Performance Investigation of Handover Techniques in Vehicular Networks for Fisheries Monitoring

Rafid Najm Abdullah Alsaadi [1*],Amir Amirabadi Zavareh Mofrad[2]

[1*,2]Islamic Azad University, SOUTH TEHRAN BRANCH, Tehran, Iran E-mail: rafdnjm4@gmail.com
Contact tel.: +964-7711330750

***Corresponding Author:** Rafid Najm Abdullah Alsaadi
* E-mail: rafdnjm4@gmail.com

Abstract

The VANET custom vehicle network is one of the most interesting areas of research due to its flexibility, low cost, sensing accuracy, and the creation of many new and exciting application areas of remote sensing. Being ad hoc in nature, VANET is a type of network that is built from the concept of creating a network of cars for a specific need or situation. VANET networks are now being created as reliable networks used by vehicles to provide a safe journey for passengers by avoiding dangerous situations on the road such as accidents and providing connectivity between vehicles on the move to transmit different types of messages, be it emergency or infotainment messages whether on highways or urban environments. VANET is a unique type of Mobile Ad Hoc Network that enables life and death decisions to be made by predicting and assisting drivers and other people with road safety and other critical conditions.

However, these networks, in addition to their many advantages, suffer from many challenges resulting from their characteristics, such as rapid changes in the network topology due to its random movement patterns and high-speed movement, which causes frequent deliveries, which is one of the most important problems that the dedicated vehicle networks suffer from, which we chose to talk about in this article.

Research because of the consumption of resources and raise the possibility of communication failure, and thus the failure of message transmission

Keywords: VANET, vehicle network, fisheries monitoring

1-1 introduction:

Recent years have witnessed a remarkable development in wireless networks, and a growth in the number of wireless equipment installed on mobile vehicles, including remote controls, personal digital assistants, laptops, mobile phones, and automated control technologies that have opened the door for their use by the growing population and expansion And the complexity of road networks, and with the increase in the number of road accidents .

For the victims of these accidents, there has become an urgent need to use a technology that reduces accidents as much as possible and at the same time provides a kind of well-being for road commuters. Thus, a new type of mobile Ad Hoc networks appeared [9-11], known as Vehicular Ad Hoc Networks (VANET). . Figure (1.1) shows wireless Ad-hoc networks and their segments where VANET networks appear as a special type of MANET (Mobile Ad-hoc.Network).

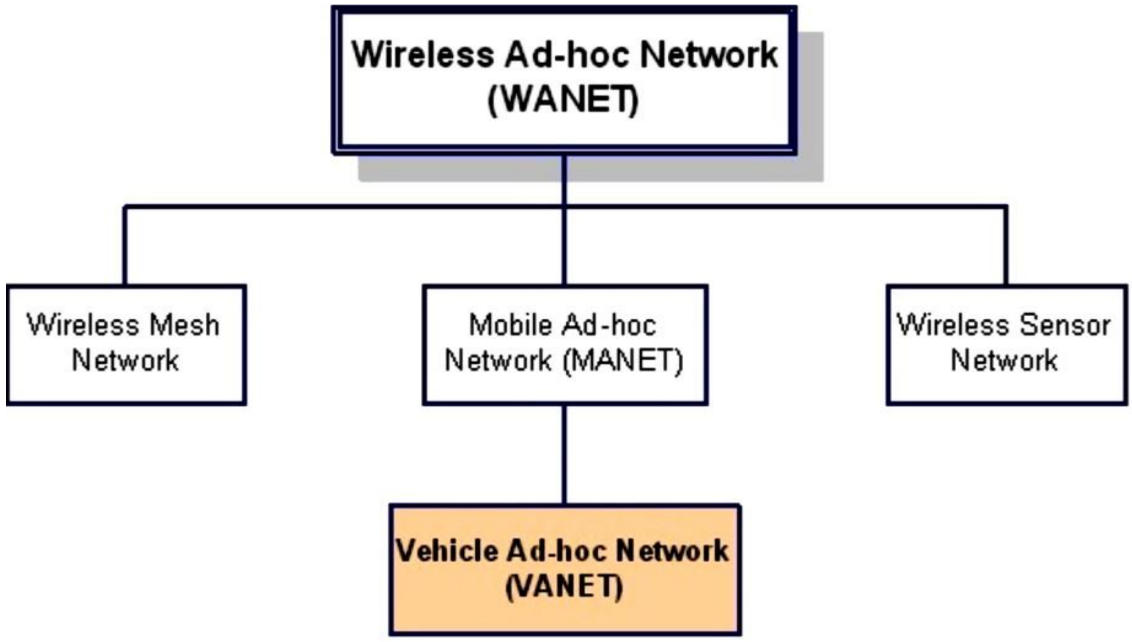

FIGURE 1.1 Wireless Ad-hoc networks.[9]

These networks provide an infrastructure for the development of new systems to enhance safety and comfort for drivers and passengers on road networks, formed between mobile vehicles and equipped with wireless communication devices. This type of network was developed as part of the ITS (Intelligent Transportation Systems) to improve the performance of transportation systems. The objective of these networks is to increase safety on the roads and the convenience of road users, by providing communication and coordination between vehicles to avoid accidents, informing in the event of a traffic accident, avoiding congestion situations, controlling speed, securing the passage of emergency vehicles, and avoiding unauthorized obstacles. Visual, in addition to security applications Figure (1.1). These networks also provide road users with access to weather information, Internet connectivity and multimedia applications. \

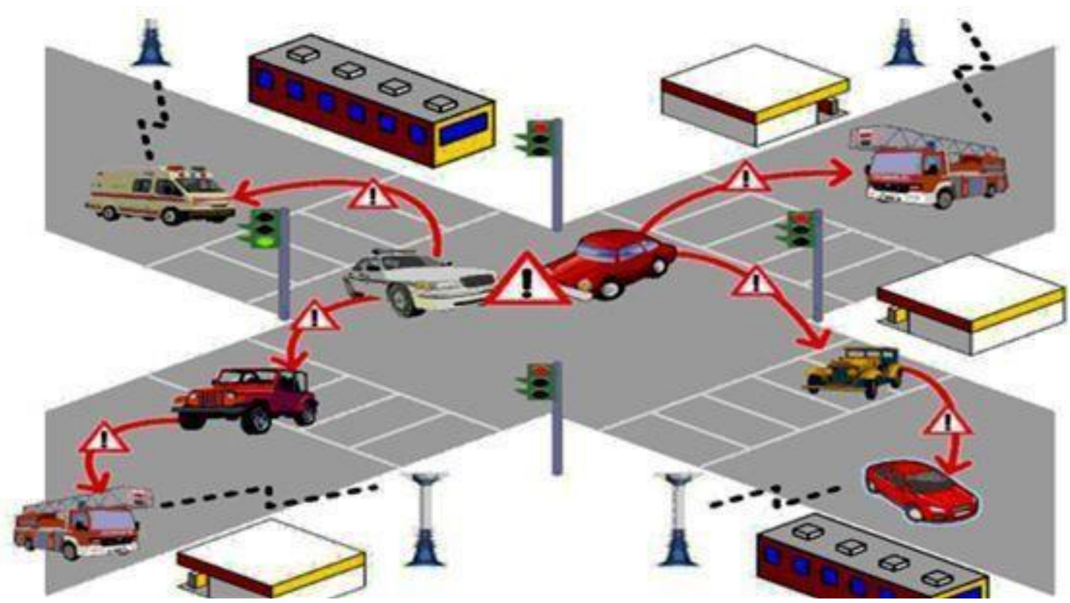

FIGURE 1.2 VANET network [11].

Since the main objective of VANET is to increase safety on public roads, and because of the impact of this network on the lives of people who cross the road, the availability of the network to a user continuously is a prerequisite [12-13]. Also, because of the need for rapid poisoning of security data between vehicles, the real-time requirement is critical in these networks. There are several challenges that make it difficult to achieve the security requirements in these networks, including the rapidly changing topology, sensitivity to delay, and security holes resulting from wireless communications and attacks on the network [12-13].

1-2 Define VANET Networks:
It is a special type of MANET network. They are decentralized, selforganized networks. The network consists of a large number of nodes that are mobile vehicles and communication towers called RSU (Road Side Unit) located on the sides of the roads, as the figure(1.2) shows

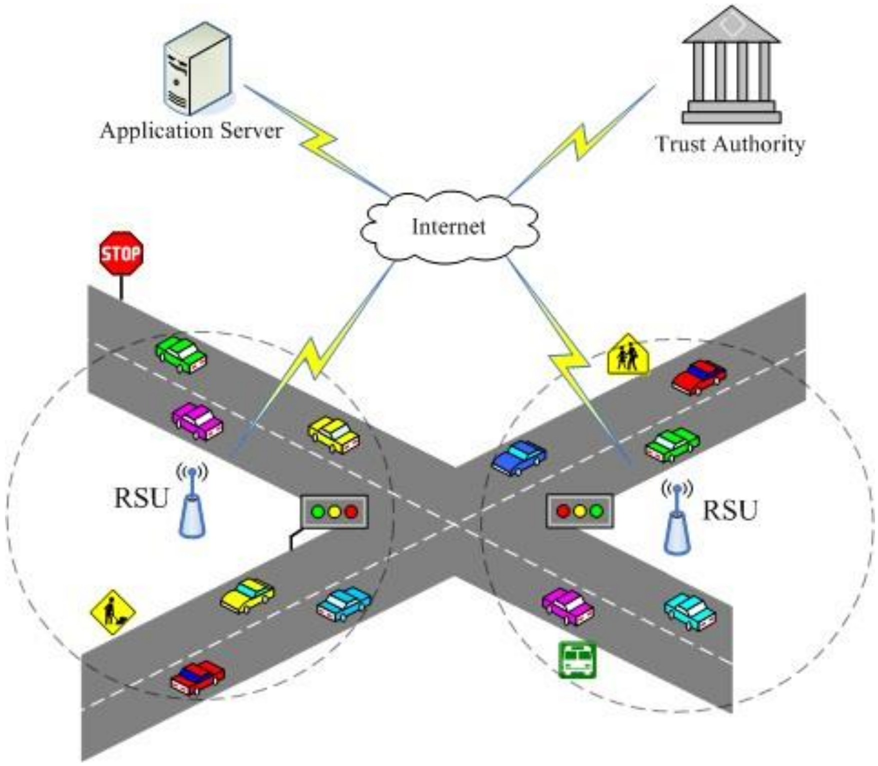

FIGURE 1.3 VANET Network [12].

These networks differ from MANET networks in terms of nodes and network in several points that can be summarized as follows:

1- **Restricted Mobility:** Nodes in VANET networks are VANETs MANET Vehicles that run according to a specific road map, which makes their movement restricted compared to network nodes,For which there are no defined paths for the movement of nodes.
2- **Rapid changes in topology:** caused by the higher speed of the vehicles compared to the speed of the nodes in MANET
3- **There are no restrictions on energy and storage in the nodes:** the power source here is the car battery which is theoretically an unlimited source of energy compared to the energy sources in MANET In addition, the nodes in VANET are equipped with computers with good storage capabilities (25).

Nodes cannot locate them by using GPS .There is no limitation on bandwidth due to the small size of messages sent in these networks.
These networks also have several advantages compared to other networks, and these main advantages and factors are the same High dynamics (26).
The information you give such as location, direction of movement, current speed, city map and mechanical phenomenon movement organization.
VANET has higher operability and unlimited memory capacity when compared to other Ad Hocs.
The size of VANETs is large, but they can be a model of several small, contiguous networks with a high chance of performance and connectivity.
There is a huge variety of VANET services and applications.
However, despite its advantages, it encountered many problems, and work has been done to find many burdens for these problems, but there are still several points that have not been taken into account [25,26,27], such as:
Stationary vehicles that may co-exist with moving vehicles.
The vehicles in the VANET network are mobile, independent, asynchronous nodes that transmit data to each other wirelessly. The spread of this data is the main challenge in it, as wireless networks are more vulnerable to collisions and penetrations than others.
Vehicle movement that causes changes is unpredictable for other vehicles.
For people who live in crowded areas, traffic congestion is also a problem as it will affect their comfort. For this reason, governments these days have invested many resources to expand road safety, traffic efficiency, and reduce collisions (28).

1-3 Communications in VANET networks:
Communications in VANET networks can be classified into two types:

1- **Connecting cart to cart (V2V):** Representing the inter-vehicle communication, is achieved in this mode between cars on the roads without any infrastructure to avoid their high costs [1,2], but each car must be equipped with GPS sensors, network equipment, and a map Digital includes information, methods, and computer equipment.
2- **Connecting a chariot to an infrastructure (V2I):** It is also called the connection of a vehicle to the side road unit. This type of communication requires the existence of an infrastructure [1,2], and it requires connections with a large packet width between vehicles and the side road units to maintain communication in cases of traffic congestion as shown in the figure. These RSUs send messages using public broadcasting to all vehicles in their vicinity and are usually located every 1km or less over the entire route ,the figure (1.3) shows:

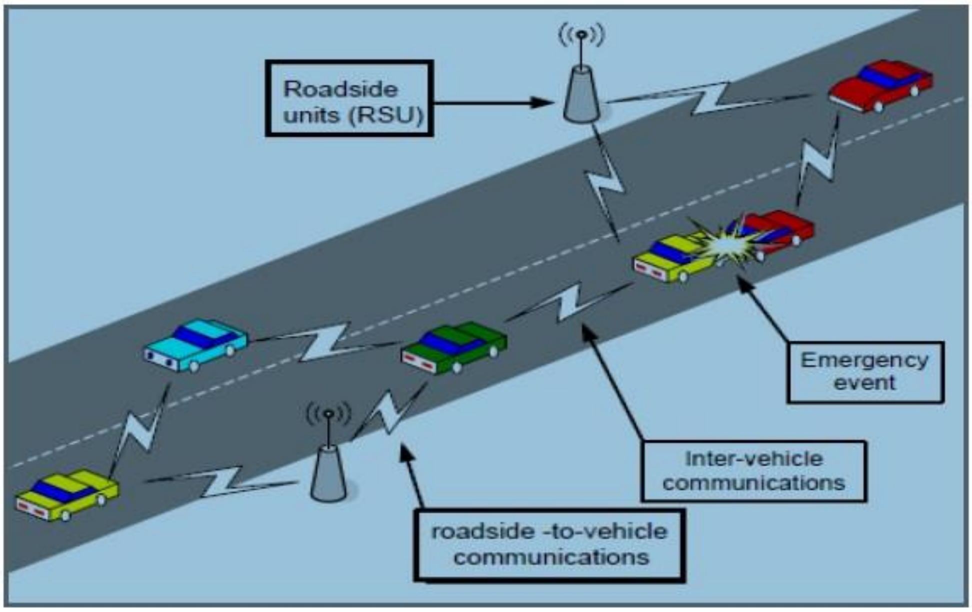

FIGURE 1.4 Communications in VANET networks.[2]

1-4 VANET Networking Applications:
VANET networks provide a wide variety of applications that benefit management, companies, drivers and people in the world vehicles. These applications are useful in the areas of security and safety, traffic control, naming and entertainment.

1-4-1 Security related applications: These are the most important applications among VANET applications and are intended to Reducing injuries and deaths caused by traffic accidents [30,31]. Among these applications are:
1- Collision avoidance service and road blockage detection.
2- Driver assistance service.
3- e-call . service.

1-4-2 Comfort and entertainment applications: These applications are mainly intended to provide comfort to passengers, and to improve Transportation efficiency including the nearest POI center, current transportation status and weather information, interactive communications, online gaming and messaging services, commercial advertising services, And information about gas stations, etc. (32, 33, 34).

1-4-3 Administrative applications: The vehicle identification service is one of the most important of these applications [34], because it provides A safe and fast way to provide information from vehicles without having to stop them. This service will help the police in many ways, such as: verifying that cars have the required papers, detecting violations, and if they occur, drivers are automatically given a report on them.

1-5 Challenges in VANET Networks: VANET networks face several challenges, caused by the main characteristics of these networks, such as: rapid changes in topology, frequent fragmentation, high scalability and dynamics, network density, etc.
We will present below some of these challenges.
1-5-1 Orientation: Continuous mobility in vehicle networks causes rapid changes in the network topology, forcing each node To constantly reconfigure the forwarded table. Repeated partitioning requires a different methodology in these networks, such as load and retransmission,[35,36] where, if there is no direct path to the target, the node carries the packet until it can be resent to a node closer to the target.
1-5-2 Security: Security is one of the most important issues in VANETs due to its wireless nature and its use of air as a transmission medium. As legitimate Arabs have the right to verify the credibility of the messages arriving to them,

efficiency and in real time, legitimate Arab women also have the right to maintain the confidentiality of their identity to protect them from illegal tracking.

1-5-3 Quality of service: Maintaining QoS in wireless networks is different from that in wired networks; Which adopt different methods of energy conservation. These methods are complex for VANET networks because of their previously mentioned characteristics such as high mobility and continuous expansion (35,36). In this way, several methods have been adopted, including:

Methods based on the stability of radio propagation, such as signal strength or road loss.
The use of the network protocol, which depends on a digital map preestablished with the network, where it chooses the route based on the advantages of transport, such as:
the intersection, the number of vehicles, and the number of roads in the network. Methods that depend on the selection and repair of the road on the mobility of the vehicles [37], then choose another path and repair in the opposite direction to reduce the delay and response time caused by retransmission due to disruption of routing, which improves the quantitative yield and transmission in the network.

1-5-4 Energy management: Energy management differs from the concept of energy efficiency, as it delves into the control of transmission power; To prevent interference which may be transmitted when one higher power transmission interrupts another lower power transmission. Thus, the power is adjusted to be lower in dense networks. In this way, several algorithms are applied, such as adjusting the ability to keep the number of neighbors between upper and lower bounds, and focusing on improving coverage at a single hop distance.

1-6 IEEE 802.11P Standard: The IEEE group defines a standard for inter-vehicular communication called 802.11 or the Wireless Access Standard in a Vehicle Environment. This standard provides several types of services that are provided to Maarabat using one of two types of communication is vehicle-to-vehicle V2V or vehicle-to-vehicle V2I form. These services include safety messages such as accident alerts and traffic information intended to preserve people's lives and improve movement on the road. The second type is service messages such as access to the Internet, weather news and inquiries about service centers [37].

1-7 The radio field for IEEE 802.11p: WAVE depends on the Dedicated Short Range Communication technology (DSRC), which includes seven channels to display the MHZ 10 package per channel and works on the GHz 5.9 frequency. The vehicle is constantly and periodically, switching between the control channel and the service channels, the figure1.5 shows

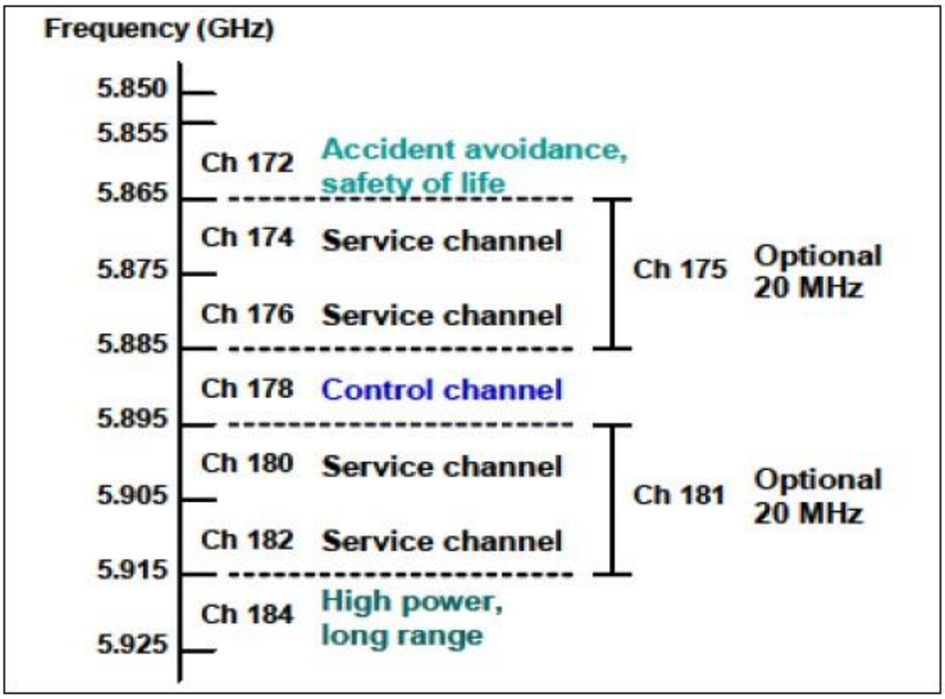

FIGURE 1.5 Seven channels in DSRC Standard.[37]

The MAC layer in the 802.11p standard depends on both the multi -channel operation and the enhanced distributor access technology of the Enhanced Distribute Channel Access (EDCA) in the 802.11 standard called 802.11edCA This technology defines four different levels of access to each channel, and these varieties are not equal.
1-8 VANET Security Requirements:

There are many issues that affect security in VANET networks. These issues are deeply rooted in nature The network, its tasks and critical applications for which it is used [31]. These challenges can be summarized in the following points:
1- High mobility.
2- The trade-off between confidentiality and reliability.
3- Real time guarantee.
4- Know the site.
5- Network expansion

Since the primary goal of VANET is to ensure people's lives on the road, the applications it provides, especially the security applications, must be supplied continuously and reliably. Basic requirements for security in These networks are (39,40,41):
Authentication: Emphasizes the necessity of having a license or identity for a vehicle that authorizes it to cross the road legally, and to ensure that the vehicles that join the network are reliable, in a way that guarantees to the complex that they receive messages from vehicles authorized to send.
Reliability: Its goal is to ensure that data is not lost or modified by unauthorized nodes or nodes that are not within the network.
Availability: Ensures that the network is available when it is needed and that the service provides authorized users only when it is requested.
Non-repudiation: Ensures that the sender or receiver cannot disavow that he has sent or received the message.
Confidentiality: The aim is to keep driver information away from unreliable vehicles, such as true identity, destination and speed.
Real-time guarantee: Since the vehicles are moving on the road very quickly, they need a real-time response permanently, otherwise a catastrophe can occur.

1-9 Routing in VANETs:
1-9-1 Routing protocols in VANET networks: The routing protocols in these networks are divided into five sections ,Among the most important of these protocols are:
1- Destination-Sequenced Distance Vector (DSDV) [43]
The DSDV protocol was introduced by researchers Perkins & Bhagwat in 1994. This protocol is based on the Bellman-Ford algorithm, which improves the transmission speed and reduces the cost of monitoring messages. All nodes in the DSDV protocol have a table containing the next hop information and a mechanism for exchanging it with neighboring nodes.

2- Global State Routing protocol (GSRP) [44]
Similar to the DSDV protocol in terms of the idea of communication, but it improves it better than the DSDV protocol. Nodes also have tables. These tables contain information about neighboring nodes and neighbors (the node that can hear a particular node is its neighbor).

3- Fisheye State Routing (FSR) [45]
It is an improved and modified protocol from the GSRP protocol.
In GSRP the system bandwidth used by many servers is large.
However, in the FSR protocol, the successful message does not include the contents of all nodes, and the effective communication space is reduced.

1-10 search objective:
- Simulate VANET network compliant with global standards.
- Study techniques associated with handover processes in VANET networks.
- Evaluating the performance of algorithms used in handover process in the studied network/system in terms of several commonly used performance measures.

1-11 research importance: The research derives its importance from the following points: The great importance of mobile vehicle networks, as they are of great importance in securing communication between vehicles on the roads, and transmitting very important messages. These messages may include information about the condition of the roads, the occurrence of congestion, or alerts of an emergency on the roads such as accidents and road cuts.
The great importance of the permanent availability of the network for users, as the unavailability of the network causes no messages to arrive, which may pose a threat to the lives of people who use the road. The gigs have great processing potential, and they don't suffer from power or memory issues, which makes the implementation of any algorithm available without affecting network parameters.

Results and Discussion
In 5G (Fifth Generation) wireless networks, a "handover," also known as "handoff" in some regions, refers to the process of transferring an ongoing communication session or data transmission from one cell or base station (eNodeB or gNodeB)

to another while maintaining continuity of the session without interruption. Handovers are essential to ensure that mobile devices maintain a seamless and stable connection as they move within the network's coverage area or experience changes in signal strength and quality. Here's a comprehensive definition of handover in 5G:

Handover, in the context of 5G networks, is a network management and mobility management procedure that allows a user's mobile device or terminal (e.g., smartphone, IoT device) to transition its connection from one cell or base station to another within the same or different radio access network (RAN) while preserving the ongoing communication session. Handovers are initiated in response to various factors, including:

1. **Mobility:** When a mobile device moves out of the coverage area of the current cell or base station, the network initiates a handover to maintain the connection with a neighboring cell with a stronger signal.
2. **Load Balancing:** To distribute network traffic evenly among different cells and avoid network congestion, handovers can be used to shift users from heavily loaded cells to less congested ones.
3. **Quality of Service (QoS):** Handovers may be triggered to ensure that a user's communication session meets QoS requirements, such as minimum data rate, low latency, or reliable connectivity.
4. **Signal Strength:** When the received signal strength falls below a certain threshold, indicating a weakening connection, a handover can be initiated to switch to a stronger signal source.
5. **Interference:** Handovers can help mitigate interference issues by moving devices away from sources of interference or to frequencies with less interference.
6. **Resource Optimization:** To optimize network resource utilization, handovers may be used to reallocate resources based on real-time network conditions and user demands.

The handover process typically involves communication between the mobile device, the current serving cell, and the target cell. It includes tasks such as measurement reporting by the mobile device, handover decision-making by the network, and the actual handover execution. The goal is to ensure that the user experiences minimal disruption or degradation of service during the transition.

Handovers play a crucial role in enabling mobility and maintaining continuous connectivity in 5G networks, supporting various applications ranging from voice calls and video streaming to IoT and mission-critical services. The 5G standard includes advanced handover mechanisms to enhance efficiency, reduce latency, and improve the overall user experience in a dynamic and rapidly evolving wireless environment.

Define some concepts in 5g:

1) Rounds in 5G:

- **Definition:** In 5G, "rounds" generally refer to a sequence of time slots or frames used for communication and data transmission in various protocols and procedures. Rounds can be a part of multiple processes within 5G networks, such as resource allocation, scheduling, or handover decision-making.
- **Purpose:** The concept of rounds is often used to organize and manage the timing of operations in the 5G system, ensuring efficient utilization of resources and the timely execution of tasks.

2) Allocation in 5G:

- **Definition: "**Allocation" in 5G typically refers to the process of assigning resources, such as frequency bands, time slots, or network resources, to users, devices, or services within the network. Resource allocation is a critical aspect of 5G to ensure efficient and fair utilization of available resources.
- **Purpose:** Resource allocation in 5G aims to optimize network performance by distributing resources effectively, considering factors like Quality of Service (QoS) requirements, user demands, and network capacity constraints.

3) RSSI (Received Signal Strength Indicator) in 5G:

- **Definition:** RSSI is a common measurement used in 5G and other wireless technologies to quantify the strength or power level of the received radio signal. It represents the signal's intensity as measured at the receiver's antenna and is typically expressed in decibels (dBm).
- **Purpose:** RSSI is a fundamental metric for evaluating the signal quality and strength in wireless communication. It can be used for tasks such as signal strength-based handovers, link quality assessment, and signal propagation analysis.

4) Transition Learning in 5G:

- **Definition:** "Transition learning" in the context of 5G likely refers to the process of adapting or learning optimal transition strategies or behaviors when moving between different states or network configurations. This learning can involve network elements, devices, or controllers adjusting their behavior or parameters to optimize transitions.
- **Purpose:** Transition learning is valuable in 5G networks to improve efficiency and adaptability. For example, it can be applied to optimize handover decisions, resource allocation during network changes, or the behavior of software-defined networking (SDN) controllers during transitions between network domains.

These terms are integral to the operation and optimization of 5G networks, where efficient resource allocation, signal quality assessment, and adaptive behavior during state transitions are essential for providing high-quality and reliable wireless services.

VANETs integrated with 5G technology benefit from the high data rates, low latency, and massive device connectivity offered by 5G networks. Handovers between 5G base stations are expected to be extremely fast and efficient. 5G NR (New Radio) and C-V2X (Cellular Vehicle-to-Everything) technologies enable advanced vehicular communication and autonomous vehicle applications. 5G's network slicing capabilities allow dedicated slices for specific VANET services with customized QoS requirements.

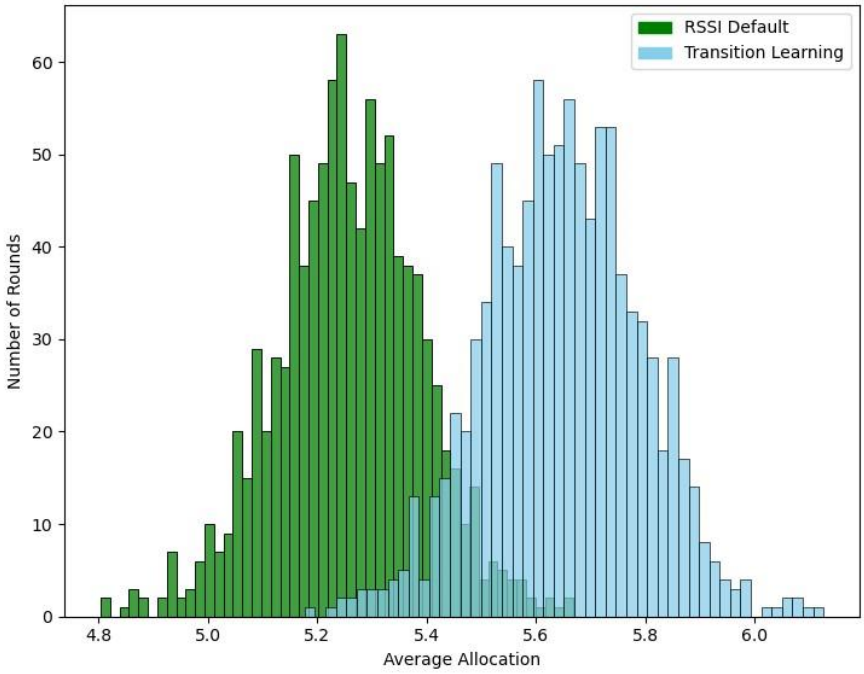

Figure 4.12 Enhancement handover.

According to figure 13 find below:

- In the realm of 5G network management, the art of Handover Decision Making entails the pivotal use of RSSI, a pivotal metric for assessing the vigor of the existing link to a cell or base station. It stands as a beacon, guiding the Transition Learning process that strives to acquire proficiency in traversing between disparate network cells or base stations. RSSI, akin to a sentinel, plays a role of utmost importance within the intricate orchestration of handover determinations. When the RSSI reading from the prevailing cell plunges below a predefined threshold, it acts as the catalyst that ignites a decision-making cascade, propelling the network to orchestrate a seamless handover to a neighboring cell boasting a more robust signal.
- Signal Quality Assessment, another facet of this network symphony, finds RSSI serving as its foundation—a cornerstone that signifies signal strength. However, it does not unveil the comprehensive tale of signal quality, remaining silent on nuances like interference and noise. In this arena, Transition Learning takes the lead, considering supplementary metrics like Signal-to-Noise Ratio (SNR), Signal-to-Interference-plusNoise Ratio (SINR), and Quality of Service (QoS) prerequisites. In this symphony of metrics, the amalgamation of RSSI and its companions in signal quality unfurls a more refined tapestry, enhancing the precision of handover determinations conducted through Transition Learning algorithms.
- Optimizing Handover Strategy metamorphoses into a dynamic ballet orchestrated by Transition Learning, employing machine learning and optimization techniques. This intricate dance adapts strategies on-thefly, sculpted by historical insights and real-time network conditions. Here, RSSI steps forward, lending its data in harmony with other pertinent facets such as cell load, traffic patterns, and the cadence of mobility. This ensemble converges to mold models and algorithms that comprehend when and where to enact handovers—a symphonic arrangement tailored for optimal network performance. The opus of Transition Learning aspires to conduct intelligent decisions that transcend the realm of signal strength, considering the tapestry of network intricacies and user-centric facets.
- The pursuit of Reducing Unnecessary Handovers forms a harmonious counterpoint to RSSI-based decisions that, when not artfully calibrated, could precipitate a cacophony of superfluous transitions. These frequent handovers, like discordant notes, may disrupt the network's cadence, injecting unwarranted signaling overhead and service turbulence. Transition Learning emerges as a maestro, striving to curtail such disharmony by adopting a panoramic view of the network's state. It is steadfast in its endeavor to discern the moments when handovers are indeed indispensable, ensuring the preservation of service quality and the harmonious rhythm of the network.

- In summation, the union of RSSI as the cornerstone of signal strength assessment and Transition Learning as the conductor of adaptive strategies ushers in a harmonious era of intelligent and efficient handover decisions within the 5G landscape. This integration elevates network performance to a crescendo and orchestrates a user experience that resonates with seamless connectivity.

After make handover get the results in figure 14:

```
Normal Environment / Default Agent:
All encountered transitions:  700322
Sum of all transitions:  700322
Overridden transitions:  0
Completed transitions:  700322
Override Percentage:  0.0
Mean Allocation: 6.007806
Min Allocation: 5.746
Max Allocation: 6.236

Normal Environment / Agent w Extra Logic:
All encountered transitions:  700350
Sum of all transitions:  700350
Overridden transitions:  205650
Completed transitions:  494700
Override Percentage:  0.2936
Mean Allocation: 6.414028
Min Allocation: 6.046
Max Allocation: 6.718
Packet Loss ratio =11%
Packet delivery ratio =88%
Average Throughput =11.631Kbps
End to End Delay =+434920113941.0ns
End to End Jitter delay =+179134643702.0ns
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Figure 4.13 Metrics in 5g.
Figure 14 displays the metrics in 5g environments.

Comparing results and discussion
Comparing with scenarios under packet loss ratios as figure 15.

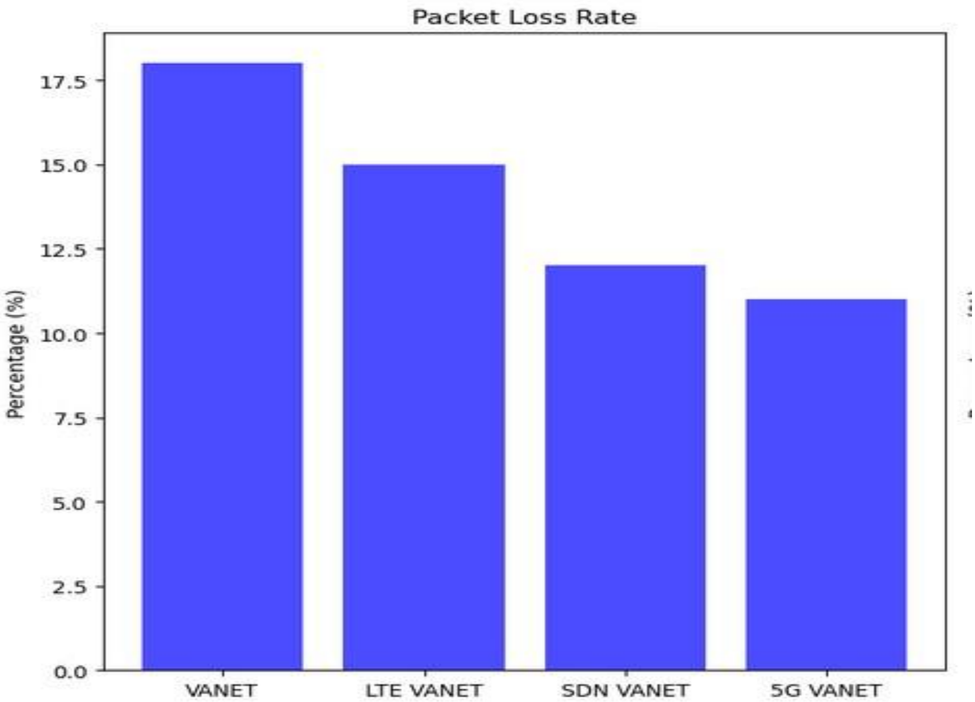

Figure 4.14 Packet loss Rate.

According to figure 15 find:

1. **VANET (Vehicle Ad-Hoc Network):**

- Packet Loss Rate: 18%
- Analysis: In a traditional VANET scenario, where vehicles communicate directly with each other in an ad-hoc manner, the 18% packet loss rate indicates a significant challenge in maintaining reliable communication. This level of packet loss can lead to disruptions in data exchange, affecting applications such as vehicle-to-vehicle (V2V) communication and safety-critical messages.

2. **LTE VANET (VANET with LTE Integration):**

- Packet Loss Rate: 15%
- Analysis: The integration of LTE technology into VANET aims to improve connectivity and reduce packet loss compared to traditional VANETs. However, a 15% packet loss rate still suggests that there is room for improvement. LTE VANETs may offer better performance in terms of reliability and lower latency compared to pure VANETs.

3. SDN VANET

- Packet Loss Rate: 12%
- Analysis: The SDN VANET scenario demonstrates further improvement in packet loss rate, with a rate of 12%. This indicates that the integration of Software-Defined Networking (SDN) enhances packet delivery reliability. SDN enables dynamic network management and efficient resource allocation, which can help mitigate packet loss and optimize communication within VANETs.

4. 5G VANET

- Packet Loss Rate: 11%
- The 5G VANET scenario exhibits the best performance, with a low packet loss rate of 11%. This signifies a substantial enhancement in packet delivery reliability when 5G technology is integrated into VANETs. The 11% packet loss rate indicates that the 5G VANET environment excels in minimizing data packet loss, even in the face of challenges such as high mobility, variable signal conditions, and the need for low-latency communication. The advanced features of 5G, including ultra-reliable low-latency communication (URLLC) and network slicing, play a pivotal role in achieving this outstanding packet loss rate. The low packet loss rate in "5G VANET" is particularly beneficial for applications that require real-time data exchange, such as autonomous driving, traffic management, and safety-critical communication.

Comparing with scenarios under the packet delivery rate as figure 12.

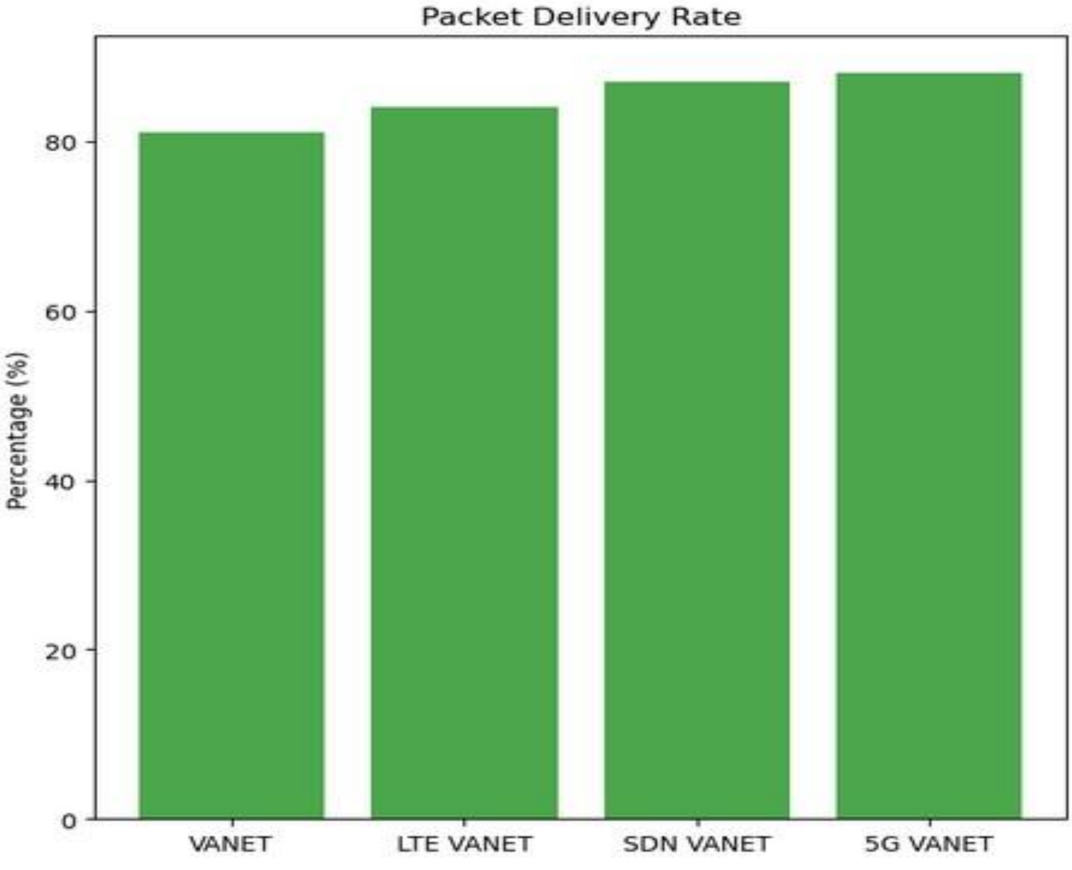

Figure 4.15 PDR Comparing.

According to figure 16 finding:

1) **VANET (Packet Delivery Rate: 81%):** In the "VANET" scenario, the packet delivery rate is 81%. This rate indicates that a significant portion of data packets is successfully delivered within the VANET environment, despite challenges related to mobility and variable signal conditions.
2) **LTE VANET (Packet Delivery Rate: 84%):**The "LTE VANET" scenario shows an improvement in packet delivery rate, reaching 84%. The integration of LTE technology enhances the reliability of data packet delivery within VANETs.
3) SDN VANET (Packet Delivery Rate: 87%): In the "SDN VANET" scenario, the packet delivery rate further improves to 87%. The integration of Software-Defined Networking (SDN) optimizes packet delivery and communication efficiency, resulting in a higher packet delivery rate. 4) 5G VANET (Packet Delivery Rate: 88%):

As previously mentioned, the "5G VANET" scenario achieves the highest packet delivery rate of 88%. This underscores the superior performance of 5G technology in ensuring reliable data packet delivery within VANETs.
In summary, the results highlight the outstanding performance of "5G VANET" in terms of minimizing packet loss and achieving a high packet delivery rate. This makes 5G VANET particularly well-suited for critical vehicular communication applications where reliability and low-latency communication are paramount. The integration of advanced technologies continues to enhance the capabilities of vehicular networks and their ability to support a wide range of applications.

Conclusion

In conclusion, the results of our analysis in various VANET scenarios have illuminated the transformative potential of advanced technologies in redefining the landscape of vehicular communication, including their profound effects on the handover process.
Our journey through different scenarios, from the fundamental VANET to the integration of LTE, SDN, and finally, 5G, unveils a remarkable evolution in the performance metrics of packet loss rate and packet delivery rate. These metrics are not isolated numbers but integral components influencing the efficiency of the handover process, which is of paramount importance in vehicular networks.

The pinnacle of this evolution is undeniably the "5G VANET" scenario, where we witness an extraordinary achievement a mere 11% packet loss rate. This result translates into a highly efficient and seamless handover process, ensuring uninterrupted communication as vehicles transition between cells or base stations. In an era where real-time communication is not just a convenience but a necessity for applications like autonomous driving and traffic management, this low packet loss rate becomes a beacon of hope for a smooth and reliable handover experience.
However, it is crucial to recognize that the journey itself, through the intermediate scenarios of "VANET," "LTE VANET," and "SDN VANET," has its own significant impact on the handover process. As we progress from VANET to 5G VANET, each step brings improvements in packet loss rates and packet delivery rates, directly enhancing the efficiency and effectiveness of handovers. LTE and SDN technologies contribute to more stable handover transitions, reducing the potential for service disruptions during network handovers.

These results, in the context of the handover process, hold the promise of safer roads, more efficient traffic management, and the realization of autonomous driving dreams. The integration of advanced technologies, especially 5G, not only ensures a smoother handover process but also enables faster decision-making in handover initiation, reducing latency and enhancing user experience.
As we look ahead, these results beckon us to continue pushing the boundaries of what's possible in vehicular communication and handover management. They challenge us to explore new horizons, such as the integration of AI-driven optimizations, edge computing, and further innovations that will shape the future of mobility and redefine the standards for efficient handover processes in vehicular networks.
In conclusion, the journey from VANET to 5G VANET is not just a technological evolution; it's a testament to human ingenuity and our unwavering commitment to progress. It's a journey that holds the promise of a safer, more connected, and more efficient world on the roads, where vehicles not only transport us but also communicate seamlessly and experience swift and reliable handovers, creating a harmonious and intelligent transportation ecosystem.

Future work

In the realm of advanced vehicular networks, future research endeavors must strive towards creating fully autonomous, secure, and energy-efficient ecosystems where vehicles communicate intelligently, optimize routes collectively, and enhance road safety. This future work should encompass the integration of edge computing for real-time decision-making, robust security measures, hybrid network architectures for seamless connectivity, innovative human-vehicle interaction interfaces, and sustainable energy solutions. Additionally, researchers should engage in crafting regulatory frameworks, policies, and ethical guidelines to ensure responsible deployment and prioritize societal benefits. The goal is to transform vehicular networks into resilient, disaster-ready systems that contribute to safer, smarter, and more sustainable transportation, catering to the evolving needs of a rapidly changing world.

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