Incentive-Aware Data Dissemination in the Vehicular Ad-hoc Networks

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DEDICATION

This thesis is dedicated to all the deserving children who do not have access to quality education especially young girls.

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Glory be to Allah (S.W.A), the Creator, the Sustainer of the Universe. Who only has the power to honour whom He please, and to abase whom He please. Verily no one can do anything without His will. From the day, I came to NUST till the day of my departure, He was the only one Who blessed me and opened ways for me, and showed me the path of success. Their is nothing which can payback for His bounties throughout my research period to complete it successfully.

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LIST OF SYMBOLS, ABBREVIATIONS AND ACRONYMS

VANETs: Vehicular ad-hoc Networks

DTNs: Delay Tolerant Network

MCS: Mobile Crowd Sensing

ONE: Opportunistic Network Environment

Abstract

Intelligent vehicles are advanced to that point that they can sense, gather, communicate and exchange information for vast areas due to their abundant resources and large movement patterns. Vehicles can act as relay nodes to deliver data from one end to another. This new emerging technology is also known as Crowd-sensing. In crowd-sensing mobile devices such as modern vehicles are used to sense, collect and deliver the information from one end to another acting as relay nodes or exchange the required information in the absence of internet connectivity.However these relay nodes act selfishly in nature to conserve their battery power, storage space, bandwidth and other resources making them non-cooperative, due to which it effects overall network performance.In this paper we proposed a mobile crowd-sensing in VANETs and considered the nodes selfishness. To deal with the problem of nodes' selfishness, we have proposed an incentive mechanism to encourage the nodes to cooperate in opportunistic environment for data forwarding using vehicular ad hoc communication. After that we have done simulations using The Opportunistic Network Environment(ONE) simulator. The results shows that by handling the non-cooperative selfishness of nodes network performance has improved.

Keywords: VANETs, Crowd-Sensing, Selfishness, Relay Nodes, Incentive mechanism, ONE simulator

Chapter 1

Introduction and Motivation

The continuous evolution of sensing technologies, mobile computing, and communication systems has paved the way for the emergence of Crowd Sensing (CS) as an innovative paradigm in the realm of sensing and computing. This transformative approach has been catalyzed by the widespread proliferation of smart mobile devices and the remarkable advancements in intelligent vehicles. These modern devices, be they smartphones or sophisticated automotive systems, come equipped with an extensive array of sensors and robust computational resources.

A distinctive feature of this paradigm is the ability of these devices to routinely gather and exchange a wealth of data, encompassing both local and environmental information. The sensors embedded in these devices, numbering in the tens, are capable of capturing diverse aspects of the surroundings, ranging from location-based data to environmental conditions. Moreover, the computational prowess within these devices enables them to process and analyze this data in real-time.

This collective capability presents a profound opportunity for these devices to collectively contribute to large-scale sensing and communication tasks. The seamless integration of numerous devices operating in unison allows for the creation of a distributed network, where each device functions as a data collection point and a communication node. This collaborative approach obviates the necessity for deploying an extensive array of specialized sensor networks, as the inherent functionalities of these widely adopted devices are harnessed for broader sensing and communication objectives.

In essence, Crowd Sensing leverages the ubiquity of smart mobile devices and intelligent vehicles to establish a dynamic and decentralized ecosystem. Through the orchestrated utilization of the built-in sensors and computational resources, these devices stand poised to fulfill substantial roles in large-scale sensing initiatives and communication undertakings, thereby reshaping the landscape of modern sensing paradigms without the traditional reliance on specialized sensor networks.[12] The heightened interest in integrating intelligent vehicles into crowd sensing arises from various factors, notably the expanded coverage provided by these vehicles, their robust processing capabilities, dependable energy supply, and enhanced flexibility in interactive functionalities.[23]

The integration of Crowd Sensing (CS) within Vehicular Ad Hoc Networks (VANETs) has given rise to a multitude of captivating applications, spanning diverse domains such as environmental monitoring, traffic control [18], and map updating [4]. The burgeoning interest in leveraging CS in VANETs is propelled by the intrinsic need for real-time, context-aware information in scenarios where traditional internet or cellular network access is unavailable. This becomes particularly crucial in remote areas or post-catastrophic events like tsunamis or earthquakes.

In these situations, individuals often find themselves without internet connectivity, seeking vital information related to traffic conditions, alternative routes, nearby accommodations, current news, and other pertinent details about their surroundings. Vehicular ad hoc communication, facilitated by CS in VANETs, emerges as a highly efficient and effective solution to address this information vacuum. Leveraging the collective intelligence of vehicles on the road, equipped with advanced sensors and communication capabilities, enables the creation of a dynamic network that disseminates relevant and up-to-date information to users in need.

The versatile nature of VANETs, underpinned by the collaborative efforts of intelligent vehicles, not only enhances traffic-related applications but also extends its utility to broader societal needs, such as disaster response and recovery. By harnessing the distributed sensing capabilities within the vehicular network, CS in VANETs proves invaluable in providing timely and accurate information to individuals navigating through challenging circumstances, thereby showcasing its potential as a resilient and responsive communication framework in diverse and challenging scenarios.

The formation of a Vehicular Ad Hoc Network (VANET) involves the collaborative efforts of mobile nodes within vehicles, strategically forwarding sensing requests and data in a hop-by-hop manner. Nevertheless, the effectiveness of this opportunistic data forwarding is hindered by resource constraints inherent to these mobile nodes, encompassing limitations in energy, storage, processing capabilities, and bandwidth. This resource constraint dilemma prompts reluctance among these relay users to transmit sensed data, thereby exerting a detrimental impact on the overall network performance.

Recognizing the challenges posed by the reluctance of mobile nodes to share sensed data due to resource constraints, there arises a critical need to implement mechanisms that address and incentivize these nodes to mitigate their inherent selfish behavior. The complexity of these vehicular networks, marked by dynamic mobility patterns and fluctuating resource availability, necessitates a nuanced approach to designing incentives. Such incentives should be tailored to encourage and reward cooperative behavior, fostering a collaborative ecosystem where mobile nodes willingly contribute to the network's efficiency, despite their inherent limitations.

By devising effective incentive mechanisms, it becomes possible to align individual node interests with the collective benefit of the VANET, thereby enhancing data-sharing practices and overall network performance. In doing so, the VANET can transcend the challenges imposed by resource constraints, creating a more resilient and cooperative environment for opportunistic data forwarding and sensing within the vehicular network architecture.

Contemporary vehicles and handheld devices come outfitted with an array of diverse sensors, including those for temperature, pollution, noise, and traffic. These sensors enable these devices to actively sense and gather data from their immediate surroundings. Subsequently, the collected data is shared among these devices as needed. However, they lack a mobile agent to filter out the collected data.

1.1 Transmission of Mobile agent instead of Data

A mobile agent refers to a fusion of computer software and associated data that possesses the capability to autonomously transfer from one computer to another through network connections, seamlessly continuing its execution on the new computing environment. Endowed with intelligent decision-making capabilities, the mobile agent can analyze collected data and determine appropriate actions. The dissemination of such agents via Vehicular Ad Hoc Networks (VANETs) serves as a strategy to enhance participation within the VANET, leveraging the mobile agent's ability to efficiently navigate and operate within the network.

Let's consider an illustrative case involving the utilization of mobile agents for traffic monitoring within Vehicular Ad Hoc Networks (VANETs). In this hypothetical scenario, we presume that vehicles operating within VANETs possess the capability to execute mobile agents. The operational sequence commences with the initiation of a mobile agent, facilitated by a predetermined set of parameters specified by the initiator.

Subsequently, the mobile agent embarks on a journey towards a designated interest area, intending to gauge traffic information with the assistance of relay nodes strategically positioned along the route. As the mobile agent traverses the VANET, it adapts its trajectory to reach the specified area of interest. Upon arrival, the mobile agent engages in the execution phase, adeptly collecting and filtering relevant data in a flexible and intelligent manner.

A notable advantage of employing a mobile agent in this context lies in its inherent intelligence, enabling it to make informed decisions based on the dynamic conditions of its surroundings. This adaptability proves particularly beneficial in optimizing its actions as it navigates the complex and dynamic VANET environment. Additionally, the mobile agent's ability to discern pertinent data allows it to selectively filter and carry only the essential information, rather than burdening the network with the entirety of collected data.

In essence, the deployment of mobile agents in VANETs for traffic monitoring represents a sophisticated approach, where intelligent agents dynamically respond to the evolving context, ensuring efficient and tailored data collection while minimizing unnecessary data transmission and congestion within the network. [20]

A mobile agent has the ability to propagate throughout a network with the objective of acquiring contextual information such as weather updates, parking availability, and traffic conditions. Notably, it boasts distinct advantages when compared to conventional data and generic algorithms. Unlike static data, which tends to lose its relevance over time due to decay, the information carried by a mobile agent remains persistent and does not deteriorate with the passage of time.

1.2 Time sensitivity

Time sensitivity is something important that we shouldn't ignore. It means that the value of the data we collect becomes less useful as time goes by. Let's take an example of services like finding where a vehicle is or getting the latest traffic updates for navigation. In these situations, it's crucial to have the most recent and accurate information. If the data is not collected and shared quickly, it might lose its value, and people relying on these services may not get the most helpful information. So, paying attention to time sensitivity is really important to make sure the information we gather is timely and useful. [19] It may be meaningless if the information takes a long time to deliver. If you receive the information sooner, it will be more significant and valuable. Therefore, it is necessary to forward the request to the target area quickly and send back the sensed data to the requester as soon as it is collected.

1.3 Incentive Schemes and Game Theory

To forward the mobile agent to the target area and to send back the required sensed data to the requester, we can employ crowd-sensing in VANETs. The intermediate nodes will act as relay nodes. However, the issue remains as to why these relay nodes would collaborate in delivering the mobile agent to the destination region. They may act selfishly in order to conserve their processing and storage resources making them non-cooperative in nature. As a result, it becomes necessary to provide incentives to the nodes to mitigate their selfish behaviour. Among the incentive based schemes Yishan *et al.* proposed an incentive mechanism, namely differentially private auction scheme, for service provisioning. [25]. Zhaolong *et al.* proposed a socially aware networking mechanism named as copy adjustable incentive scheme which encourages the selfish nodes to relay the messages for the nodes inside the community as well as for the nodes outside the community.

Game theory serves as a decision-making framework, particularly useful when dealing with devices that aren't naturally inclined to work together. The main goal is to encourage these devices to cooperate effectively. To achieve this cooperation among devices, various game theory models come into play, each using incentives as a way to foster collaboration among non-cooperative entities.

One such model is the Nash bargaining theory, which involves finding a fair way for devices to make decisions together. Another model is the Stackelberg game, where one device takes the lead and others follow, creating a structured approach to collaboration. Rubinstein's game theory model is yet another approach, introducing strategies for negotiation and decision-making among devices.

By employing these game theory models, we can design ways to incentivize relay nodes, making them more cooperative in nature. Essentially, game theory provides a thoughtful strategy to encourage devices to work together harmoniously, promoting collaboration and effective decision-making in scenarios where cooperation might not be the default behavior.. Zhan *et al.* addressed the problem of nodes' selfishness by using Nash bargaining model [12]. Fan *et al.* designed a Stackelberg game for data offloading in VANETs [21]. Yasir *et al.* modeled the interaction between two nodes as a Rubinstein game. [22] The Rubinstein game theory model stands as a significant and versatile framework with wide-ranging applications in diverse fields such as economics, political science, and computer science. This model serves as a valuable tool for researchers seeking to comprehend strategic decision-making processes. Its utility extends to the analysis of how individuals or organizations navigate choices over time, considering factors like private information and the sequential nature of decision-making within the game.

Through a comprehensive exploration of the Rubinstein game theory model, researchers are empowered to delve into the intricacies of negotiation strategies, optimal decision paths, and the dynamic interplay among participants. This area of study provides a captivating lens through which real-world scenarios can be understood, offering valuable insights that contribute to the enhancement of decision-making processes. In essence, the Rubinstein game theory model emerges as a rich and illuminating domain, facilitating a deeper understanding of strategic decision-making dynamics across various disciplines.

1.4 Problem Statement and Contribution

In situations where internet connectivity is unavailable, such as in remote regions or during natural disasters, individuals have a heightened need for critical information on topics like news, location, and traffic. Vehicular Ad Hoc Networks (VANETs) emerge as a viable solution in such scenarios, facilitating effective communication between nodes. In this context, VANET nodes operate as both information sources and relays, with intermediate nodes serving as crucial relays in the absence of a direct connection.

However, a significant challenge arises due to the reluctance of these relay nodes to assist, primarily driven by constraints in their resources, such as limited battery capacity and buffer space. Addressing this issue, the proposed approach in this research involves the application of game theory to mitigate nodes' reluctance or selfish behavior. By introducing strategic decision-making models within the VANET framework, the research aims to incentivize cooperative behavior among relay nodes, ensuring a more efficient and responsive communication network even in resource-constrained environments.

The prior work has some limitations:

1. Some proposed work considers that the nodes are not reluctant and are cooperative in nature.

2. Some incentive schemes relay the data upto two hops only. However, it might be the case that the target area is not located at a two hop distance.

3. Time sensitivity is not given much importance in some schemes.

4. Some proposed work however, tackles only one task at a time. But in actual there are more than one tasks to be tackled at the same time and to be delivered to the target region.

5. In some proposed work, the generic data is being communicated. The disadvantages of communicating data to the target region are that the generic data algorithm is heavier than specific mobile agent code which consumes more network resources. Also, the data values decay over time whereas, mobile agent does-not decay over time.

Taking into account the limitations outlined earlier, this study employs the Rubinstein game theory model to address the challenge of non-cooperation or selfish behavior exhibited by nodes, extending its application to multiple hops while considering the critical factor of time sensitivity. The research specifically focuses on mitigating the reluctance of nodes to cooperate within a multi-hop communication framework, emphasizing the sequential nature of decision-making. In the proposed approach, the Rubinstein game theory model is strategically utilized to simultaneously manage diverse tasks, encompassing the delivery of a mobile agent to the designated target region and the subsequent transmission of sensed data back to the original requester. This simultaneous handling of multiple tasks aims to enhance the overall efficiency and effectiveness of the communication process within the network, demonstrating the versatility of the Rubinstein game theory model in addressing complex scenarios within the realm of cooperative decision-making among nodes.

1.5 Motivation

Natural disasters, including earthquakes and tsunamis, exert significant adverse effects on the stability of internet connectivity and communication systems. The occurrence of such disasters has the potential to inflict substantial harm on the physical infrastructure that sustains the internet, encompassing undersea cables, cell towers, and power lines. The resultant damage can precipitate disruptions in internet service, impeding the seamless communication of individuals through online platforms. Moreover, the cascading impact of power outages induced by these disasters amplifies the challenges, exacerbating the difficulties in maintaining consistent and reliable internet connectivity during critical times. The intricate interplay of these factors underscores the vulnerability of internet infrastructure in the face of natural calamities, emphasizing the need for robust contingency plans and resilient communication strategies to mitigate the impact of such disruptions.

In situations where individuals lack access to the internet or cellular networks, such as in remote or disaster-stricken areas following events like tsunamis or earthquakes, there is a heightened demand for essential information. People seek details regarding traffic conditions, available routes, weather updates, hotel accommodations, news, and other pertinent information about their surroundings. Recognizing the challenges posed by the unavailability of conventional communication infrastructure in these scenarios, vehicular ad hoc communication emerges as a valuable and efficient alternative. Leveraging the capabilities of vehicles equipped with communication technologies, this mode of communication proves to be a practical solution, enabling the seamless exchange of crucial information and services even in environments where traditional connectivity is compromised. This approach not only addresses the immediate informational needs of individuals in challenging circumstances but also underscores the adaptability and effectiveness of vehicular ad hoc communication in bridging communication gaps during unforeseen events.

The motivation of this paper is to make communication available even in the absence of internet connectivity. For this purpose in this paper we have used Vehicular adhoc network for this purpose. As vehicles are advanced to that point that they have millions of sensors applied or stocked in them, that they can be used to sense, collect, and communicate the information from one area to another.

When internet connectivity is unavailable, vehicles establish direct communication with one another through wireless technologies like high-speed interfaces or dedicated short-range communication (DSRC). This enables the exchange of crucial information such as traffic conditions, road hazards, and emergency alerts among vehicles. Vehicular Ad Hoc Networks (VANETs) play a pivotal role in creating a self-organizing network among proximate vehicles, forming a decentralized communication system. In the absence of an internet connection, this approach ensures that vehicles can still share valuable information, contributing to the enhancement of road safety. This innovative strategy serves as a resourceful means to sustain communication in challenging situations, showcasing the adaptability and effectiveness of VANETs in promoting safer road environments.

Chapter 2

Literature Review

Crowdsourcing (CS) is an evolving paradigm that intricately weaves together dynamic crowd knowledge and the capabilities of mobile devices, creating a framework for decentralized, pervasive services, and applications. This innovative approach stands out for its effectiveness in collecting a diverse array of sensory data within pervasive contexts, leveraging the collective intelligence of human contributors. The synergy achieved by combining traditional Information and Communication Technology (ICT) with state-of-the-art mobile communications renders crowdsourcing not only a cost-effective but also a high-quality solution. Its versatility extends across a myriad of fields, providing invaluable services in ubiquitous circumstances where the integration of crowd knowledge and mobile technologies facilitates the advancement of innovative solutions.

In the realm of decentralized, pervasive information services, crowdsourcing emerges as a transformative force. By seamlessly integrating crowd knowledge and mobile technologies, it not only addresses existing challenges but also catalyzes the development of novel solutions across various domains. Crowdsourcing's role in fostering innovation and cost-effective services positions it as a key player in shaping the landscape of decentralized information dissemination, demonstrating the profound impact of this paradigm in enhancing our approach to pervasive applications and services.[19].

Effective data dissemination plays a pivotal role in crowd sensing, a phenomenon extensively explored across diverse domains along with mobile crowd sourcing, including delay tolerant networks (DTNs) [14, 5, 9], wireless sensor networks (WSNs) [26, 2, 3], and among others [27, 6]. In the next section the data collection using mobile agents and agents transmission is thoroughly studied. Furthermore crowdsourcing is studied in terms of non-incentive based mechanisms and incentive based mechanisms which are then subdivided into non-game theoretic and game theoretic strategies.

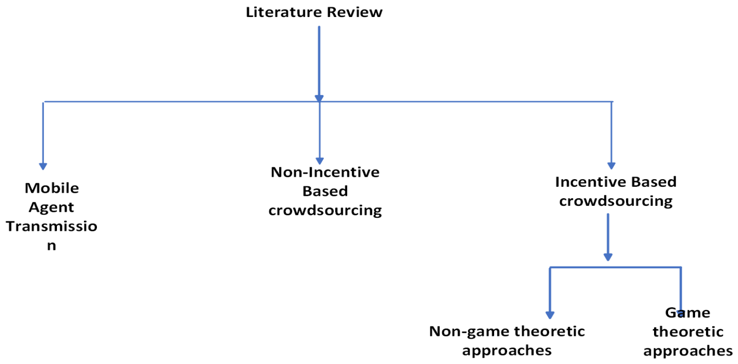

Figure 2.1: Literature Review

2.1 Mobile Agent transmission

A mobile agent, in the context of computing, refers to a cohesive amalgamation of computer software programs and associated data designed to autonomously traverse from one computer to another through network connections. This migration allows the mobile agent to seamlessly continue its execution on the new computing environment. In the context of Vehicular Ad Hoc Networks (VANETs), facilitating such mobile agent functionality necessitates the integration of a specialized middleware known as a mobile agent platform. Examples of such platforms include JADE and SPRING, which serve as essential frameworks for enabling the mobility and functionality of these intelligent agents within the dynamic and interconnected environment of VANETs. [1]

In the expansive realm of network dissemination, a mobile agent assumes the role of an entity designed to permeate the network environment with the primary objective of aggregating comprehensive information from its surroundings. This encompasses the retrieval of diverse data sets such as weather updates, parking availability, and traffic conditions. The inherent advantage of employing mobile agents in this capacity becomes apparent when compared to traditional data dissemination methods and generic algorithms. Unlike static data, which inevitably loses its value over time due to decay, mobile agents exhibit a unique quality of temporal persistence. This longevity ensures that the mobile agents remains consistently relevant and up-to-date, presenting a dynamic and robust approach to information gathering within networked environments. Additionally, this intelligent entity possesses the capability to make decisions based on the information it collects and takes the initiative to filter out any unnecessary data. Another noteworthy advantage lies in the fact that a mobile agent carries a specific algorithm tailored for its purpose. For instance, the algorithm for gathering data to monitor traffic differs from the one used for monitoring the weather. This specificity means that, instead of employing bulky generic algorithms, a mobile agent utilizes compact, task-specific codes. This streamlined approach enhances efficiency and allows for more precise data collection and processing in different scenarios.. [20] Therefore, the transmission of mobile agents utilizes fewer resources, including bandwidth and buffer space, due to their smaller size when compared to generic messages. Surprisingly, despite these advantages, the literature has predominantly overlooked the topic of mobile agent transmission.

The mobile agent transmission mechanism, introduced by Junichi *et al.*, serves as a proposed solution for the dissemination of data within a network. In this mechanism, the speed at which an agent is transmitted correlates with the dynamics of the vehicle nodes within the network. The selection of the subsequent mobile node is determined by the directional trajectory and speed of nearby nodes in motion. It's worth noting that the origin node responsible for generating information messages remains stationary, forming a fixed point within the network.

While the proposed approach assumes a cooperative behavior among nodes, acknowledging the collaborative exchange of information, it is essential to recognize the inherent complexity introduced by the reality of nodes exhibiting selfish behavior to conserve their resources. This aspect raises critical considerations, as the proposed model may not fully encapsulate the dynamics of real-world scenarios where nodes within a network often prioritize resource preservation, adding a layer of nuance that necessitates further exploration and refinement in future studies.[7]

Oscar *et al.* considered spatial crowdsourcing in VANETs. They have derived a monitoring process using mobile agent. The vehicles could be willing to transport a mobile agent closer to their destination by detouring its original path and in return gets some virtual currency which is directly proportional to the social cost, the time that collaborators need to invest to help the mobile agent. [20].

However, in the proposed work if the relay node detour its original path only then it will get a reward otherwise the relay node will not get any reward for forwarding the mobile agent. But in reality even the relay nodes are going in the direction of mobile agent's destination, why would it forward the mobile agent without getting any benefit or reward as the resources of relay node is still being utilized. No negotiation algorithm is being proposed in this work.

In our proposed work, we have addressed the above mentioned problem and focused on giving the rewards to each relay node by proposing an incentive based algorithm. Also, we focused on the time sensitivity by reducing the delivery time of the mobile agent.

2.2 Non-incentive based crowd-sourcing

Non-incentive techniques operate under the assumption that the majority of relay nodes within the network inherently exhibit cooperative behavior in forwarding data, without receiving any form of compensation for their efforts. However, the practical application of these techniques may face challenges, as they can potentially underperform in the real-world scenario marked by the selfish tendencies of nodes. This is particularly evident when nodes operate under resource constraints, influencing their willingness to actively participate in data forwarding without adequate motivation. In the following section, a comprehensive exploration is undertaken, scrutinizing various non-incentive-based crowd sourcing mechanisms. This investigation is conducted with diverse objectives in mind, aiming to shed light on the efficacy and limitations of these mechanisms in addressing the complexities introduced by the selfish nature of nodes and resource constraints within the network. Through a nuanced examination, a more profound understanding of the intricacies involved in non-incentive techniques for crowd sourcing is sought, facilitating informed insights for future enhancements and optimizations in the realm of cooperative data forwarding.

Yin *et al.* delved into the realm of data collection within vehicular networks, introducing an innovative answer gathering technique. This technique is grounded in a data aggregation path model, prioritizing the precision of responses or sensed data while concurrently minimizing communication costs. To ensure the holistic quality of collected data, the approach incorporates a Gaussian mixture model for effective task assignment. It is noteworthy, however, that the proposed methodology is tailored for addressing a singular task at a time, overlooking the reality where multiple tasks may need simultaneous attention and resolution. The recognition of this discrepancy underscores the need for future advancements in the proposed framework to accommodate the concurrent handling of multiple tasks, aligning more closely with the multifaceted demands of practical scenarios.[30]

Azizur *et al.* delved into the domain of crowdsourcing within vehicular networks, offering a novel perspective through the introduction of a trust-based Cooperative Data Forwarding mechanism. This mechanism is intricately tied to a social-aware routing protocol, emphasizing trust as a key factor in data forwarding activities. Notably, the proposed approach operates with a singular copy of data within the network, a design choice aimed at minimizing the utilization of network resources. While this design decision is intended to mitigate resource consumption, it also comes with the potential drawback of diminishing overall network performance. The concentration of a single data copy, while resource-efficient, raises considerations regarding the system's ability to effectively handle data dissemination demands, thus warranting a nuanced evaluation of the trade-offs involved in optimizing network performance and resource utilization within this proposed framework.[13]

2.3 Incentive based crowd-sourcing

In response to the inherent inclination of relay nodes towards self-interest and non-cooperative behavior, there has been a discernible shift towards the proposition and exploration of incentive-based strategies. These strategies are strategically designed with the overarching goal of transforming relay nodes from naturally selfish entities to cooperative contributors within network dynamics. This shift in focus is driven by the understanding that, without appropriate motivational mechanisms, relay nodes may prioritize individual interests over collaborative engagement, potentially leading to suboptimal network performance and resource utilization. Thus, the research landscape has witnessed a surge in interest and efforts to devise and implement incentives that align the individual objectives of relay nodes with the collective well-being of the network.

In this section several incentive-based methods have been substantially researched as non-game theoretic approaches and game-theoretic approaches with distinct goals.

2.3.1 Non Game-theorectic approaches

Zhaolong *et al.* introduced a new way to encourage cooperation among selfish nodes in data forwarding, and they named it the "copy adjustable incentive mechanism." To make things simpler, they divided the network into two types of communities: social communities and non-social communities. When nodes help by forwarding data within a social community, they receive rewards, and the same goes for nodes in non-social communities. However, if a node's rewards fall below a specific value (known as the threshold), it won't be able to receive services for relaying its messages in the network. In such a situation, the node needs to maximize its rewards by helping other nodes relay their messages. Interestingly, the proposed approach does not include a mechanism to model negotiations among nodes.

In summary, Zhaolong *et al.*designed a system where nodes are rewarded for helping others, but if their rewards drop too low, they need to relay messages for others to increase their rewards. The system divides the network into social and non-social communities, each with its own set of rewards for cooperative behavior. However, one thing to note is that the proposed system doesn't include a way for nodes to negotiate with each other. [10]

Yuxin *et al.* aimed to tackle the challenge of selfish behavior among nodes in a network by introducing a fair credit-based incentive scheme. In this proposed approach, every node in the network is considered to be equally valuable. Once data successfully reaches its destination with the help of relay nodes, each of these nodes is rewarded with an equal amount of credit. The degree of cooperation in forwarding data is then determined by the cumulative credit value associated with each node. If a node exhibits less cooperation, it faces the consequence of being unable to access services for relaying messages within the network. In such instances, the node is prompted to enhance its cooperative behavior by maximizing the accumulation of credits, thus improving its prospects for receiving services in the future. However, it's worth noting that the study primarily focused on time sensitivity and did not account for other crucial factors such as a node's energy levels, security considerations, and available buffer space for storing data.

This fair credit-based incentive system, as envisioned by Yuxin *et al.*, introduces a democratic approach wherein all nodes are regarded as equally important contributors to the network. The mechanism ensures that each node is fairly credited for its role in data forwarding, fostering a cooperative environment. However, the study's limitation lies in its exclusive emphasis on time sensitivity, neglecting other significant factors that influence a node's overall performance and effectiveness in the network. As the exploration of incentive schemes continues, there remains an opportunity to refine and expand upon these models to encompass a broader spectrum of considerations, ultimately contributing to the evolution of more comprehensive and equitable cooperative strategies within network dynamics.[24]

Yishan *et al.* introduced a way to keep your information private while also encouraging Internet Service Providers (ISPs) to offer better services. They came up with a privacy-preserving incentive system that allows ISPs to choose suitable edge networks to provide services and, in return, get incentives from these ISPs. Importantly, this all happens while keeping your privacy protected and staying within budget limits. The system uses a special method called a differentially-private auction-based incentive mechanism to achieve this balance between getting good services, maintaining privacy, and working within budget constraints. [25]

Zenggang *et al.* introduced an innovative incentive scheme that involves a negotiation process among nodes, allowing for a maximum of two negotiation attempts to reach an agreement regarding the relay of data. Within this proposed framework, nodes engage in negotiation rounds, and if an agreement is successfully reached, the participating relay node is entitled to receive a specified reward. This negotiation-based incentive scheme is designed to promote cooperative behavior among nodes by providing them with a structured mechanism for resolving potential conflicts and reaching mutually beneficial agreements related to data relay within the network. The two-step negotiation process offers a balanced approach, ensuring that nodes have the opportunity to discuss and finalize the terms of data relay cooperation, contributing to a more cooperative and incentivized network environment.[29]

Yanyan *et al.* tackled the challenge of getting people to join a task using device-to-device (D2D) communication while making sure everyone's privacy is protected. They did this by using a distributed approach that simplifies each participant's decision-making process. The main idea of their solution is that nodes who've already taken part in crowdsourcing tasks (called Seed nodes) can invite more mobile users to join the task, making it perform better and earning everyone more rewards. However, these Seed nodes need to be careful not to choose users who might dominate them and send the data to the task organizer before the Seed nodes do. This way, the Seed nodes won't get the rewards they were expecting. It's important to note that the suggested solution didn't give much attention to the urgency of time in completing the tasks.

In summary, Yanyan *et al.* found a way to encourage more people to participate in tasks using device-to-device communication while keeping everyone's privacy intact. They introduced a system where experienced nodes, called Seed nodes, invite others to join the task for better performance and rewards. However, there's a challenge in making sure these Seed nodes choose participants wisely to avoid losing their expected rewards. The solution didn't focus much on time sensitivity, which is something to consider for future improvements[31]

2.3.2 Game-theorectic approaches

Game theory is like a set of rules for making decisions when devices in a network don't always want to work together. In this framework, devices that don't naturally cooperate are encouraged to team up. There are different ways to do this, and they're called incentives-based game theory models. These models help make devices, known as relay nodes, cooperate more. Some examples of these models include Nash bargaining theory, Stackelberg game, and Rubinstein's game theory model.

Imagine you have a bunch of devices in a network, and they don't always want to help each other out. Game theory steps in to create a set of strategies or rules to convince these devices to collaborate. One way to do this is using Nash bargaining theory, which helps find fair deals so that everyone is happy with the outcome. Another approach is the Stackelberg game, where one device takes the lead, and others follow, creating a structured way to cooperate. Then there's Rubinstein's game theory model, which looks at strategic decision-making to make sure devices work together efficiently.

So, game theory is like a playbook for getting devices in a network to play nice and work together, and there are different strategies, like Nash bargaining, Stackelberg game, and Rubinstein's model, to make sure everyone cooperates for the greater good.

Zhou *et al.* came up with a way for parked cars to form a network, like a team, to store and share data with cars that are on the move. They also included roadside units (RSUs) that act like helpers by saving copies of data and sharing it with the cars that request it. Here's the interesting part: parked cars and RSUs compete against each other to be the ones providing the data that's requested. They want to do this because it helps them earn rewards. To make this all work smoothly, they used something called a Stackelberg game, which is like a set of rules for communication between three groups: the parked cars, the RSUs, and the moving cars.

In their system, RSUs and parked cars decide how much they'll charge for sharing data, and they send these charges to the car that's asking for the data. Then, the car that needs the data gets to choose where to get it from based on the prices sent by the RSUs and parked cars. The interesting part is that the car can get some data from parked cars and the rest from RSUs. However, it's important to note that the study focused on a situation where moving cars directly connect with parked vehicles and RSUs in a single hop. Also, they didn't pay much attention to how the cars move around.[11]

Yasir *et al.*developed an innovative peer-to-peer (P2P) incentives game, where nodes that share common subscribed interests are more inclined to help relay messages. Conversely, nodes with non-overlapping interests tend to be less willing to participate in message relay. The key challenge addressed in this system is fostering cooperation among inherently selfish nodes. To achieve this, the researchers introduced a Rubinstein game theory model, which serves as the underlying framework for incentivizing collaboration among nodes that might otherwise be reluctant to relay messages. In this sophisticated model, the dynamics of the game encourage nodes with similar interests to collaborate in the message relay process, enhancing overall cooperation within the network.

In the intricacies of this P2P incentives game, the nodes' willingness to relay messages is intricately tied to the alignment of their subscribed interests. Nodes that share common interests find motivation to actively participate in relaying messages, promoting a collaborative environment. On the other hand, nodes with divergent interests exhibit reluctance to engage in message relay activities. The introduction of the Rubinstein game theory model strategically addresses this scenario by introducing incentives that encourage nodes to overcome their inherent selfishness and actively contribute to the relay process. By leveraging this nuanced game theory model, Yasir *et al.* aim to establish a cooperative network where nodes are incentivized to relay messages based on shared interests, thus contributing to the overall effectiveness and collaborative dynamics of the P2P communication system. [22]

Hamta *et al.* addressed the problem of non-cooperation of nodes by designing an incentive mechanism as a Stackelberg game.The proposed work focused on reducing the delay while improving the message delivery time. However, it ignored other factors like accuracy of data, node's energy, and buffer space. [28]

Yufeng *et al.* designed an incentive mechanism for crowd-sensing the data by employing the Nash bargaining model. The suggested approach additionally considers the time value of the data that was acquired, whose value will decay over time. This work, however, focuses on the time sensitivity and ignored other factors like node's energy, cache space. [16]

As discussed above in the literature the schemes, however, have advanced but still have certain shortcomings. For the purpose to overcome these shortcomings, this paper presented the incentive based data dissemination technique in the vehicular networks using mobile agents. An incentive aware mobile agent dissemination and crowd sensed data algorithm is designed in this paper by modeling the Rubinstein game theory model. Our proposed work expands to multiple hops to meet the real life requirements. Our work also considers the time sensitivity and tackles multiple tasks at a time.

Chapter 3

Methodology

3.1 Problem Analysis

In environments where internet connectivity is lacking, such as in remote areas or during natural disasters, there is an increased demand for crucial information such as news updates, location details, and traffic conditions. Vehicular Ad Hoc Networks (VANETs) present themselves as a practical solution in such circumstances, enabling efficient communication between nodes. Within the framework of VANETs, the nodes serve a dual role as both providers of information and relays. Particularly noteworthy are the intermediate nodes, which play a pivotal role as essential relays, stepping in to facilitate communication when a direct connection is unavailable.

In these scenarios, where traditional network infrastructure may be absent, VANETs create a decentralized and adaptive communication network. Vehicles equipped with communication devices act as dynamic nodes, capable of sharing critical information among themselves and with others. The significance of VANETs becomes evident as they not only allow vehicles to serve as sources of vital information but also ensure the seamless relay of such information through intermediate nodes, addressing the challenges posed by the absence of direct connections in these communication-restricted situations.

3.2 Problem Statement

In settings devoid of internet connectivity, such as mountainous terrains or areas affected by disasters, leveraging VANETs for crowd-sourcing emerges as an efficient strategy for deploying mobile agents to specific regions and gathering sensed data. The concept of forwarding mobile agents has often been overlooked in existing literature. However, the base paper [20] introduces the implementation of forwarding mobile agents. Despite this, the original approach lacks consideration for the inherently selfish nature of nodes and lacks the integration of a negotiation mechanism. In practice, nodes exhibit selfish behavior owing to their limited resources. This selfishness, when coupled with non-cooperation among nodes, can significantly undermine network performance.

The practical implications of implementing VANETs for crowd-sourcing in communication-challenged environments are underscored by the need to address the selfish tendencies of nodes. The base paper [20] introduces the concept of forwarding mobile agents but falls short in acknowledging the selfish nature of nodes and neglects the incorporation of a negotiation mechanism. Recognizing the resource constraints that induce selfish behavior in nodes, it becomes imperative to explore strategies that not only account for this inherent selfishness but also mitigate its potential impact on network performance, thereby enhancing the overall effectiveness of crowd-sourcing via VANETs in data collection from targeted regions.

3.3 Architecture Of The System

The emergence of Mobile Crowd Sensing (MCS) signifies a pioneering paradigm in sensing and computing. This innovative approach capitalizes on the ubiquity of smart mobile devices, leveraging the sensors embedded within them to systematically gather and share local as well as environmental data. The inherent capabilities of these devices present an opportunity to conduct expansive sensing endeavors without the need for extensive and specialized sensor networks. By harnessing the collective power of widely-used smart devices, Mobile Crowd Sensing facilitates the seamless collection and exchange of data, offering a versatile and efficient alternative to traditional methods that rely on dedicated sensor infrastructures.

The transformative nature of Mobile Crowd Sensing is rooted in the widespread adoption of smart mobile devices, which serve as multifaceted tools for both data acquisition and dissemination. Through the regular utilization of sensors embedded in these devices, a broad spectrum of data pertaining to local and environmental conditions can be systematically captured and shared. This approach obviates the necessity for deploying intricate sensor networks, as the interconnected nature of smart devices enables the orchestration of large-scale sensing activities. Thus, Mobile Crowd Sensing emerges as a dynamic and scalable paradigm, harnessing the collective sensing capabilities of everyday mobile devices to revolutionize the landscape of data gathering and exchange.

In the realm of mobile crowdsensing within Vehicular Ad Hoc Networks (VANETs), the system encompasses a set of vehicles denoted by the notation N = {1, 2, ..., n}. These vehicles, modern in design, are equipped with an extensive array of sensors, numbering in the order of hundreds. These sensors, ranging from position sensors to temperature sensors, gas sensors, and acceleration sensors, among others, [15] enable the vehicles to adeptly collect and store data from their surrounding environment. In a testament to their advanced capabilities, these vehicles are not merely passive data collectors; they are endowed with the autonomy and intelligence to communicate and exchange the amassed data seamlessly among themselves. This imbues them with a level of efficiency in their operational behavior, marking a paradigm shift towards autonomous and intelligent vehicular entities in the context of mobile crowdsensing.

The intricate network of sensors embedded within modern vehicles, comprising diverse functionalities such as positional awareness, environmental monitoring, and kinetic measurements, represents a technologically sophisticated framework. This convergence of sensor technologies empowers vehicles within VANETs to function as dynamic data hubs. Beyond their individual data acquisition capabilities, these vehicles exhibit a collective intelligence as they engage in reciprocal communication, sharing the acquired data with one another. This transformative integration of sensing and communication not only renders the vehicles efficient in their data-gathering activities but also underscores their autonomous and intelligent attributes, setting the stage for a paradigm wherein vehicular entities contribute actively to the broader landscape of mobile crowdsensing.

In our scenario we're considering, vehicles are fitted with computer systems capable of running a mobile agent platform, exemplified by applications like Grasshopper, Aglets, Tryllian, JADE, SPRINGS, and others as mentioned in [1]. Moreover, each vehicle is equipped with a wireless communication device, enabling mobile agents to operate and traverse between vehicles, ultimately reaching specific areas of interest for data processing. Described as a mobile agent, this entity combines computer software and associated data, possessing the ability to autonomously move from one computer to another via network connections. Once migrated, the mobile agent seamlessly continues its execution on the new computer.

When a mobile user seeks information about a specific region, like monitoring temperature or identifying available parking spaces, they start by defining relevant parameters. Subsequently, a mobile agent is initiated with the specified parameters to process the request. To obtain the required information, the mobile agent must travel to the designated area of interest, relying on support from intermediate vehicles during its journey.

But the question is why these intermediate vehicles collaborate in transmitting the mobile agent to the interest area. They may act selfishly in order to conserve their battery power, storage space, bandwidth, and other resources making them non-cooperative in nature. So incentives will be given (incentive mechanism is explained later) to these nodes to make them cooperative in nature so that they will help mobile agent in reaching the interest area.

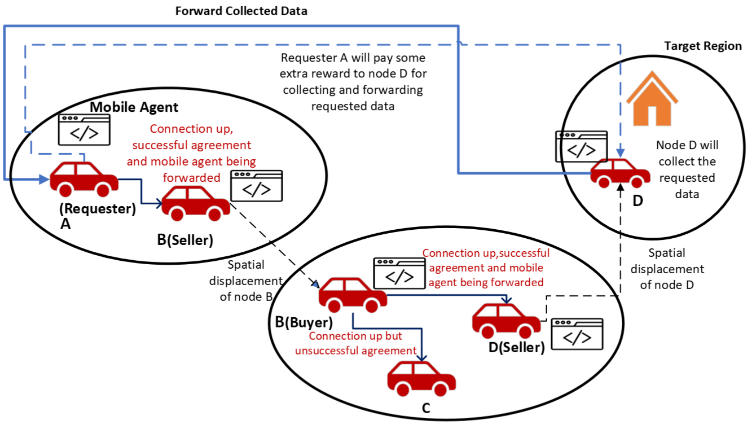

Figure 3.1: Mobile Agent Transmission and forwarding of collected data to the requester in VANET

In Figure 3.1, consider the scenario where Vehicle A requires specific weather information for a designated target region. To fulfill this need, Vehicle A initiates the deployment of a mobile agent specialized in acquiring weather data. As the vehicles traverse within the Vehicular Ad Hoc Network (VANET), when Vehicle A encounters Vehicle B, a negotitaion takes place. Both vehicles share critical information, including their estimated time to reach the target region or the respective distances to the specified destination. Utilizing this shared data, a relay node is strategically selected.

The selection of the relay node marks the initiation of a negotiation phase between Vehicle A and Vehicle B. This negotiation is a pivotal step in determining the viability and conditions of the mobile agent's transfer from Vehicle A to Vehicle B. Successful negotiation leads to the seamless transfer of the mobile agent to Vehicle B, enabling it to continue its journey toward the target region. Importantly, to foster a cooperative environment and incentivize the active participation of Vehicle B in this collaborative effort, Vehicle A offers certain incentives to Vehicle B. These incentives serve as a tangible acknowledgment of Vehicle B's role as a relay node and aim to encourage continued collaboration within the VANET framework.

Following the effective transfer of the mobile agent to Vehicle B, the latter progresses to a new region where it encounters both Vehicle C and Vehicle D. In this encounter, Vehicle B assesses and selects the suitable relay nodes from among Vehicle C and Vehicle D. Unfortunately, an agreement cannot be reached with Vehicle C; however, a successful negotiation transpires with Vehicle D. Consequently, the mobile agent is successfully transferred to Vehicle D.

With the mobile agent now in its possession, Vehicle D proceeds to relocate itself towards the specified target region. Upon reaching the target, Vehicle D autonomously delivers the mobile agent to the designated area. Notably, Vehicle D undertakes the task of collecting pertinent weather information from the target region. Subsequently, this acquired data is transmitted back to the originating requester A. As after successful delivery of collected/sensed data to the requester vehicle A, the vehicle A provides some extra reward to the vehicle D.

The occurrence of successful negotiations between vehicles is not guaranteed on every occasion. Mobile users exhibit a degree of reluctance in forwarding mobile agents to target areas, given the consequential depletion of their battery, storage, and other essential resources. To address this inherent hesitancy and stimulate greater cooperation among mobile users in the crucial task of mobile agent forwarding, this paper introduces an incentive mechanism.

Recognizing the substantial resource consumption associated with mobile agent forwarding, mobile users may exhibit reservations about actively participating in this process. Consequently, to foster a more cooperative environment within the network, the proposed incentive mechanism serves as a strategic tool. This mechanism aims to motivate and encourage mobile users to actively engage in forwarding mobile agents by offering rewards or benefits, thereby mitigating their reservations and promoting a more collaborative and participatory approach in the Vehicular Ad Hoc Network (VANET) context.

The relay nodes will get some incentives as a result of forwarding the mobile agent to the target area. The requester has a virtual currency "p_b" which it will pay to the relay node. If destination is not arrived the carrier of the mobile agent will act as a buyer node and finds a suitable seller node to relay the mobile agent. The buyer node will pay some virtual currency "p_b" to the seller node. As a result of which a seller node will earn that virtual currency "p_b".

As a reference, in Figure (3.1) vehicle A is a requester node and has a virtual currency "p_b" which it will pay to vehicle B, which is a seller node who is selling its services of relaying to the requester node A. In the next step as target region is not arrived yet, vehicle B will now act as a buyer node, which will buy services of relaying from another node in a VA-NET, and vehicle D is now a seller node. Vehicle B pays virtual currency "p_b" to the vehicle D.

In the network, a vehicle that refrains from helping others in the transfer of their mobile agents and predominantly relies on purchasing services from others will inevitably face consequences related to its virtual currency. Over time, this virtual currency becomes depleted due to the lack of reciprocation in aiding others. The diminishing virtual currency subsequently hampers the vehicle's capacity to procure services and forward its requests to the designated target region. This financial constraint acts as a compelling incentive, compelling the vehicle to transition from a non-cooperative stance to a cooperative one within the network.

As the virtual currency diminishes, rendering the vehicle incapable of sustaining its service acquisition and request forwarding capabilities, a paradigm shift occurs. The economic constraints drive the vehicle towards a cooperative approach, aligning with the network's collaborative ethos. By actively participating in cooperative actions and earning rewards as a result, the vehicle not only replenishes its virtual currency but also mitigates its erstwhile selfish behavior. This dynamic interplay of financial incentives serves as a mechanism to enforce cooperation within the network, ensuring a balanced and mutually beneficial environment where vehicles are motivated to contribute actively in the collective functioning of the Vehicular Ad Hoc Network (VANET).

3.4 System Model

In our proposed model we considered N no of vehicles i-e N={0,1,2,.....,n}. We have divided the vehicles into different groups on the basis of no of interface, the interfaces

List of notations and their significance	
Notations	Significance
N_i	Node carrying a mobile agent
N_k	Node encountered with node i
D	Target region
d	Centre point of target region
R_D	Radius of target region
$S_{k,d}$	Distance from a node to the centre point d of the target region
$(\phi_{k,d}$	Moving direction of node k
V_k	Moving speed of a node k
$T_{k,d}$	Time taken by node k to travel to the centre point of target region d
$S_{k,d}^{pro}$	Projected distance of node k from the centre point of target region d
X	Time window in which the future location of node will be predicted
$w_{i,rcr}$	Willingness of seller node i to relay a mobile agent
m_k	Mobile agent k
$b_{i,c}$	Current buffer space of node i at time t
$b_{i,f}$	Initial buffer space of a node i
x	Richness of node i in terms of virtual currency
$x_i(t)$	Virtual currency node i possesses at time t
x_{rh}	Richness threshold
u_s	Utility of a seller node
u_b	Utitliy of a buyer node
p_b	Price a buyer pays to seller for relaying an agent
$c_{i,r}$	Cost of receiving a mobile agent of node i
$size_{m_k}$	size of a mobile agent k
$c_{i,b}$	Cost of bargaining
r_{b,m_k}	Residing time of mobile agent k in a buyer's buffer
$c_{i,s}$	Cost of storing a mobile agent

Table 3.1. List of notations and their significance

they use to communicate, their moving speed and their movement models. M={1,2,3,—–,m} no of mobile agents are being generated to move to the target region, process over there and send back the sensed data to the requester or the initiator of the mobile agent. Further steps that are being followed are discussed below:

- **Information sharing:** We assume that each vehicular node is equipped with GPS capabilities, enabling the acquisition of real-time geographic information such as current location, moving direction, current distance from the target region, and moving speed. Upon encountering each other, nodes engage in the exchange of this information. Subsequently, a routing decision is formulated based on the shared information, leading to the selection of a relay node.

  Let's denote N_i as a node carrying a mobile agent with the intention of delivering it to a target area, while N_k represents the encountered node without a mobile agent. The exchange between N_i and N_k involves sharing details such as current distance from the target region, moving direction, current location, and moving speed. Leveraging this shared information, a calculation is performed to determine either the time required to reach the target region or the projected distance from the target. The relay node selection process, (explained in detail later), relies on comparing these calculated values. The node with a shorter time to reach the destination or a smaller projected distance is chosen as the relay node.

- **Estimating radius of target region:** We considered the target region as a circle. D is the target region or destination with d as its central point, and its radius is denoted as R_D.

- **Relay node selection:** The following scenarios are taken into consideration

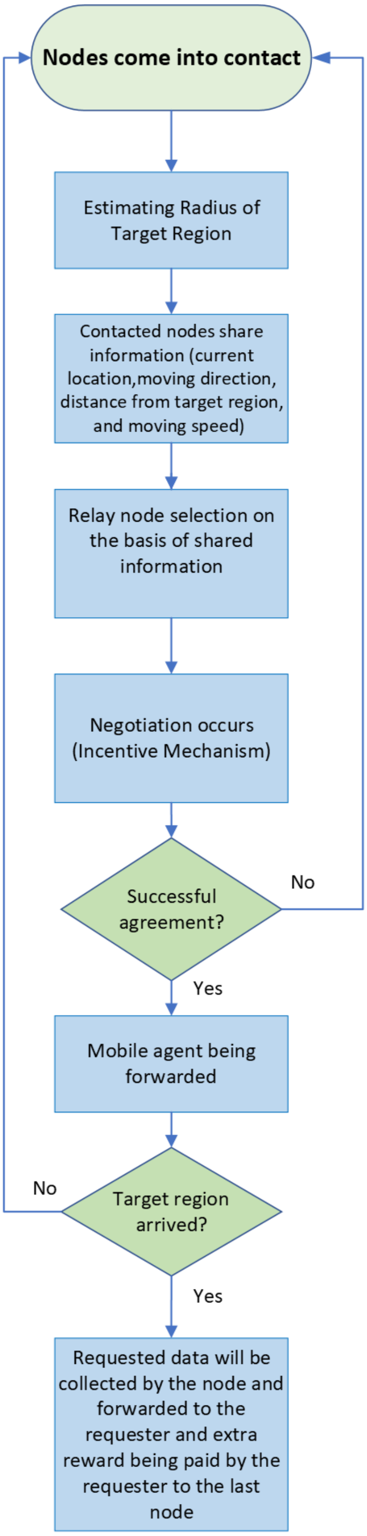

Figure 3.2: System model

when choosing the relay node based on the distance $S_{k,d}$ measured from N_k to d ,the direction that N_k is travelling in as indicated by $\phi_{k,d}$ and the speed of node is indicated by V_k.

- **Case 1:** $((S_{k,d} > R_D) \cap (\phi_{k,d} < (\pi/2))$

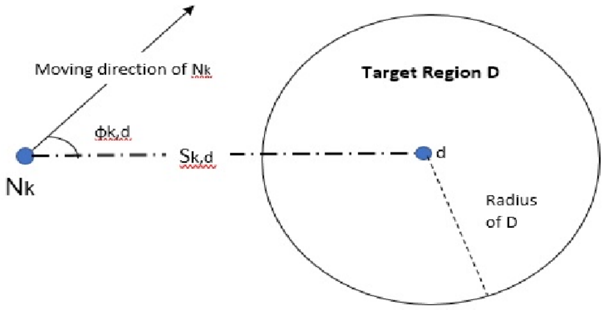

Figure 3.3: Case 1: N_k is moving towards the target region D. [8]

This case happens when N_k is moving towards the target region D as shown in fig 3.2 N_k is qualified by its time duration $T_{k,d}$ to travel in the direction of the target region. $T_{k,d}$ is calculated as:

$$T_{k,d} = \frac{S_{k,d} - R_D}{cos\phi_{k,d} * V_k} \tag{3.1}$$

N_k is considered as a preferable relay node given that $(T_{i,d} > T_{k,d})$ because of its quicker approach to the target region and in return minimising the delivery delay. So, the node with smaller time duration to reach to the target region will be selected as a relay node.

- **Case 2:** $((S_{k,d} > R_D) \cap (\phi_{k,d} >= (\pi/2))$

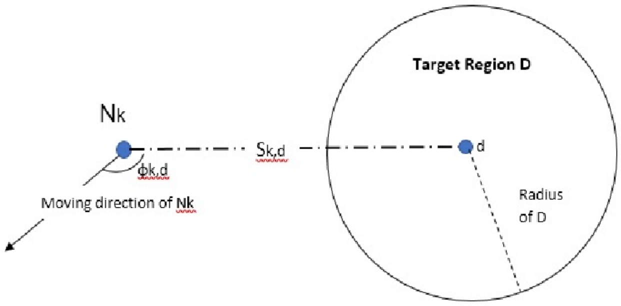

Figure 3.4: Case 2: N_k is moving away from the target region D. [8]

This case happens when N_k is moving away from the target region D as shown in fig 3.3.

N_k is qualified by its projected distance $S_{k,d}^{pro}$ which is calculated from N_k' to the boundary of the target region where N_k' is the predicted location calculated within the time window X. $S_{k,d}^{pro}$ is calculated as:

$$S_{k,d}^{pro} = S_{k,d} - X * cos\phi_{k,d} * V_k - R_D \tag{3.2}$$

N_k is considered as a preferable relay node given that ($S_{i,d}^{pro} > S_{k,d}^{pro}$) because it is closer to the target region. However, both the nodes are moving away from the target region the idea here is to choose that node as a relay which is more closer to the target region to keep the mobile agent/data closer to the proximity. [8]

3.5 Incentive Mechanism

An incentive mechanism is a clever strategy or system designed to motivate individuals to behave in specific ways or make particular choices. The primary objective is to align the personal interests of individuals with the larger goals of a system or a game. It's like creating a plan that encourages everyone to work towards the same positive outcomes.

To break it down, let's say there's a game where everyone can win if they work together. An incentive mechanism in this context might involve giving rewards, like points or bonuses, to players who collaborate and make choices that benefit the whole team. This is because people are naturally more inclined to do things when they know there's something good waiting for them in return.

In the real world, incentive mechanisms are crucial in solving problems like selfishness, where individuals might prioritize their interests over others. They also come in handy when resources are limited, and there's a need to encourage cooperation. By offering incentives, which can be anything from tangible rewards to recognition, systems can promote positive behaviors and foster a sense of teamwork. Essentially, incentive mechanisms aim to turn individual motivations into collective success, making sure everyone wins by contributing positively to the overall system or game.

The incentive mechanism is applied when two nodes come across each other and one node acting as a buyer node wants to forward a mobile agent to the target region, by taking the help from the other node acting as a seller node. But why would the seller node help a buyer node in forwarding a mobile agent as it wants to conserve its resources. It may act selfishly. To handle this situation, a bargaining game is formulated between the two nodes. The buyer node, who is the first mover in the game, offers a price to the seller node, based on its remaining buffer space and the residing time of a mobile agent in its buffer. If the seller node rejects the price, it can make a counteroffer to the buyer node. If they reach an agreement on the price, the mobile agent is then forwarded. This bargaining process helps to ensure the cooperation and that both nodes can be benefited. A seller node offers the price depending on its willingness and richness.

- **Willingness of seller node i to relay a mobile agent:**

  $$w_{i,rcr} = \beta_1(\frac{b_{i,c}}{b_{i,f}}) + \beta_2(1 - \frac{min(dist_{min}, dist_{current})}{dist_{current}}) \tag{3.3}$$

  Each node has a finite amount of buffer space, which gradually gets less as more data is stored in it. $b_{i,f}$ is the initial buffer space of a vehicular node i whereas, $b_{i,c}$ is the filled buffer space at a given time. This factor is to find out the remaining buffer space at given time t. If available buffer is more , the node's willingess is high to relay a mobile agent. Distance of a node i from a target region also impact the willingness of a node.In the worst case scenario, the distance of node i shall either remain the same or shall increase from the target region as it moves. Thus, $dist_{min}$ shall be equal to $dist_{current}$. Consequently, $1 - \frac{min(dist_{min}, dist_{current})}{dist_{current}}$ shall be equal to zero. On the other hand, in the best case scenario, node i shall cross the center point of the target region at which point min_{dist} equals zero. Consequently, $1 - \frac{min(dist_{min}, dist_{current})}{dist_{current}}$ becomes equal to 1. β_1 and β_2 are the weights assigned to both the factors.

- **Richness x_i:** The richness of a node i denotes the virtual currency of a node which indicates the degree of co-operation of a node i.

  $$x_i = \frac{x_i(t)}{x_{rh}} \tag{3.4}$$

  where, x_i is the virtual currency i possesses at time t. x_{rh} is richness threshold. Every node will try to increase its virtual currency in order to reach to the level of richness threshold. Once a node achieves the threshold value or greater than threshold value i-e $x_i >= x_{rh}$ then x becomes 1. Thus, the value of x_i is in the range [0,1]. Insufficient virtual currency will make the seller highly motivated to relay the mobile agent and it will charge low price. In the case of buyer, low virtual currency will make difficult for buyer to buy services to relay its mobile agent. Thus, it is bound to cooperate with others as a seller to be able to earn the requisite virtual currency. This feature of the proposed model encourages the otherwise selfish nodes to cooperate.

3.6 Game Theory

Game theory is a branch of mathematics and economics that studies strategic interactions among individuals or entities, known as players, who make decisions based on the actions of others. It provides a framework for analyzing how these players, each pursuing their own interests, might behave in various situations where their choices influence the outcomes for all involved.

The central concept in game theory is the "game," which isn't necessarily a recreational activity but rather a formal model representing a situation with players, strategies, and payoffs. Players can be individuals, companies, nations, or any entities making decisions in a given context. Strategies are the possible courses of action available to each player, and payoffs represent the outcomes or rewards associated with the combination of strategies chosen by all players.

Game theory explores different types of games, including cooperative and non-cooperative games. In a non-cooperative game, players act independently, making decisions based on their self-interest without formal agreements. On the other hand, cooperative games involve players forming coalitions and making joint decisions to achieve common goals.

One of the key tools in game theory is the "Nash equilibrium," named after mathematician John Nash. In a Nash equilibrium, no player has an incentive to change their strategy unilaterally, given the strategies chosen by the other players. This concept provides insight into stable points in strategic interactions.

Game theory has applications in various fields, including economics, political science, biology, and computer science. It helps analyze scenarios like business competition, negotiations, and international relations, providing a valuable framework for understanding and predicting the strategic choices individuals or entities might make in different situations.

Various types of bargaining games exist, each with distinct characteristics. Here are some common types:

3.6.1 Ultimatum Game:

In an ultimatum game, one player proposes how to divide a sum of money, and the other player can either accept or reject the offer. If rejected, neither player receives anything.

3.6.2 Nash Bargaining Game:

The Nash bargaining game is a cooperative bargaining model where players aim to find an agreement that maximizes the product of their individual utilities. The Nash solution represents a fair and efficient outcome.

3.6.3 Stackelberg Game:

The Stackelberg game is a strategic interaction model in game theory where one player, known as the leader, makes decisions first, and the other player, called the follower, observes those decisions and responds accordingly. Named after economist Heinrich von Stackelberg, who introduced the concept in the 1930s, the Stackelberg game is commonly used to analyze scenarios involving asymmetric information or decision-making power.

3.6.4 Rubinstein Bargaining Model:

In the Rubinstein bargaining model, players take turns making offers and counteroffers. The game continues until an agreement is reached or a predetermined deadline is reached.

3.7 Rubinstein Game Theory Model

We formulated the incentive mechanism as a Rubinstein Game Theory model. In the Rubinstein game, there are two players who engage in a sequential bargaining process. In the Rubinstein game, there is a predetermined number of rounds. In each round, the players take turns making offers and counteroffers to try and come to an agreement. This back-and-forth process allows them to negotiate and find a mutually acceptable outcome.

The game starts with one player, known as the proposer, making an initial offer. The other player, known as the responder, can either accept or reject the offer. If the responder accepts, the game ends, and both players receive their respective payoffs according to the agreed terms. However, if the responder rejects the offer, the game continues to the next round.

In each subsequent round, the proposer can make a new offer, and the responder has the choice to accept or reject it. The process continues until an agreement is reached or a predetermined number of rounds is completed.

The key feature of the Rubinstein game is that it allows for strategic behavior and negotiation tactics. Players must consider their preferences, expectations, and the potential outcomes of accepting or rejecting offers. The game theory framework helps to analyze the strategies and equilibrium points that emerge from this bargaining process.

Overall, the Rubinstein game provides insights into the dynamics of bargaining situations and how players can strategically navigate the negotiation process to reach mutually beneficial outcomes.

We formulated the game up-to two rounds. In round 1 a buyer proposes an offer. If a seller accepts the offer, a mobile agent is being relayed by the seller node. If seller node does not accept the offer, game goes to the second and the final round in which a seller node makes an offer to a buyer node. If an agreement happens between them a mobile agent is being relayed.

After reaching a successful agreement, the buyer and seller nodes have the following expected utilities:

- **Utility of seller**: The expected utility of seller for relaying the agent is:

$$u_s = [w_{i,rcr}.x_s.p_b] - [(c_{i,r}.size_{m_k}) + c_{i,b}] \tag{3.5}$$

Here, when the willingness of a seller increases it will charge high price for relaying buyer's agent. x_s is the richness level of a seller. Low virtual currency will make the seller highly motivated to relay the mobile agent and it will charge low price because when in future the same seller node act as a buyer node it will need a virtual currency to buy services from other nodes.If it doesnot possess enough virtual currency it will not be able to buy services which in return helps to mitigate node's selfish behaviour.p_b is a price a buyer pays to seller for relaying an agent. $c_{i,r}$ is the cost of receiving a mobile agent which depends on a size of agent as bandwidht and energy are being consumed.The bigger the size of an agent the more bandwidth and energy it will consume. $c_{i,b}$ is the cost incur to bargain with the buyer.

- **Utility of buyer**: The expected utility of buyer for relaying an agent is:

$$u_b = [\frac{1}{r_{b,m_k}}) + (\frac{b_{i,c}}{b_{i,f}})].x_b - [(c_{i,s}.size_{m_k}) + c_{i,b} + p_b] \tag{3.6}$$

where, $r_{b,m_k,b}$ means buyer b has been caching m_k for t units of time i.e. it is residing time of m_k in b's cache. The more time a mobile agent k resides in a buffer the more money it will have to pay to the seller. Thus to maximize its own utility it should forward the mobile agent k as soon as it finds the suitable seller node. $b_{i,c}$ is the current buffer space of node i at given time t. $b_{i,f}$ is the initial buffer space of node i. This factor is to calculate the available buffer space of node i. If buffer available is more, the buyer will be more patient and will try to maximize its utility by waiting for a seller node who will charge relatively low amount.x is a richness level of a buyer node i. Node with low virtual currency will not be able to buy any services from other nodes. So, to increase its virtual currency first it will have to cooperate with others as a seller to earn the requisite virtual currency.$c_{i,s}$ is a storage cost of a mobile agent k which depends on a size of mobile agent k. The bigger the size of mobile agent k the cost incur will be high. $c_{i,b}$ is the bargaining cost with a seller node. p_b is a cost buyer pays to seller node.

The Rubinstein bargaining game is shown in a figure 3.4 below: where, u_b and u_s

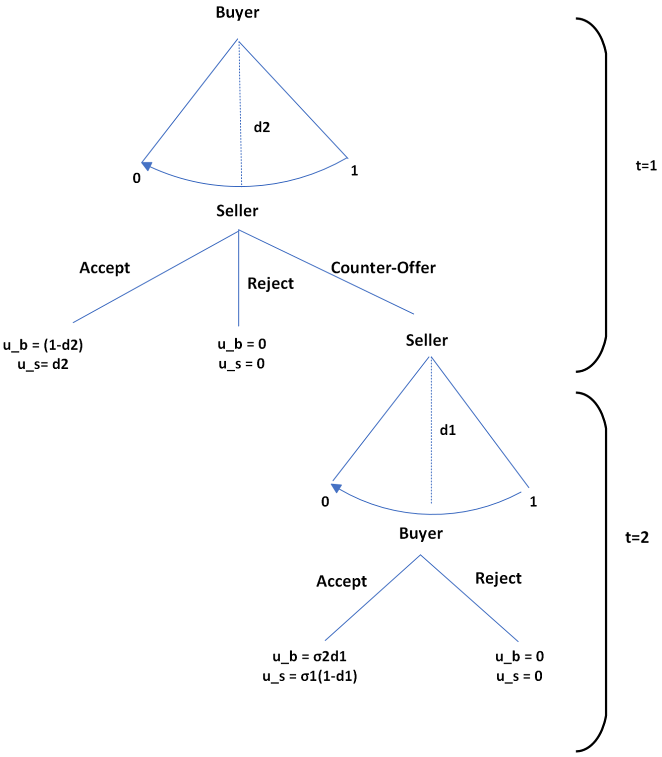

Figure 3.5: Rubinstein game model between buyer and seller

is a utility of a buyer and utility of a seller. $\sigma 1$ and $\sigma 2$ are the discount factors of seller and a buyer node, which represents the cost or disadvantage associated with delaying the agreement. In our case the cost of delaying is bargaining cost and storing cost of mobile agent. This delaying cost increases after each unsuccessful round. So, it is better to agree today rather than agreeing tomorrow that is to agree earlier to avoid an extra delay.

$$\sigma 1 = -c_{i,b} \tag{3.7}$$

$$\sigma 2 = -[c_{i,s} + c_{i,b}] \tag{3.8}$$

3.8 Sub-game Perfect Equilibrium

From equation(3.5.1):

$$u_b = [\frac{1}{r_{b,m_k}}) + (\frac{b_{i,c}}{b_{i,f}})].x_b - [(c_{i,s}.size_{m_k}) + c_{i,b} + p_b] \tag{3.9}$$

The reward it gains should be greater than the cost it pays to the seller i-e Reward > Cost

$$[\frac{1}{r_{b,m_k}}) + (\frac{b_{i,c}}{b_{i,f}})].x_b > [(c_{i,s}.size_{m_k}) + c_{i,b} + p_b] \tag{3.10}$$

Rearranging equation (3.5.6)

$$[\frac{1}{r_{b,m_k}}) + (\frac{b_{i,c}}{b_{i,f}})].x_b - (c_{i,s}.size_{m_k}) - c_{i,b} > p_b \tag{3.11}$$

$$p_u b = [\frac{1}{r_{b,m_k}}) + (\frac{b_{i,c}}{b_{i,f}})].x_b - (c_{i,s}.size_{m_k}) - c_{i,b} \tag{3.12}$$

let us say, $p_u b$ is upper threshold value which a buyer will offer.

From equation(3.5.2):

$$u_s = [w_{i,rcr}.x_s.p_b] - [(c_{i,r}.size_{m_k}) + c_{i,b}] \tag{3.13}$$

The reward it gains should be greater than the cost it pays to the seller i-e Reward > Cost

$$[w_{i,rcr}.x_s.p_b] > [(c_{i,r}.size_{m_k}) + c_{i,b}] \tag{3.14}$$

Rearranging equation (3.5.10)

$$p_b > [(c_{i,r}.size_{m_k}) + c_{i,b}]/[w_{i,rcr}.x_s] \tag{3.15}$$

$$p_b > [(c_{i,r}.size_{m_k}) + c_{i,b}]/[w_{i,rcr}.x_s] \tag{3.16}$$

$$p_l b = [(c_{i,r}.size_{m_k}) + c_{i,b}]/[w_{i,rcr}.x_s] \tag{3.17}$$

let us say, $p_l b$ is lowest threshold value which a seller will accept.

- **Using backward induction:**
- **During time period t=2**

Seller is a proposer

Buyer accepts any offer d1 coming from seller if and only if $\sigma 2d1 >= p_u b$ i-e d1 >= $p_u b$. Seller knowing that buyer accepts any offer d1 satisfying d1 >= $p_u b$, makes an offer maximizing his utility function i-e:

$max_{(d1>=p_u b)}$ $\sigma 1(1 - d1)$ such that:

d1 = $p_u b$

which gives seller a payoff of

$\sigma 1(1 - p_u b)$

- **During time period t=1**

Buyer is a proposer

Seller rejects any offer d2 from buyer that is below what he will get for himself during the next period, $\sigma 1(1-p_u b)$ i-e he rejects any offer d2 such that: $\sigma 1(1-p_u b) >$ d2. Buyer then offers to seller an offer d2 such that maximizes his own utility that is:

$max_{(d2>=sigma1(1-p_u b))}\ (1-d2)$ such that:

d2 $= \sigma 1(1-p_u b)$

which gives seller a payoff of

$1-\sigma 1(1-p_u b)$

Therefore, we can describe the sub-game perfect equilibrium of this game:

- Buyer offers d2$=\sigma 1(1-p_u b)$ in periods t=1 and accepts any offer d1 $>= p_u b$ in t=2.
- Seller offers d1$=p_u b$ in t=2 and accepts any offer d2 $>= \sigma 1(1-p_u b)$ in t=1.

Chapter 4

Results and Discussions

In this section we have done the experiments to check the feasibility of our proposed incentive based mechanism using mobile agents in VANETs. For the evaluation purpose we have used Opportunistic Network Environment (ONE) and used real road map.Also we have done comparison with the base paper [20]. In the base paper if the relay node detour its original path only then it will get a reward otherwise the relay node will not get any reward for forwarding the mobile agent. But in reality even the relay nodes are going in the direction of mobile agent's destination, why would it forward the mobile agent without getting any benefit or reward as the resources of relay node is still being utilized. No negotiation algorithm is being proposed in the base paper. The base paper considers that nodes are co-operative in nature. In our proposed work we have considered the nodes selfishness and tried to mitigate the problem by giving incentives. And then evaluated how nodes selfishness effect the performance of a network.

4.1 Parameters in the simulation

- **City map:** We have used Helsinki map as shown in fig (4.1) The world size we have taken is 4.5km, 3.4km (width,height). We have virtually divided the map into 4 cells as shown in fig (4.2). If a requester node lies in cell 1 or cell 3, it will make a request of an information in cell 2 or cell 4. This is done so to avoid target region or destination near the requester.

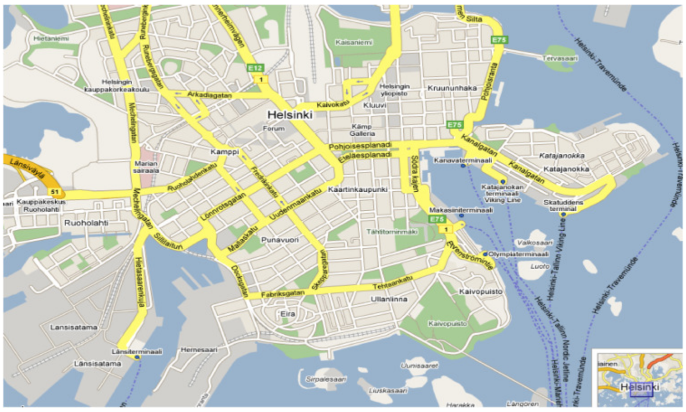

Figure 4.1: Helsinki map [17]

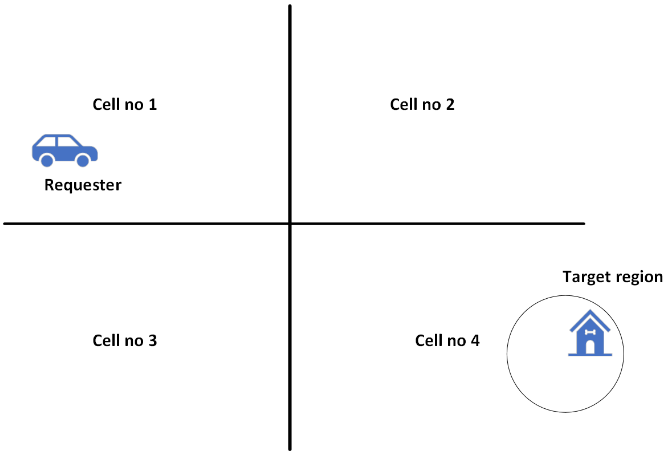

Figure 4.2: Virtually division of map

- **Broadcast interface:** For broadcast interface we have used high-speed simple broadcast interface. The transmit speed is 10Mbps and the transmit range is 50 meters.

- **No. of hosts:** We have used a range from 30 to 120 no.of hosts for different simulations. Also , we have divided the hosts into groups, for example cars and trams. Also, later these groups are divided into selfish and non-selfish nodes.

- **Hosts speed:** The speed of hosts ranges from 20km/h to 80km/h for diffrent simulations.

- **Movement model:** The movement model we have used is Shortest Path Map Based Movement.

- **Buffer size:** The buffer size of hosts is 5M bytes.

- **Message size and event generation:** The message size is 500k,1M.

  The message generation event occurs after every (2000s,2500s)

- **Hop strategy:** When nodes come into contact with each other, a mobile agent carrier node will select the appropriate relay node on the basis of time taken to reach the destination or projected distance from the destination. After relay node selection, nodes will bargain and if agreement happens between them the mobile agent gets forwarded and carrier node will pay some virtual currency to the relay node.

4.2 Metrics evaluated in the simulation:

- **Average time taken by mobile agent to reach the destination:** We have calculated the average time taken by mobile agents to reach the destinations i-e from the creation of mobile agent to reach the destination on the basis of speed, no. of vehicles and selfishness.
- **Average total hops:** We have calculated the average hop counts taken by mobile agent to reach the destination i-e no. of relay nodes till the destination arrived.
- **Delivery ratio:** We have calculated the delivery ratio (delivery percentage) of mobile agents i-e how many mobile agents have reached the destination among the mobile agents being created.

4.3 Performance Evaluation:

In the first section, we evaluated the impact of varying speed and no. of vehicles on the metrics described.

In the next section we have evaluated the effect of selfishness of nodes in comparison with the algorithm in which selfishness is mitigated by giving incentives.

4.3.1 Impact of Speed on Average time taken by mobile agents to reach the destinations:

In these sets of simulations we vary the speed of vehicles and compared the time taken by mobile agent to reach their destination/target regions. On the x-axis we have taken speed in km/h whereas, on the y-axis we have taken the average time taken in seconds. The total mobile agents generated are 43. We have kept the no. of vehicles constant i-e 60. In can be seen by the figure 4.3 that as the speed increases, the average time taken by mobile agents to reach the target region decrease. This suggests that there is an inverse relationship between speed and average delivery time. In simpler terms, when the speed is higher, messages tend to reach their destination more quickly. It's important to note that this relationship may vary depending on other factors, such as network traffic etc. But in general, a higher speed typically leads to a shorter delivery time for messages.

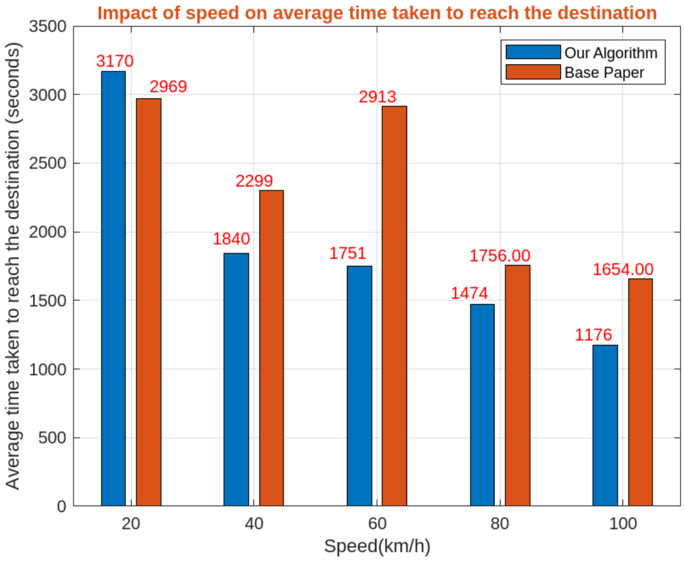

Figure 4.3: Impact of speed on average time taken by mobile agents to reach the destinations

Also, it can be seen clearly in the figure 4.3 that our algorithm reduces the delivery time of mobile agent to the destination as compared to base paper algorithm.

4.3.2 Impact of Speed on Average hops count to reach the destinations :

In this set of simulations, we experimented with different vehicle speeds and compared on average how many hops the mobile agents need to reach their target regions. The x-axis represents the vehicle speed in km/h, while the y-axis represents the averge no. of hops. The number of vehicles was kept constant at 60, and a total of 43 mobile agents were generated.

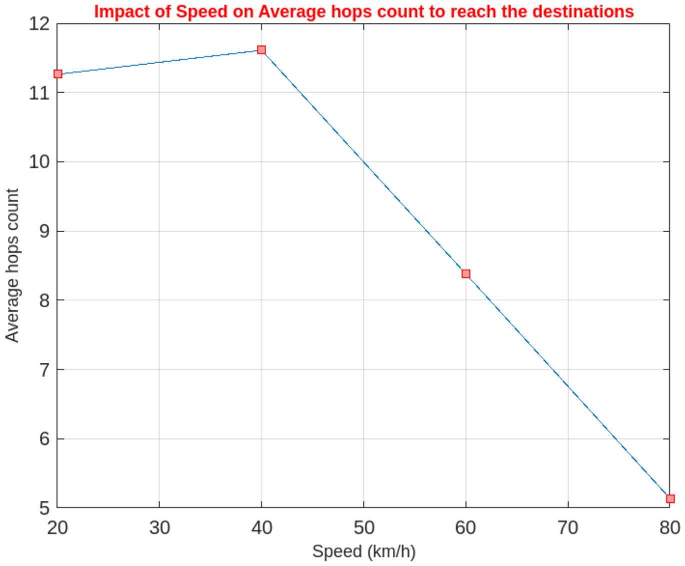

Figure 4.4: Impact of Speed on Average hops count to reach the destinations

As shown in a figure 4.4, the x-axis represents the speed of the vehicles, and the y-axis represents the average number of hops required for a mobile agents to reach their destinations.

We have different speeds of vehicles plotted on the x-axis, ranging from low to high. On the y-axis, we have the corresponding total number of hops needed for the mobile agents to reach their destinations.

The graph 4.4 allows us to observe how the speed of the vehicles affects the total number of hops. Generally, as the speed of the vehicles increases, the mobile agents can reach their destinations in fewer hops.

Conversely, when the speed of the vehicles decreases, the mobile agents may need to go through more hops to reach their destinations.

4.3.3 Impact of Speed on Delivery ratio :

In this series of simulations we tested different vehicle speeds and looked at how speed effects the delivery ratio of a mobile agent i-e how many mobile agents are successfully delivered to their target regions . We kept the number of vehicles constant at 60 and generated a total of 43 mobile agents.

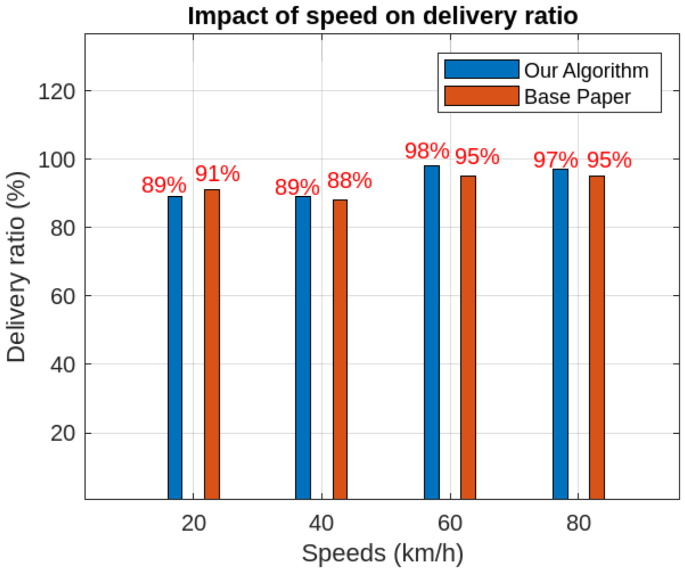

Figure 4.5: Impact of Speed on Delivery ratio

In the figure 4.5 the x-axis represents the speed of the vehicles, while the y-axis represents the delivery ratio.

The delivery ratio refers to the percentage of mobile agents that successfully reach their intended target regions. As the speed of the vehicles increases, the delivery ratio improved. This means that a higher percentage of mobile agents will be successfully delivered.

On the other hand, as the speed of the vehicles decreases, the delivery ratio may decrease as well. This indicates that a lower percentage of mobile agents will reach their destination successfully.

4.3.4 Impact of Varying No.of vehicles on Average time taken by mobile agents to reach the destinations :

In these simulations, we examined how the different number of vehicles affects the time it takes for mobile agents to reach their destinations. We specifically looked at how varying the number of vehicles impacts the time it takes for a mobile agent to reach its target. Throughout the simulations, we maintained a constant speed of 80 and generated a total of 43 mobile agents.

By observing the figure 4.6, if we increase the number of vehicles, it can potentially lead to faster travel times for the mobile agents. With more vehicles available, there may be fewer delays due to more options for mobile agent to relay , allowing the mobile agents to reach their destinations more quickly.

On the other hand, if we decrease the number of vehicles, it may result in longer travel times for the mobile agents. With fewer vehicles on the road, there could be less options for mobile agent to relay, which can slow down the mobile agents' journey to their targets.

Also, it can be seen clearly in the graph that our algorithm reduces the delivery

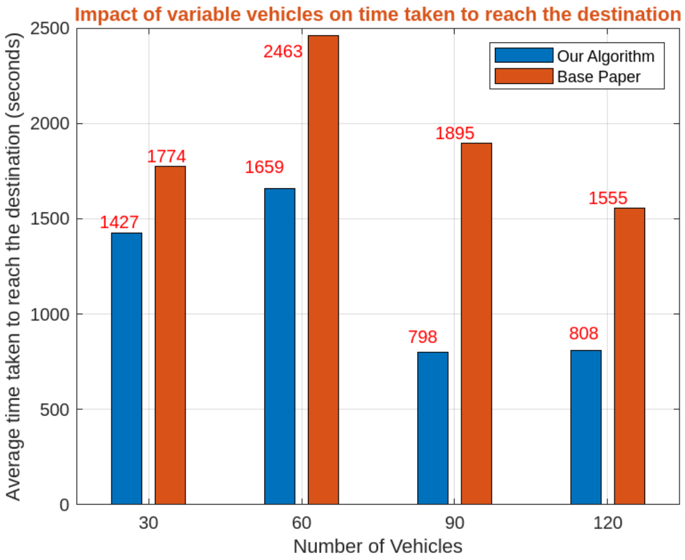

Figure 4.6: Impact of Varying No.of vehicles on Average time taken by mobile agents to reach the destinations

time of mobile agent to the destination as compared to base paper algorithm.

4.3.5 Impact of Varying No.of vehicles on Average hops count to reach the destination :

In these simulations, we looked at how changing the number of vehicles impacts the total number of hops required by mobile agent to reach the destinations. We kept the speed constant at 80 and generated a total of 43 mobile agents. By varying the number of vehicles, we were able to observe how it affected the overall efficiency and effectiveness of the mobile agents in reaching their destinations.

It can be observed in the figure 4.7, that by increasing the no of vehicles, the hop counts also increases. This is due to more potential and better options available to mobile agents to relay. So, they are directly proportional to each other.

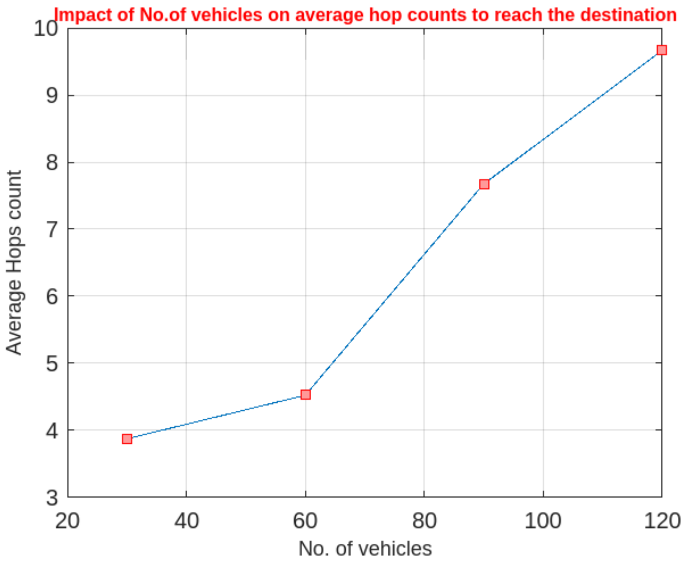

Figure 4.7: Impact of Varying No.of vehicles on Average hops count to reach the destination

4.3.6 Impact of Varying No.of vehicles on Delivery ratio:

In these simulations speed is kept 80km/h and total no. of mobile agents generated are 43.

It is observed by the figure 4.8 that No. of vehicles have slight effect on the delivery ratio. Mobile agents, however, reaches to their target regions no matter how much time they take to reach.

However, it can be seen in the figure 4.8 that our algorithm slightly increases the delivery ratio.

4.3.7 Impact of Selfishness ratio on Average time taken by mobile agents to reach their destinations:

In these simulations, we have kept total no. of vehicles constant i-e 30 and speed 60km/h.

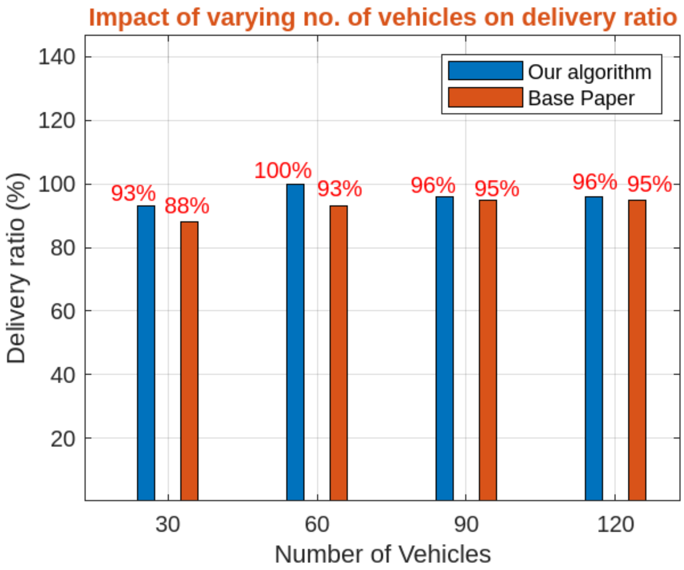

Figure 4.8: Impact of Varying No.of vehicles on Delivery ratio

We observe how different selfishness levels effect the performance of the system. Also, we then compare our proposed algorithm in which the problem of selfishness has been removed by using the bargaining. It can be seen in a figure 4.9 that selfishness shares direct relation with time taken to reach the destinations. If more nodes are selfish in a network, it would become difficult for mobile agents to reach the destinations. So, time taken by nodes to reach the destinations will be increased. As, selfishness decreases the time taken to reach decreases.

In the figure 4.9 0.00% shows our proposed algorithm, in which nodes' selfishness has been removed by using incentives. It is prominent in the graph that due to our proposed solution time taken by nodes decreases and mobile agents reach their destinations in lesser time comparatively.

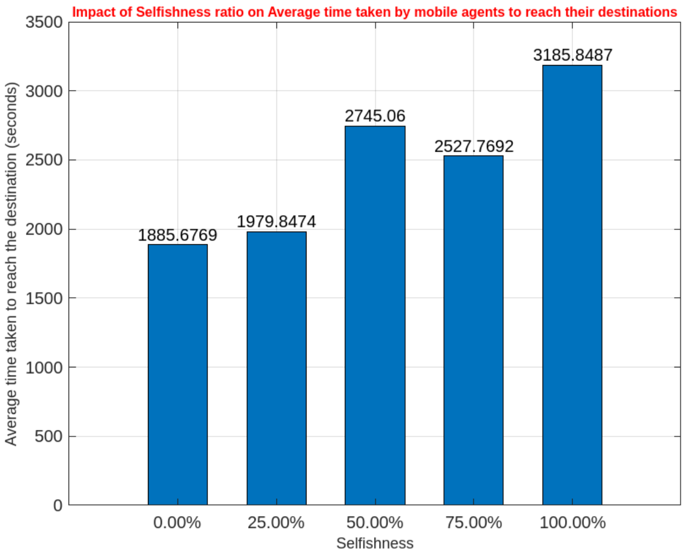

Figure 4.9: Impact of Selfishness ratio on Average time taken by mobile agents to reach their destinations

4.3.8 Impact of Selfishness ratio on Average total hops to reach the destinations:

In these simulations, we have kept total no. of vehicles constant i-e 30 and speed 60km/h.

It can be observed from the figure 4.10 that due to increase in selfishness of nodes the no. of hops decreases. This is due to the fact that without any rewards nodes will be reluctant to help and act selfish. As a result, the hop count decreases until it becomes '0' when all nodes in a network are selfish.

4.3.9 Impact of Selfishness ratio on Delivery ratio:

In these simulations, we have kept total no. of vehicles constant i-e 90 and speed 80 km/h. It can be observed from the figure 4.11 that Selfishness has an impact on delivery ratio. Due to selfishness the delivery ratio decreases comparatively to the delivery ratio

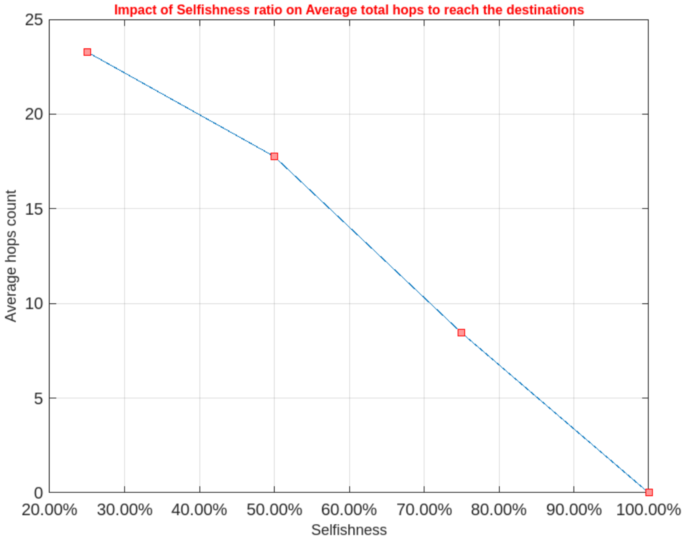

Figure 4.10: Impact of Selfishness ratio on Average total hops to reach the destinations:

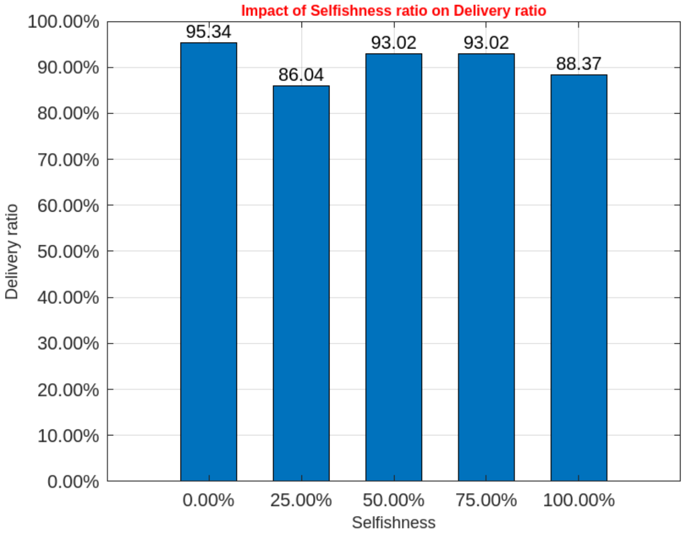

Figure 4.11: Impact of Selfishness ratio on Delivery ratio

obtained from our proposed algorithm on the same settings. In the graph 0.00% shows the results of our proposed algorithm.

Chapter 5

Conclusion And Future Directions

This research project was motivated by a multifaceted set of goals, each contributing to a comprehensive exploration of incentive-based mechanisms. One of the primary objectives was to conduct a thorough examination of existing literature and scholarly works pertaining to incentive-based mechanisms. The intent was to undertake a meticulous analysis to gain a nuanced understanding of the diverse approaches that have been previously explored within this domain. By delving into the existing body of work, the aim was to discern patterns, identify gaps, and extract valuable insights that could inform the present research.

In addition to scrutinizing incentive-based mechanisms, another pivotal goal was to delve into the implementation of various game models within the framework of game theory. Specifically, the focus extended to the Rubinstein game theory model. The research sought to unravel the intricacies of different game models and, in particular, elucidate the complexities arising from the selfish behaviors exhibited by nodes in the context of data dissemination. Recognizing the challenges posed by these behaviors, the research aimed to propose an innovative solution by leveraging the Rubinstein game model. By aligning the principles of game theory with the intricacies of data dissemination challenges, the objective was to devise a framework that not only identifies the hurdles but also strategically overcomes them through the application of the Rubinstein game model.

5.1 Problems and Our Contributions

The antecedent research endeavors focused on incentive-based mechanisms within Vehicular Ad Hoc Networks (VANETs) were not without their limitations. Notably, certain studies operated under the assumption of universal cooperation among all nodes, a premise that often diverges from the complexities encountered in real-world scenarios. Recognizing the inherent variability in the cooperative nature of nodes, this assumption may not faithfully represent the diversity of behaviors exhibited by vehicular entities within a VANET.

Moreover, certain incentive schemes featured constraints, such as restricting data relay to a maximum of two hops. While such limitations may be suitable for scenarios with proximate destinations, they may prove insufficient when the intended recipient is situated at a more considerable distance. The adequacy of data relay mechanisms becomes a critical factor, especially in expansive VANETs where destinations could be dispersed across varying spatial scales.

Another facet where previous research exhibited limitations was the treatment of time sensitivity within incentive schemes. Some schemes did not accord sufficient importance to the temporal dimension, overlooking the critical aspect of time in data dissemination scenarios. In real-world VANET applications, the time-sensitive nature of certain information, such as traffic updates or emergency notifications, necessitates a meticulous consideration of temporal dynamics in the design and implementation of incentive-based mechanisms. Addressing these limitations becomes imperative for advancing the effectiveness and applicability of incentive-driven approaches in VANETs.

Moreover, certain proposed research efforts exhibited a tendency to address singular tasks in isolation, overlooking the inherent complexity of real-world scenarios where multiple concurrent tasks demand simultaneous attention and delivery to the intended target region. The limitation of a task-centric approach became apparent when confronted with the multifaceted nature of operations within Vehicular Ad Hoc Networks (VANETs), where a spectrum of diverse tasks necessitates integrated and cohesive solutions. Generic data communication was another limitation, as it consumed more network resources compared to specific mobile agent code. Additionally, the values of generic data decayed over time, whereas mobile agents did not.

To address these limitations, the proposed work utilizes the Rubinstein game theory model. It tackles the issue of node non-cooperation (selfishness) up to multiple hops while considering time sensitivity. In this approach, multiple tasks, that is delivering the mobile agents to their target regions and sending back sensed data to the requesters', are handled simultaneously.

5.2 Findings and insights

By thoroughly examining the scheme through these simulations, we were able to gather valuable insights into its performance and effectiveness in different scenario. Nodes are selfish by nature and to make them co-operative incentive mechanisms plays a great role. The results shows that data dissemination is effected negatively due to selfishness. This thesis brings attention to the potential of the proposed algorithm in addressing the issue of node selfishness and enhancing the data communication process in VANETs. It sheds light on how the algorithm can mitigate selfish behavior among nodes and improve the overall efficiency of data transmission.

By carefully observing and analyzing the graphs, it becomes evident that when the selfish behavior of nodes is eliminated, there are noticeable improvements in data delivery time, the number of hops required, and the overall delivery ratio. It's clear that removing selfish behavior has a positive impact on these key metrics.

5.3 Future work

The current thesis has made significant contributions to our understanding and improved data dissemination in VANETs. However, there are still many areas that are ready to be explored and expanded upon.

- **Concept of caching:** In the research we conducted, we only considered a single instance of a mobile agent moving around the network. However, we're thinking about how we can make improvements in the future. One interesting idea is to introduce a caching system for the mobile agent that carries the most frequently requested data.

  Here's how it could work: Instead of having just one mobile agent going around, we could store copies of the mobile agent at specific points in the network. These copies would contain information that people often ask for. So, when someone else in the network needs that same information, they can simply send out a request message. Any node (or point) in the network that has a cached copy of the mobile agent can quickly respond with the needed data. This way, we don't always have to rely on the original mobile agent traveling across the entire network.

The idea of caching is like having a backup of popular information in different spots, making things more efficient. It could potentially speed up responses and make better use of resources in networks where vehicles communicate with each other. Exploring this concept further in future research could help us understand how caching strategies might improve the overall performance of Vehicular Ad Hoc Networks (VANETs).

- **Security and privacy:** Security and privacy are crucial in any network to protect the data from potential damage or unauthorized access.In future work we can implement measures such as encryption, authentication, and access control to ensure the confidentiality, integrity, and availability of the data. By incorporating robust security mechanisms, we can safeguard the information and prevent any potential threats or breaches.

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