	**Improvements (%)**	**Smart middleware**	**Greedy heuristics**	**Improvements (%)**	**Smart middleware**	**Greedy Heuristics**	**Improvements (%)**
Simulation attempt scenario ↓	**100 nodes**			**200 nodes**			**300 nodes**			**400 nodes**			**500 nodes**		
1	219	222	0.68	319	326	1.09	378	429	6.32	310	321	1.74	421	491	7.68
2	212	235	5.15	289	299	1.70	318	389	10.04	289	310	3.51	428	456	3.17
3	243	263	3.95	291	298	1.19	319	349	4.49	276	296	3.50	410	425	1.80
4	253	274	3.98	278	289	1.94	312	378	9.57	256	278	4.12	429	436	0.81
5	251	274	4.38	289	297	1.37	238	298	11.19	327	376	6.97	418	429	1.30

Table 7 For throughput measurement between simulation attempts

Throughput															
Architecture comparison →	**Smart middleware**	**Greedy heuristics**	**Improvements (%)**	**Smart middleware**	**Greedy heuristics**	**Improvements (%)**	**Smart middleware**	**Greedy heuristics**	**Improvements (%)**	**Smart middleware**	**Greedy heuristics**	**Improvements (%)**	**Smart middleware**	**Greedy heuristics**	**Improvements (%)**
Simulation attempt scenario ↓	**100 nodes**			**200 nodes**			**300 nodes**			**400 nodes**			**500 nodes**		
1	91	81	5.81	94	91	1.62	85	83	1.19	97	92	2.65	95	93	1.06
2	92	84	4.55	93	90	1.64	87	85	1.16	95	94	0.53	95	92	1.60
3	95	89	3.27	93	89	2.20	90	87	1.69	97	89	4.30	94	90	2.17
4	92	85	3.95	94	91	1.62	91	89	1.11	94	84	5.62	93	88	2.76
5	90	84	3.45	97	94	1.57	92	80	6.98	91	86	2.82	91	89	1.11

As the values in Tables 5, 6, and 7, we can see that there are five simulation attempts for the measurement of latency, power dissipation, and throughput; when the nodes are decreasing, the performance of system can be checked, is also increased, and is giving more efficient results in terms of latency (i.e. is reduced). But when the nodes are increased in simulation attempts, there is requirement of GPU instead of a CPU. So, by upgrading the system requirements, nodes can be increased and on higher number of nodes the network will perform reliably, efficiently and will give high throughput.

6.1 Declaration

This study highlights the crucial role of Intelligent Transportation Systems (ITS) in improving road safety and public health. Through integrating vehicular ad hoc networks (VANET) and middleware architecture, the findings indicate improved traffic flow and safety, aligning with present studies on accident reduction and sustainable urban development. The study of overall performance metrics—latency, power dissipation, throughput, and standard overall performance—displays the operational benefits of these technologies. However, numerous barriers exist. The focus on precise overall performance metrics may additionally overlook user reputation and external elements like climate. The reliance on heuristic techniques along middleware and VANET networks raises questions on the robustness of the outcomes and their long-term effectiveness in real- world scenarios. Practically, implementing VANET systems entails considerable infrastructure investment, which may be tough in growing regions. The dynamic nature of traffic complicates data collection, necessitating sophisticated simulations. Moreover, variations in vehicle types and driving behaviours had been no longer completely explored, warranting further studies to enhance expertise of ITS deployment demanding situations.

6.2 List of abbreviations

See Table 8.

Table 8 List of abbreviations

Abbreviations	Description	Abbreviations	Description
ITS	Intelligent Transportation Systems	LoRaWAN	Long-Range Wide-Area Network
VANET	Vehicular Ad hoc Network	VCoT	Vehicle Cloud of Things
V2I	Vehicle to Infrastructure	QoS	Quality of Service
V2V	Vehicle to Vehicle	QoE	Quality of Experience
EIA	Electronic Industry Alliance	TWRNs	Traffic Wireless Relay Networks
RSU	Roadside Unit	AI	Artificial Intelligence
WiMax	Worldwide Interoperability for Microwave Access	LAN	Local Area Network
GPS	Global Positioning System	GPU	Graphics Processing Unit
IoV	Internet of Vehicles	CPU	Central Processing Unit
IoT	Internet of Things	3G	Third-Generation Mobile Communication
DMRE	Distributed Multi-Agent Reinforcement Learning	HPPO	Hybrid Proximal, Policy Optimisation
WVs	Worker Vehicles		

7 Conclusion and future prospects

V2V is a wireless communication link with VANET and is a version of MANET which is now an emerging field. Due to significant node mobility, the VANET example is a wireless multi-hop network with a constraint on quick topological changes. Middleware is a type of software that connects modules or organisational frameworks and requires complex segmentation for many parameters. In this article, middleware allows essential services like competition, transactions, threading, and messaging. It also supports numerous contact modes, such as sync invocations, the passage of asynchronous communication, and the cooperation of well-liked objects. Here, the focus is on middleware, which includes tools for managing administration, application facilities, email, authentication, and APIs as well as advanced wireless modules, effective algorithms, database servers, software servers, and content management systems, among other things.

The work is analysed on diverse performance parameters in terms of latency, power dissipation, throughput, and overall cumulative performance on various nodes. The cost factor decides the time–space complexity and resource optimisation perspectives and should be minimum when all the factors are compared to the classical greedy heuristic-based approach on multiple nodes to achieve a higher degree of performance in the network.

VANETs are presented with a range of technical difficulties in implementation and management due to decreased stability, scalability, low compatibility, and low intellect. Several natural methods have been devised to solve scientific problems in various fields up to now, but a wide variety of algorithms exists with higher performance factors. Any of the ways that can be learned are Ant Colony Optimisation, Cuckoo Hunt, Bee Algorithm, Particular Swarm Optimisation, Bat Algorithm, Simulation Application, Flower Pollination Algorithm, and several more. Because new problems are continually emerging where current approaches are not successful, nature-based algorithms are a highly active field of study which can be integrated for future scope. Meta-heuristic methods can be extended to a variety of problems separate from the issue. The combination of nature-based algorithms with meta-heuristic methods shows promise for tackling future scopes and a wide variety of problems beyond the immediate difficulties at hand when new challenges develop where conventional approaches may not be successful.

Author contributions
Conceptualisation was performed by RK and PS; methodology by XC and PS; software by MS; validation by XC, PS, and MS; formal analysis by TK; investigation by TK and PS; resources by XC; data curation by PS; writing—original draft preparation by MP and TK; writing—review and editing—by PS and MP; visualisation by RK; supervision by RK; project administration by PS; funding acquisition by XC. All authors reviewed the results and approved the final version of the manuscript.

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Availability of data and materials
Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

Declarations

Ethical approval
Not applicable.

Competing interests
The authors declare no conflicts of interest to report regarding the present study.

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