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Advanced Vehicular Ad-Hoc Network (VANET) technology using Blockchain

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Abstract: With rapid expansion in wireless technology, telecommunication is most explored fields of research and Vehicular Adhoc networks in particular. In this review, a VANET design is presented which focuses on high quality video streaming using data dissemination between high speed vehicles. It is achieved using best forwarder in every ring centered on the aggregate of all vehicles available in the network to reduce multi-hop routing. The emergency messages are authenticated using blockchain to have improved security of sensitive information. A comparison of routing protocols namely AODV, OLSR and DSDV is also presented in this review
Keywords: VANET, multi hop routing, blockchain, ad-hoc networks, AODV, OLSR, DSDV

I. INTRODUCTION

Vehicular ad hoc networks (VANETs) are very popular networks since they bring out more efficiency while transferring the data and meet all the safety requirements. They are used in many applications such as road transport, dangerous location alert, monitoring traffic, real-time video relay, calamity alert and a lot more. Robust routing protocols are needed to avoid collision of vehicles. The routing protocols of VANETs are classified as topology routing, dissemination routing, opportunistic routing and geographic routing according to their mode of operation.

By considering many important factors such as traffic, communication, reaction time into account, the algorithm is mainly used to reduce the number of accidents as far as possible. TrafficAware Routing (TAR) protocols are very powerful since they can handle frequent communication disruptions efficiently and hence, they are used in real-time traffic control. Many sensors are placed in the vehicles to broadcast the messages through the network. This plays a major role in preventing serious accidents. In this work transmission of alert messages, announcements, warning messages, calamity messages across the Ad-hoc networks is presented. The communication can be between the vehicles or between the vehicle and other infrastructure. Road Side Unit (RSU) plays a very important role in both cases as there are possibilities of fake messages being transmitted that could misguide the network and do harm more than good.

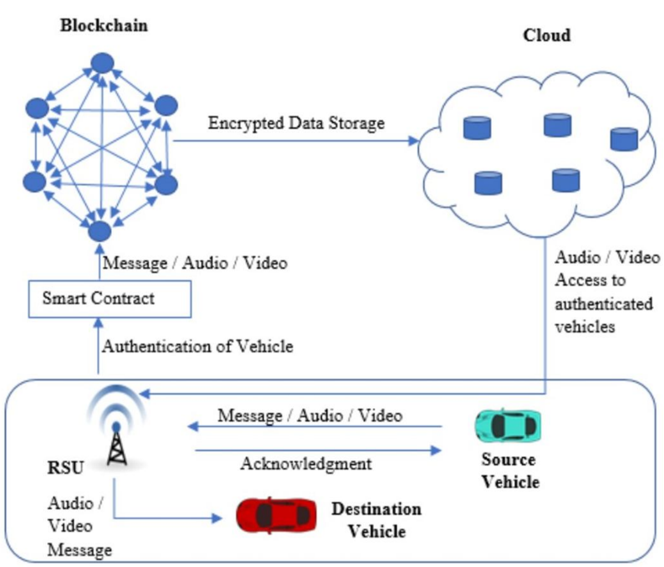

Fig. 1. Blockchain Integration for enhanced Security

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The location-based routing protocols are categorised as Geographical zone two tier routing (GZTR), Greedy perimeter stateless routing (GPSR) and Greedy border superiority routing (GBSR). The location of vehicles is changing every instant due to their very high speed. Therefore, location-based becomes an obvious necessity. GZTR divides the coverage area into different zones and allocates packets to every relay node of all the zones. It also identifies the best route between the source and the destination by taking both density and distance into consideration. Sometimes, protocols are chosen based on its ability to deliver the bulk of data packets also while maintaining integrity. In that view, protocols such as Ad-hoc On-demand Distance Vector (AODV) protocol, Optimized Link State Routing (OLSR) protocol, Destination Sequenced Distance Vector (DSDV) are used. In this work, the 3 protocols are compared using NS3 simulation software in the same system through the performance parameters notably the end to end jitter delay, packet loss ratio, throughput and packet delivery ratio.

The main criteria presented in this study is to use a single VANET environment to handle both video transmission routing and data dissemination. The channel with better quality is selected to reduce the packet loss which incidentally is one of the major challenges faced during video transmission. The number of routing hops are reduced by adopting ring partition-based routing which also elevates the routing performance.

II. METHODOLOGY

A. Error Messages-Data Dissemination

Data dissemination is provides an additional layer of safety to transmitted messages in order to safeguard nearby fast moving vehicles. The beacon messages are sent from the vehicle to the RSU. The beacon message is basically a frame of data consisting of six different fields namely the speed of the vehicle, vehicle number, timestamp, the type of service, the length of message and the deadline. Frame structure of a beacon message is shown below in Figure 2.

Vehicle ID Number	Vehicle speed	Timestamp	Vehicle position	Type of service	Length of message	Time limit

Fig. 2. Beacon Message Configuration

The identity is given to every vehicle in order to evade the interference from nearby or unauthorized vehicles. The speed of the vehicle is calculated as:

$$A = \sum_{b=1}^{M(a)} \frac{|X_a - X_{ab}|}{M(a)} \quad (1)$$

where, the average speed 'A' is calculated by approximating the speed of the vehicle 'a' and 'ab', which represents b^{th} neighbouring vehicle. (i.e., 'a'), 'X_{ab}' represents the speed of the b^{th} vehicle, 'M(a)' denotes the number of neighbouring vehicles. The position of the vehicle is evaluated after the prediction and inclusion of average speed in the beacon which is calculated as follows:

$$P_u = p + \text{Vehicle speed} \times (t_2 - t_1) \times \cos\theta$$

$$(2)$$

$$Q_u = q + \text{Vehicle speed} \times (t_2 - t_1) \times \sin\theta$$

Where 'P_u' and 'Q_u' denote the current vehicle position and previous vehicle position respectively, 't_1' and 't_2' denote the current time instant and previous time instant respectively, θ is phase which is calculated as:

$$\theta = \tan^{-1}\left(\frac{l_2 - l_1}{m_2 - m_1}\right) \quad (3)$$

Where (l_2,m_2) denotes the current position and (l_1,m_1) denote the previous position of the vehicle respectively.

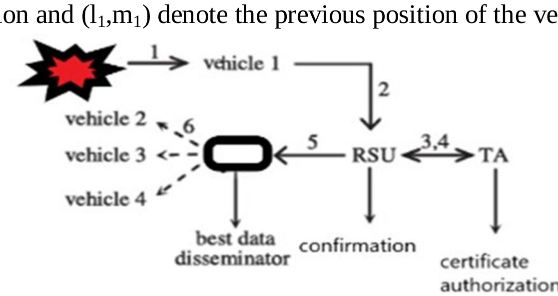

Fig. 3. Error Message Dissemination Process

Fig 3 shows the data dissemination process for error messages in which the message is checked for authenticity in order to encrypt using ECC (Elliptic Curve Cryptography) algorithm and its hash value is stored in the blockchain cloud. Post encryption, the message is saved in the cloud and forwarded to RSU which sends it to the neighbouring vehicle available in the network. The vehicle selection for broadcasting is based on following parameters:

$$\sum_{j=1}^{n} Pj = \text{Number of Adjacent Vehicles}_{\ j} + \text{Current Position}_{\ ,}\ \text{Speed of vehicle}_{\ j}$$

Where, ‘P_j’ denotes the vehicle present in the network. The timestamp field denotes the moment at which the beacon packet gets expired. The service type is very vital since it conveys whether the message is of emergency or non-emergency nature which also is of variable nature. The time limit field is the last field which denotes the particular instant before which the packet determines its desired destination which can be single or multiple.

$$\alpha_C = F_C + 1$$
$$\beta_C = T_C + 1 \tag{4}$$

In equation (4), the terms (F_c, T_c) denote the false count number and true count Number respectively where false count gets incremented by 1 for each drop in the packet and non-relevant packets are forwarded undesirably or when false position of information is taken when error message gets transmitted. Similarly, when the packet is successfully delivered, the true count is incremented by 1.

B. Ring Partitioning

In order to improve the performance of routing, ring partitioning is executed. All the vehicles available in the network easily communicate with each other due to the constitution of multi-hop routing. Ring partitioning is deployed in order to reduce the number of hops, thereby facilitating multi-hop transmission of data and information.The source vehicle selects the route for data transmission by requesting the nearest RSU. The first step involves the measurement of Euclidian Distance using the formula:

$$U_{(S,t)} = \sqrt{(S - S_C)^2 + (T - T_C)^2} \tag{5}$$

where, $U_{(S,t)}$ denotes the Euclidian Distance and P(s,t) indicates the coordinate of vehicles and P(S_c, T_c) indicates the coverage restraint of the vehicle. Also,

$$X_0 = \frac{x}{n} \tag{6}$$

(7)

$$a_1 = \frac{\sqrt{X_0}}{\pi} \quad \text{X=} \tag{8}$$

$$L_{sj} = \frac{R}{U(S,T)} \tag{9}$$

where the term X_0 denotes the average area of each ring and the term X denotes the area of the inner circle, ‘n’ is the total number of rings to be constructed. The radius for the same is predicted using:

$$a_k = \sqrt{\frac{X_0 + \pi a_{k-1}^2}{\pi}} \tag{10}$$

where k is iterated from 1 to n-1 and also explains the iterative formation of the ring until the vehicle has reached the destination. The next step involves selection of the best forwarder from all the rings and conduction of multi-hop routing in order to transmit the data packets successfully. Based on the destination, the number of rings is altered, which also varies the hop count.

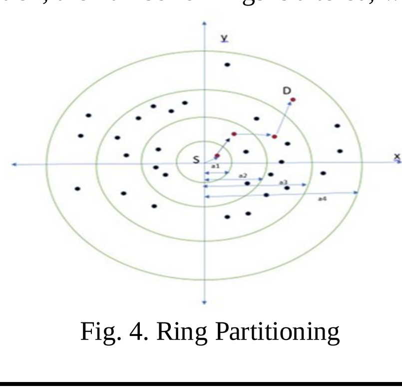

Fig. 4. Ring Partitioning

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Fig 4 illustrates the concept of Ring partitioning. 'a1' is the ring at which the source vehicle is situated and 'a4' is the ring at which the destination vehicle is situated. Three intermediate hops are present between source and destination. The aggregate value of each vehicle is used to select the best forwarder post partitioning which is calculated as follows:

$$P_j = \alpha N_{adj} + \beta Z_i + \gamma S_j + \delta L_{si} + TS_j$$

where the aggregate value of 'j' vehicles is calculated taking certain parameters into consideration namely: N_{adj} which denotes the number of adjacent vehicles, Z_{tj} which denotes the direction of moving vehicle, S_j which denotes speed of the vehicle, L_{sj} which denotes the stability of the link, T_{sj} which denotes the true score and the four constants α, β, γ, δ are related as $\alpha+\beta+\gamma+\delta=1$. The vehicle situated in the ring with a higher value of P_j is declared as best forwarded vehicle. The procedure is repeated for each ring, the destination vehicle is reached successfully.

C. Lossless Video Transmission

As the vehicles are move at very high speed, transmitting the video effectively becomes the challenge in the case of VANETs as they can be monitored online from cloud storage and due to high mobility of the vehicles, huge loss in packets are a possibility which leads to poor quality of the video. To address these issues, the quality of the channel is validated before transmission of video frames which are of three types and are mentioned as follows:

- **I-Frame**(intra frame) which contains complete information of images of the frame and undergoes independent decoding.
- **P-Frame**(predicted frame) which enhances compression by deducting temporal redundancy.
- **B-Frame**(bidirectional frame) which undergoes decoding with help of other frames.

and therefore I-frames are regarded as vital ones in comparison to other frames and are given more priority. They are transmitted through the most trusted channel with the highest quality for video transmission. In this method, the initial values of all the frames are counted. The quality of the channel is determined by three factors namely state information, signal to noise ratio (SNR) and bandwidth of the channel and is given by:

$$Q_k(t) = B_k lb\left(1 + \bar{C}\frac{S_k}{I_k}\right) * SI_k$$
$$\bar{C} = \frac{-1.5}{\log(5 \times BR)} \tag{12}$$

where $Q_k(t)$ represents the channel quality for k channel, B_k represents the bandwidth of the k^{th} channel, S_k and I_k are SNR values and S_{Ik} represents state information of k^{th} channel which is used to determine the state of the channel (whether it is ON or OFF), c denotes the limiting factor. The vacancy of the channel is calculated with help of a transition diagram. Suppose α and β represent the 'ON' and 'OFF' state probability respectively, the video transmission is improved by choosing the appropriate channel. The state of the channel depends upon the state probability. The ON and OFF states are determined as follows:

$$ON_k = \frac{1-\beta C(k)}{2-\alpha I(k)-\beta C(k)}$$
$$OFF_k = \frac{1-\alpha I(k)}{2-\alpha I(k)-\beta C(k)} \tag{13}$$

where the state may be either 'ON' or 'OFF' and the measure is utilised to identify the channel quality. If the channel quality is good, consequently the video transmission has a good quality.

III. ROUTING PROTOCOLS

In general, routing protocol defines methods and rules that are needed for routing/connecting different nodes present in a network. It is needed to have the best route while connecting keeping in mind to reduce the losses. This is one of the most important challenges when VANET is considered. There are mainly three types of routing protocols namely:

A. Proactive Routing Protocols

In *Proactive Routing Protocols* all the nodes keep the information related to the subsequent nodes (i.e) all the nodes constantly maintain the information related to the other nodes to ensure that there is no interruption in the path. These include *OLSR Protocol* and *DSDV Protocol*

1) *OLSR Protocol:* IN OLSR protocol, any update in a connections are broadcasted to all the nodes in a network thereby increasing the network overhead. OLSR transmits two messages namely the ping and a message to control the topology where Pings are used to find the data about the connection status and topology control message is used to broadcast the information to neignbouring nodes with the help of multi point relay (MPR) which reduces the overload much similar to pure link state protocol
2) *DSDV Protocol:* DSDV Protocol is an enhanced version of Bellman Ford Algorithm which resolved the problem of looping in routing by maintaining the sequence number information of each node. In DSDV, the metric used is the number of hops, which avoids looping problems during routing

B. Reactive Routing Protocol

In contrast to proactive protocol, reactive protocols do not contain information about all the nodes and has only information of nodes that it encounters instead. Protocols included here are *AODV Protocol*, *DSR Protocol*, *DYMO Protocol*

1) *AODV Protocol:* In Ad-hoc on demand Distance Vector Protocol, the nodes transmit the information related to the topology only on demand. Each node in the network acts like a router which gets the route information whenever there is a need to transmit data
2) *DYMO Protocol:* In Dynamic MANET on demand protocol is an addition to AODV which can be implemented as both reactive and proactive protocols
3) *DSR Protocol:* Dynamic Source Routing protocol is a productive protocol made for multi hop WANET routing. It is a auto adjust and configuring protocol that does not require any administration. The two-main functions of DSR protocol are route discovery and maintenance.

C. Hybrid Protocol

This is a combination of both proactive and reactive protocol which reduces the overhead and delays mainly attributed to the periodic sharing of topology information. It has been proven to improve the efficiency, throughput but trades off with latency in new routes. In this work, three protocols are considered for comparison study namely AODV, DSDV and OLSR protocol(s) and are simulated using NS3 simulation software.

IV. SIMULATION SETUP

Ns3 simulator is a network simulator that performs network simulations and when combined with SUMO creates a VANET environment. It is a real-time application since real-time road map is used and real-time traffic is monitored. Primarily, C++ is used since it supports a considerably good Graphical User Interface (GUI). Ns3 is a C++ based simulation library and framework which provides an IDE which consisting of elliptical base, l graphical runtime environment and other tools. It is widely used as a platform for scientific as well as industrial purposes.

It has a modular architecture which makes the simulation kernel to embed seamlessly. It requires a linux operating system base for simulation. NS3 framework is used as a base along with other frameworks so that it can be utilised for simulating vehicular networks.

In this system, an Ns3 model is developed from modules in which communication takes place through error messages. All the modules are programmed in C++ with the Ns3 configuration and parameters being held as it logs the simulation runs. Post simulation, the code is linked with the user interface and simulation kernel and all the simulation results are logged along with the scalar and vector files which inturn are visualized using NetAnim software. The animation verifies the routing and the communication taking place between the vehicles

V. RESULTS

In the simulation process as explained earlier, Open System Map Web Wizard tool which is a component of SUMO software is used to generate real time vehicular data as shown in Fig 5. The simulation then generates the vehicular data as shown in Table I, which explains the number of vehicles generated in the stipulated simulation time (150s in this system), total route length, depart delays and the time loss factor.

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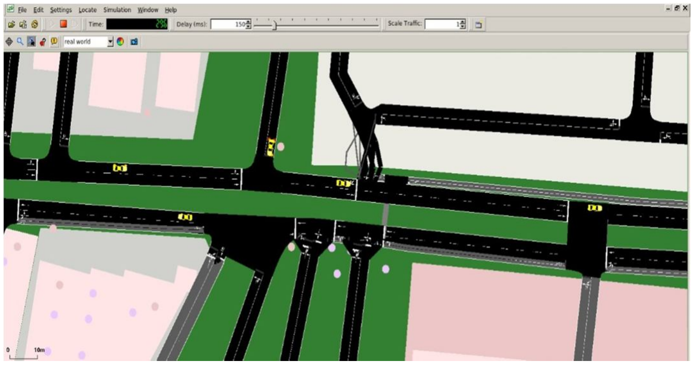

Fig. 5. Real time vehicular data generation

Duration	822ms
Real time Factor	642.336
Vehicles Inserted	97
Vehicles Running	0
Vehicle Waiting	0
Route length average	1740.25
Duration	141.25
Waiting time	5.54
Time Loss	38.54
Depart Delay	-0.49

Using the above obtained data, the files are embedded into the VANET construction code which is then run and simulated with the help of NS3 simulation software. Network Animation (NetAnim) tool which is an essential component of NS3 simulation software used in visualization and simulation of networks is used as shown in fig 6. The process is repeated by choosing the three protocols (AODV, OLSR, DSDV) as mentioned earlier and the results obtained from the simulation are tabularised in Table II as shown below

Quantity	AODV	OLSR	DSDV
Total Sent Packets	5950	146	336
Total Received Packets	315	111	272
Total Lost Packets	5635	35	64
Packet Loss Ratio	75.23	23.17	19.35
Packet Delivery Ratio	24.77	76.83	79.65
Throughput(Kbps)	22.309	2.235	2.623
End to End delay(ms)	3.75	2.41	8.22
End to End Jitter Delay(ms)	3.27	1.17	1.75
Total Flod ID	16	6	10

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The VANET shows consistent results with all the three mentioned protocols. In order to improve security of the data and sensitive

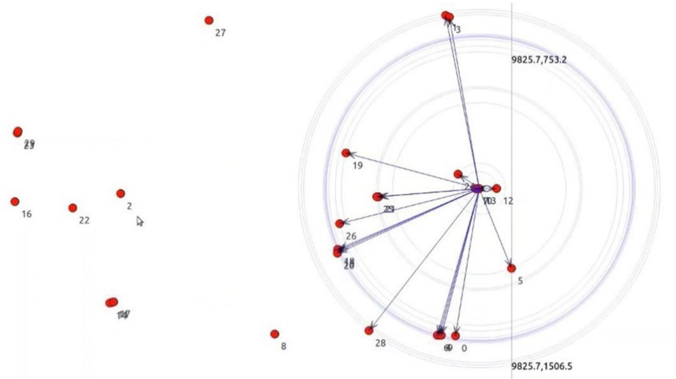

Fig. 6. Animated visualization of routing and ring partitioning

information, blockchain is then integrated into the design code and the simulation yields a much improved security of data through hashed form of storage in the cloud. An improved blockchain integrated routing mechanism is visualized from the simulation runs as shown below in Fig 7.

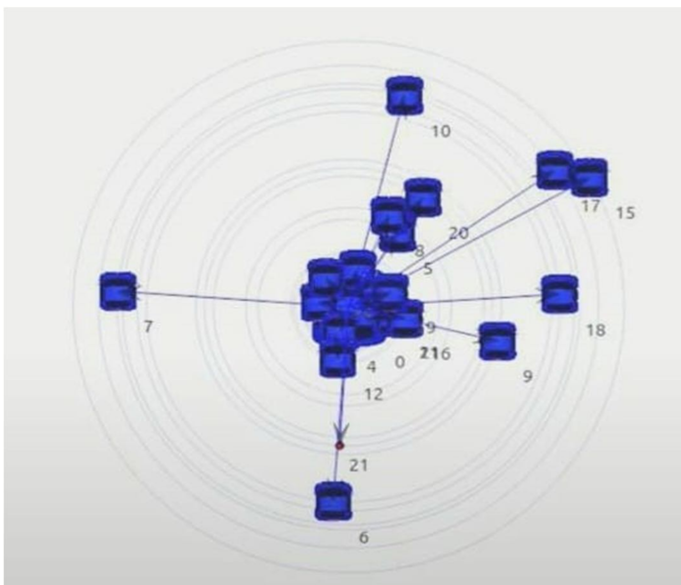

Fig. 7. Routing with blockchain integration-enhanced security

VI. CONCLUSION

In the proposed system, the overall performance of the VANET is enhanced and the interference from unauthorized vehicles are prevented. The hash value stored in the cloud is close to 256 bits. The proposed system minimizes the probability of road accidents significantly by employing sequenced communication strategies.

The security of the transmission is reaches its maximum level with the incorporation of blockchain technology. In the proposed system, three important concepts of VANETs are proposed namely lossless video transmission, error message dissemination and routing. The routing begins with hexagonal partitioning and best forwarder is selected for data transmission. A Verification is done before dissemination to evade any vulnerability. Video transmission is the challenge due to packet losses, deteriorating quality and so on. These issues are sorted through priority assignments to the video frames and Channel State identification is executed to select the most reliable channel which helps to transmit large videos even though the vehicle is highly mobile. It is also eminent that AODV protocol is more efficient in terms of throughput and number of packets sent where as OSLR and DSDV protocols are efficient in places where low loss systems are required. Depending upon the system requirements, the relevant protocol is dynamically selected.

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