JIMMA UNIVERSITY
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Community Recognition Incentive Scheme for Social Aware Networks

By:

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Declaration

I declare that this thesis is entitled Community Recognition Incentive Scheme for Social Aware Networks is my original work and has not been presented for degree in any Universities and all source of references used for this thesis work have been properly acknowledge.

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This thesis has been submitted for examination with my approval as University Co-advisor.
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DEDICATION

I have dedicated this thesis to my beloved parents (mother, father, brothers and sisters) who never stop giving of themselves in innumerable way to help me in every aspect and their appreciation.

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Above all, I would like to thank GOD for giving me the strength to achieve whatever I have achieved so far. Next to this, I would like to express my sincere appreciation to my advisor, Dr. Ahmedin Mohammed for his guidance, encouragement and continuous support through the course of this thesis starting from problem finding, developing work plan and what we achieved in this study specially he sacrifice his time during my challenging situation in finding and selecting study area and show me the direction to understand about the research and start to find gap.

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LIST OF ACRONOMY

ASNET: ad hoc social network

CAIS: copy adjustable incentive scheme

CAR: context aware routing

CID: community id

CIS: community based incentive scheme

ConDis: content dissemination

ConSub: content subscribe

CRIS: community recognition incentive scheme

CRV: current recognition value

CRV_{rn}: current recognition value of relay node

CRV_{sn}: current recognition value of source node

DTN: delay tolerant network

DTSN: delay tolerant social network

GTFT: generous tit for tat

IRONMAN: incentives and reputation for opportunistic networks using sociAl networks

MANET: mobile ad hoc network

Md: message delivered

MDN: message destination node

MDR: multiplicative decreasing reward

MKAR: multiple knapsack assignment restriction

MS: message size

MuRIS: multi-receiver incentive-based scheme

NDI: node dependence-based

ON: opportunistic network

ONE: opportunistic network environment

OSN: opportunistic social network

QoS: quality of service

RCAR: reputation context aware routing

RN: relay node

SANs: social aware networks

SN: source node

SNA: social network analysis

SSAR: socially selfishness aware routing

SUCCESS: secure user-centric and social-aware scheme

Thvc: current threshold value

Rcvn: current recognition value of nodes

TTL: time to live

TTP: third trust party

VANET: vehicular ad hoc network

VASNET: vehicular ad hoc social network

ABSTRACT

For improving the network performance of today's Internet a new paradigm called Social Aware Networks (SANs) is emerged. This new paradigm of network exploits social properties of involved entities or mobile users to guide the design of protocols due to the human centric nature of recent mobile networks. Because of nodes' mobility, it is difficult to maintain an end-to-end connectivity between source and destination. As a result, the research efforts come up with this new network paradigm as solution to existing challenges. This new paradigm considers social properties of individuals for developing different forwarding algorithms and improve the connectivity among nodes. In order to achieve a better performance, the cooperation among nodes is important such as participation of well-behaving nodes are considered to be the default scenario for most of the exiting protocols in this networking environment. However, due to selfishness (misbehaving) nature of individuals, some nodes conserve their resources such as buffer spaces. This brings data forwarding activity degraded in terms performance evaluation metrics such as delivery ratio.

Therefore, in this work an incentive mechanism among social selfish nodes for data forwarding activity to improve the performance based on community recognition incentive scheme called CRIS is proposed. The implementation of this work is employed tit for tat strategy to forward data among nodes of different communities as mutual benefit of encounter nodes to tackle selfishness behavior of nodes. To promote cooperation among nodes first grouped them into a communities based on their interest. Then nodes give forwarding service to each other within inter-community communication to get recognition value.

The evaluation result compares the proposed scheme with non-incentive and selfishness routing mechanisms and also existing works in terms of delivery ratio, overhead ratio, hopcount and average latency. The results illustrate that community recognition incentive scheme outperforms both mechanisms (non-incentive and selfishness routing mechanisms) and other incentive schemes with higher message delivery ratio, less overhead ratio and high hop counts. At optimal message generation time intervals, delivery ratio of CRIS is 94% while 71% and 50% for non-incentive and selfishness routing mechanisms, respectively. In terms of overhead ration, non incentive scheme is less than both schemes which is 63 in CRIS while 65 for selfishness routing scheme.
Keywords:- *Socially Aware Networking; social selfishness; community recognition;incentive scheme; Tit for Tat.*

CHAPTER 1

INTRODUCTION

1.1 Background

Social aware networks (SANs) a new paradigm to improve the network performance of today's internet. This paradigm employed opportunistic networks follows the store-carry-and-forward paradigm. When a node receives a message from another node, the former stores the message in its buffer. The concerned node can possibly move with the message stored in its buffer. In other words, a node carries a message while it moves. Finally, when the node comes in contact with another node which could take a considerable amount of time the former forwards the node to the latter with the hope that the latter can deliver the message to its corresponding destination. The mobility patterns of mobile devices strongly depend on the carrier' movements, which are closely related to their social relationships and behaviors. As a result, today's mobile networks are becoming human centric which means mobility pattern of devices depend on the mobility or movement of their carriers (e.g. human, vehicles, or animals). SANs enables researchers to design routing, forwarding, replication, dissemination and selfishness behavior detection algorithm to improve the existing internet extract social properties of individuals [1][2]. This new paradigm helps to address efficiently use of mobile devices resources such as memory spaces with social properties that focus on wireless communications and ad hoc networks with mobile devices for different types of networks such as MANETs, VANETs, DTNs or ONs.

Figure 1.1 below reveals that the combination of SANs with other types of networks and form other type of networks in which protocols and algorithm proposed and presented by using the advantage of social properties to bring the solutions in the previous networks. In SANs, nodes are normally grouped into different communities according to their social relationships such as family, classmates, coworkers, in general with common interest. This paradigm was emerged to improve network protocol performance. Because of nodes' mobility, an end-to-end connectivity between source and destination is difficult to maintain. Therefore, nodes usually follow store-carry-and-forward fashion for forwarding data [3]. Social properties of individuals in SANs are extracted from Social Network Analysis (SNA) [4][5] which is a useful and powerful tool for studying relationships between human beings, as well as patterns and implications in sociology field. In SANs the big issue now a day is selfishness behavior of users to conserve their resource such as buffer, energy and bandwidth for only their own benefit. Selfish nodes have an impact on data management such as data forwarding because their unwillingness behavior of sharing resources such as buffer. The social selfishness behavior of users is still an issues in data management process such as data forwarding activities for SANs. Therefore, selfishness behavior of nodes require incentive mechanism to facilitate cooperation among each other.

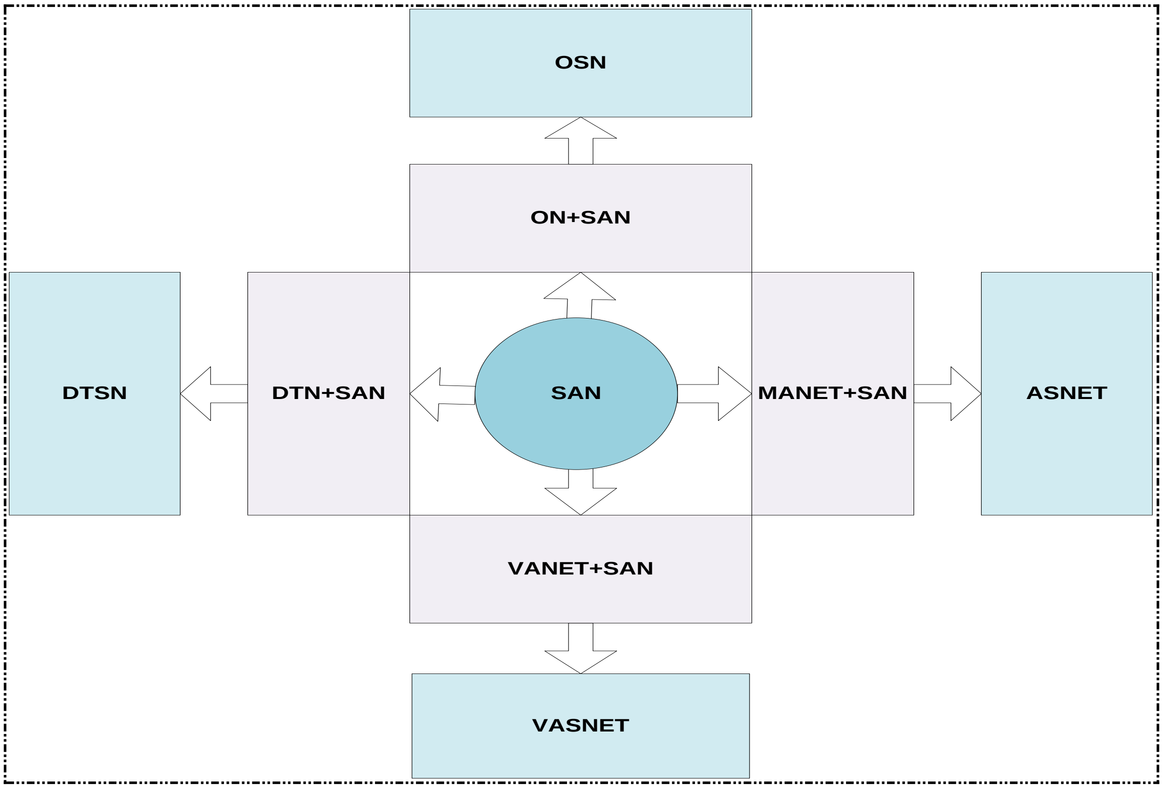


Figure 1.1 Social aware network paradigms

Therefore, incentive scheme is a mechanism that helps to promote cooperation among social selfishness behavior of individuals for data forwarding, replication, dessimination and allocation. There are different strategies available to design an incentive scheme such as reputation based, credit based as well as tit-for-tat. These strategies have their own characteristic to develop an algorithm [1]. For instance reputation-based incentive schemes is a scheme that give reputation to the node which provides services to the other node specifically to which it forwards messages for the other nodes [6][7]. Therefore, node with good reputation value can receives services from other nodes in the network. Based on the threshold value reputation of node is less than threshold value set then node may ignore from the network and distribute its selfishness behavior to other nodes in network. Then to get service from the other node it start to forward data for others and increase its reputation value. The incentive scheme strategy is tit-for-tat (TFT) which is based on every node forwards as many messages for a neighbor as the neighbor forwards for it just as mutual benefit is also proposed. In this schemes, every node forwards as many messages for a neighbor as the neighbor forwards for it. There are studies that conducted to tackle the selfishness behavior of users based on tit-for-tat based strategy such as [8]-[11]. The other strategy which helps to improve network performance through virtual currency payment for node is called credit-based schemes. In this mechanism, virtual currency would be provide to nodes when it forwards packets for others. There are studies which proposed an incentive scheme based on credit based strategy such as [6][12][13]. Therefore, the objective of incentive scheme in the network is to improve the performance of the network through construct cooperation behavior among nodes. For example, there are an algorithms that forward data blindly without considering selfishness behavior of users such [14][15]. However, in real scenario nodes usually will have selfishness behavior in order to save resources and they are not willing to forward packets received from those with whom it has no social ties, but it forwards packets received from nodes with stronger ties in the case of limited resource [15][16]. Many research efforts on incentive mechanisms are exploited to stimulate the individual selfish nodes to cooperate but still social selfishness in SANs is one of the open issues as explained by Xia *et al.* [1]. Therefore, incentive scheme is an important mechanism to tackle selfishness behavior of node in the network through applying the strategies discussed above.

In this thesis, we propose CRIS incentive scheme with the concept of community construction and TFT (tit for tat) strategy to make cooperation among nodes of different communities. A node get recognition when it give buffering and forwarding service for nodes outside its community. At the same time the recognition of nodes which get services will reduces from the recognition value accumulated previously. Hence, a node should balance the recognition value when it gain and give forwarding services. When node get services its recognition value decrease while increase when it share resource and give service among nodes of different community. If both source node and relay nodes are in the same community, the node will not gaining and losing recognition since they have strong relationship and considered to be willing to each other. The general concept of community recognition with TFT strategy is to tackle selfishness and make nodes cooperate to each other in the network to achieve better network performance.

1.2 Statement of the Problem

There are many socially-aware routing algorithms that have been proposed to increase data delivery and reliability. However, they are designed purely based on contact opportunity without considering users' willingness and assume that all nodes are willing to forward packets for others. This means they didn't considered the presence and the impact of selfishness behavior in the network. Therefore, different socially-aware forwarding algorithms forward data blindly without considering selfish nodes which is critical issues in store carry forwarding paradigm [3][14][15].

However, there are nodes that exhibit selfishness behavior and are not cooperate with other to conserve their resource such as buffer space for only their own benefit [2][18] which nodes should give service to get benefit from other. Selfishness behavior of nodes have an impact in data management activates specifically data forwarding. Therefore, the presence of such users could degrade the performance of data forwarding process in the networks by reducing delivery ratio, and increasing latency and overhead. However, there are studies that indicate the impact of social selfishness behavior in data forwarding process such as [15][19][20].

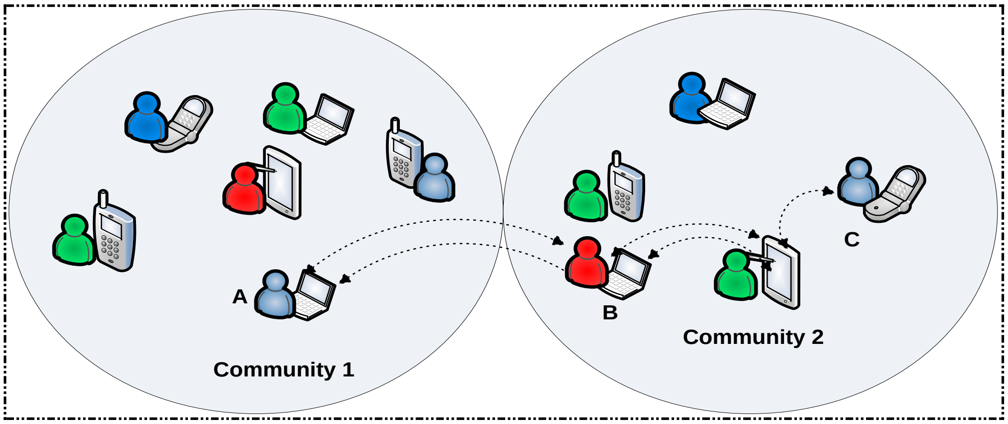


Figure 1.2 Inter-community communication among nodes

There are individual and social selfishness behavior of nodes. Individual selfishness behavior of node is a behavior that are not willing to give services for any other nodes whereas social selfish users are willing to forward packets for others with whom they have social ties or to community whom they are belongs but they are unwilling to outside of their social tie or community [1]. Figure 1.2 above demonstrates a simple scenario which could represent campus network. Here user **A** may need to forward data from **community 1** to user **C** which is located in **community 2**. But node **A** forwards data to node **C** through intermediate node **B** which is located in **community 2**. However, if node **B** is social selfish for conserving it storage space it drops data and so that data originated from node **A** could not arrive at destination node **C** because of selfishness behavior of user **B** and decrease data delivery ratio while increasing delivery delay. Ofcourse, different works are conducted to come up with a soulition for selfishness issue in data forwarding activity for opportunistic type of networks as reviewed in literature review. However, most of the studies are proposed and presented for individual selfishness. Ofcourse there are some studies that use the advantage of social properties for tackling social selfishness behavior such as [21][22]. Even if, those incentive scheme were proposed for tackling selfishness behavior of users, social selfishness behavior of users is still an open issues and need to further studies according to Xia *et al.* [1].

Therefore, proposing a novel incentive scheme for tackling social selfishness behavior of users is necessary. In this study we proposed community recognition incentive scheme called CRIS and stimulate social selfishness behavior of users by giving recognition to nodes which are cooperate with other to buffer and forwarding data. At the beginning when two nodes are encounter to each other they may have initial level of recognition value and threshold value. The incentive algorithm initiate intermediate node to buffered message from other node of different community. Nodes will cooperate to each other based on recognition value of each node by following TFT approach for mutual benefit among nodes of different community. In our proposed scheme, it's assumed that nodes within the same community are willing to each other and share their forwarding resources such as buffer space. This means nodes from same community have high social relationship and strong social tie between them. But when their social relationship between individual is weak they exhibit selfishness behavior to each other to conserve their resource. Generally social selfish nodes have no altruistic behavior to each other. Therefore, incentive mechanism is important technique to bring cooperation for giving and gaining forwarding services. In the proposed scheme, when nodes cooperate and forward for community where they didn't belong to, they are able accumulate recognition value which helps them to gain the equivalent service it gives. Accordingly, CRIS improves network performance in terms of performance evaluation metrics such as delivery ratio, delivery delay, overhead ratio and hopcount.

1.2.1 Motivation

In SANs architecture there are different data management activities such as routing and forwarding mechanisms, data dissemination and incentive scheme. As discussed in background section of this Chapter different routing and forwarding as well as data dissemination algorithms are proposed based on social properties. However, most of the research efforts on data forwarding and dissemination algorithms does not considered the selfishness behavior of nodes. On the other hand, incentive mechanism is a mechanism that exploited to stimulate the individual in data forwarding process as well as dissemination. Those proposed routing and forwarding schemes that are not able to consider impact of selfishness behavior on the performances of their forwarding activity. However, selfishness behavior of individuals have an impact on the performances of forwarding in terms of delivery ratio, delivery delay, hopcount and overhead ratio. This is an issue that drive us to contribute community recognition incentive scheme (CRIS) to tackle selfishness related challenges. It enables them to cooperate in data forwarding process to improve the network performance.

1.3 Objectives

1.3.1 General objective

To propose community recognition incentives scheme for SANs to address problems imposed by social selfishness behavior.

1.3.2 Specific objectives

- Grouping of nodes into communities based on community structure from social properties and inter community communication among selfish nodes.
- Proposing incentive scheme for promoting cooperation among social selfishness behavior of nodes for better network performance with buffering and forwarding.
- Stimulating selfish users to cooperate for sharing their buffer space and willing to forwarding for other node within inter community communication.
- Recognizing nodes that are willing to share its buffer space for promoting cooperation.
- Implementing and evaluating the proposed scheme in terms of delivery ratio, overhead ratio, hopcount and delivery delay performance evaluation metrics.

1.4 Methodology

In this study, we proposed CRIS scheme based on recognition of community in which nodes belong to and bring willingness behavior among nodes to tackle selfishness behavior. Therefore, to come up with solution in the study we followed different approaches that are elaborated in the remaining part of this section.

1.4.1 Literature Reviews

For the effectively achievement of this research result, different literatures for SANs were reviewed.

1.4.2 Community Formation

Community is one of social properties of human mobility and structure which inspired from gregarious property of society, in which mobile nodes contact frequently [4][14] to be member of same group. Individuals have more social connections with other individuals inside their own community than with individuals outside. Different research works witnessed for the advantage of community structure in data forewarding process such as [3][23][24][25].

Thus, in our proposed scheme, CRIS, nodes grouped into different community based on their interest dynamically. Therefore, working enviromnet, similar religion followers, classmates and family are our common basic interest for forming a community.

1.4.3 Approach

In the literature review in Chapter 2, there are reputation, credit and tit for tat approaches or strategies that helps to develop incentive mechanism and promote cooperation among selfishness behavior of users. Tit for Tat is an approach that follow principle that "*I will do for you as much as you did for me*" [1] for mutual benefit. This means, node **B** buffered message for node **A** then node **A** also buffered for **B** as much as **A** buffered for **B** from Figure 1.2 in Section 1.2.

1.4.4.1 Tit for Tat Strategy in Different Disciplines

Tit for tat was introduced by Robert Axelrod [26], who developed a strategy where each participant in an iterated prisoner's dilemma follows a course of action consistent with his opponent's previous turn. According to this author, if triggered, a player subsequently responds with revenge, but if he is not, the player cooperates. Also according to [27] tit-for-tat does whatever the opponent has done in the previous round of Robert Axelrod tournament and it will cooperate if the opponent has cooperated which has indicate the cooperation with tit for tat strategy. For instance, tit for tat is an expression in the mathematical area of game theory, relevant to a problem called the iterated prisoner's dilemma. In Biology tit for tat has been used to describe the concept behind how groups of animals have come to live in largely or entirely cooperative societies, rather than the individualistic [28]-[31]. Also in social psychology the tit-for-tat strategy has been beneficial use to social psychologists and sociologists in studying effective techniques to reduce conflict.

However, different research efforts witnessed that some of the approaches may not effective strategy for designing and implementing algorithms and achieve what planned [32][33]. They give more emphasis to TFT approach than others approaches such as credit based, reputation based and game theory approaches to achieve what planned in incentivizing selfish nodes in the network and make more cooperation among nodes. According to those studies, in opportunistic type of network, nodes are connected opportunistically which is difficult for credit based incentive scheme to provide centralized credit bank since usually it requires network and it is difficult to achieve cooperation among nodes. Similarly, because of complexity, the game theory approaches also has high overhead and delay issue in the network. Moreover, the TFT does not require the existence of trusted nodes, secure hardware or centralized credit bank [33].

1.4.5 Datasets

In different literatures real trace dataset which is most well-known and appropriate dataset for type of network such as social aware networks that follows store-carry-forwarding principles is INFOCOM2006. It was collected using group of people who carry smart phone device and share data through Bluetooth interfaces [2][25][34][35] in CRAWDAD.

1.4.6 Parameters

From social properties social community of nodes utilized as parameters for designing the cooperation scheme since they are most popular social properties to design different algorithms. In addition to those social properties others parameters such as number of nodes, initial, threshold values, initial recognition value, movement model, message generation time intervals, constant values to minimize and maximize recognition value are utilized as parameter.

1.4.7 Evaluation Environment

Since opportunistic networks follows store-carry-forward fashion, we employed opportunistic network environment (ONE) simulator tool that was designed for evaluation of DTN routing scheme. As different researchers witnessed and used it for evaluation of their work, ONE is well designed tool for DTN routing and it allows creating scenarios upon different synthetic movement models and real-world traces [34][36][37][38].

1.4.8 Mobility Model

Mobility is also one of simulation parameter which provide communication among nodes in the network. Therefore, mobility of nodes in the network will help to bring them in contact. Otherwise they are disconnected world to each other. There are different movement models available for different types of traces and different scenarios and explored by different researchers [37][39] and their application. For instance, Map-Based Mobility**,** is a map based movement models constrain the node movement to paths defined in map data in which nodes moves in the path defined in map.

Even if these mobility models are simple to understand and efficient to use in simulations they do not generate inter-contact time that match real-world traces, external dataset, especially when the number of nodes in the simulation is small. The other mobility model, external movement model**,** uses external data of node location and reads timestamped node locations from a file and moves the nodes in the simulation accordingly. On the other hand, the stationary movement model, use predefined connection traces from real traces dataset. So, the simulator should create connections among the nodes exactly as trace specifies. Generally, to evaluate our work we use external real trace dataset and employed external movement model.

1.5 Scope of the Study

In this study the proposed incentive scheme could bring the cooperation behavior among nodes for data forwarding process in for social aware networks. And this incentive scheme have been implemented and tested by adopting non incentive routing algorithm which is forward data blindly without considering selfishness. This means there is no expectation to design routing algorithm for this study. Instead we design incentive scheme which improve forwarding capability of nodes in the forwarding activity for better network performrmances in terms of delivery ratio, delivery delay, overhead ratio and hopcount metrics on the top of blindly forwarding algorithm. Also in this study we considered buffer space to promote cooperation but not consider energy constraint. In addition to this, some social selfish nodes may exhibit and act maliciously with intention to disturb the function of the networks and it might be drop packets, congestion of the wireless channel, and even forge false packets. However, this are security issues which need to propose another security mechanism to detect and mitigate them. Therefore,this study did not consider security issues which is out of the scope of study.

1.6 Application Area

Application area of the result of this study could be implement for different real world environments. For example at meeting in campus environment or gevernmental meeting for automatic information sharing, natural disaster recovery situations, military deployments, wildlife tracking and nomadic networks applications. In addition to this, it could also be implemented for vehicular ad hoc social network through Bluetooth communication interface.

1.7 Contribution of Study

The significance of the result obtained from this study could improve network performance through data forwarding and applicable for an environment where infrastructure less networks deployed to improve communication cost. Selfishness behavior of nodes in social aware networks have an impact on the network performance through of forwarding process. As a result, in this work we proposed and contributed CRIS incentive scheme that have capability to call those unwilling users for cooperating through sharing buffer space for data forwarding in the network for improve the performance of the network in terms of performance evaluation metrics such as delivery ratio, overhead ratio, hopcount and delivery delay.

Generally, CRIS has better forwarding capability than routing algorithm which is not considered selfishness behaviors of nodes in the network. We evaluated and compare our work with existing forwarding algorithm spray and wait. Finally, we come with better network performance in message forwarding activities in terms of increasing message delivery ratio, reduce overhead, reduce delivery delay, and increase hopcount.

Also this study, will be the bench mark for the coming researchers regarding to data management and for tackling socially selfishness behavior of individuals. Also the study can give fruitful contribution locally by implementing at invironment where it enables to solve problem in the society in addition to scientific contribution. For instance we can apply this work in the area of densely people available such as meeting or market who use phone that support logged to Bluetooth of other devices and able to transfer data among people for infrastructure less network environment. The scientific contribution of the study is proposed and present CRIS incentive scheme that make nodes to cooperate by sharing their resource such as buffer for forwarding activity to nodes which grouped to different community. Even if source node and destination node are in different community CRIS has capability to tackle misbehaving nodes and bring cooperation to share their resource to improve network performance that affected by selfish nodes in the network.

1.8 Limitation of the Study

In this study we did not consider security issue because there is probability of occurring some malicious nodes in the network that affect the network performance and security issues. Therefore, security is an issue that needs another research effert why not considered as a part of this study. On the other hand, we consider only buffer space constraints of nodes to become selfish in order to conserve their storage space. This means there is no consideration of energy constraints as part of the study. In addition to this there is no expectation of designing of data forwarding algorithm but we designed and implemented incentive algorithm for promoting cooperation among nodes on the top of forwarding algorithm.

1.9 Organization of the Study

This thesis organized as follows, the second Chapter of the study is literature review which contains social aware networks paradigms subsections that describes about social aware network architecture, non-social aware algorithms, social aware based forwarding activities and forwarding with selfishness behavior of individuals. The third Chapter describes on earlier done related works on the area which has four subsections; such as section one reputation based incentive schemes, section two credit based cooperation mechanisms, section three tit for tat cooperation mechanisms, the last section is game theory based incentive algorithms and then we summarize the chapter with summary section. Chapter four defines the details of proposed scheme, CRIS. The fifth Chapter presents implementation and experimental evaluation of proposed scheme CRIS. Finally, Chapter six present conclusion and future works.

CHAPTER 2
LITERATURE REVIEW

2.1 Social Aware Networks Paradigm

Several algorithms are proposed recently for routing in social aware networks (SANs). In Social Aware Networks architecture there are different data management activities such as routing and forwarding mechanisms, data dissemination and incentive scheme [1]. The main objective of presenting SANs paradigm now a day is because the mobility patterns of mobile devices strongly depend on the users' movements, which are closely related to their social relationships and behaviors. And the major features of SANs is that social awareness becomes essential information for the design of data magement activities in in different network types. Since mobile devices have close relationship with objects in society, because they are usually carried by people, animals or vehicles their mobility depends on those factors. Human beings becomes the main actors of mobility of nodes and take consideration from information technology in academic as well as in industry.

2.1.1 Social Aware Networks Architecture

Social aware network architecture has four layers such as sensing, learning and analysis, protocols and application layers.

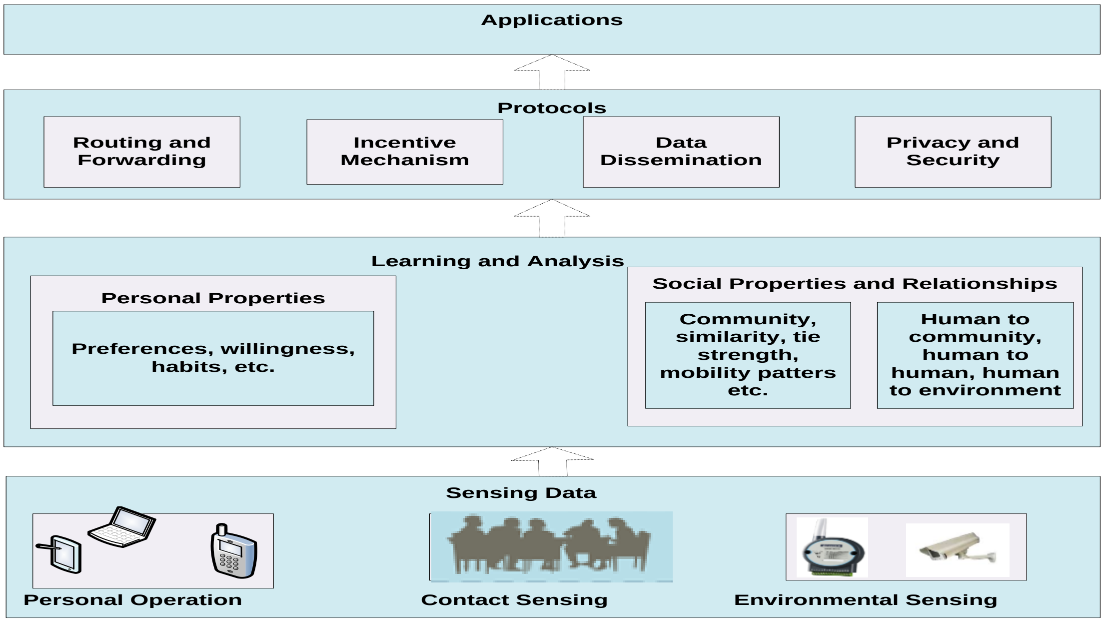


Figure 2.1 SANs Architecture [1]

In Figure 2.1, the first layer is sensing data layer with personal operation, contact sensing or environment sensing. In the second layer which learning and analysis layer there are personal property and social property and relationship. In the social property in this layer community, similarity tie strength, mobility patters are presented. In the third layer, protocols layer, there are four sub layers such as routing and forwarding, incentive mechanism, data dissemination and privacy and security layers. So that, these properties are important metrics to design algorithm for network solution specially to use mobile nodes resource efficiently and to maintain end-to-end connectivity between source and destination for opportunistic networks.

2.1.2 Non-SANs Forwarding Algorithms

Previously different forwarding algorithms are proposed and presented without considering importance of social properties for improving network performances. For instances, there studies which proposed forwarding algorithms unaware of social properties such as [40]-[42]. Routing algorithm in [41], is route packets based on information past encountered or history with other nodes to optimize packet delivery or resource of node such as bandwidth. The other in [42], routing protocols that forward single copy of packets from source nodes and intermediate node to all its neighbors to mitigate the effects of a single path failure proposed by distributed message through the neighborhood. However, these forwarding algorithms didn't take any advantage of social metrics that have capability of improving network performance by maintain connectivity among nodes in the network.

2.1.3 SANs based Forwarding Algorithms

In recent decades different research efforts have been done for forwarding algorithms for opportunistic networks to come up with network performances in terms of data forwarding and dissemination by employing some social properties such as community structure, similarity, betweenness, degree of centrality and social tie strength. According to the witness of [14][17] and [43] message forwarding algorithms using social properties aforementioned is better network performances in terms of performance evaluation metrics such as delivery ratio, delivery delay and overhead ration. For example, in [14] by employing two social metrics such as similarity and betweenness to estimate the importance and activities of the nodes in the network and leverages such information to make decision message forwarding activity. The other study proposed in [17], which employed community social structure to decide message forwarding process. The other routing algorithm, BEEINFO [43], also employed community from social characteristic to group mobile nodes with bee colony characteristics. Lonkar and Mehetre [44] proposed on interests of the people inspired from Artificial Bee Colony Algorithm. It considers the individuals' identifying and learning capability to gather information of density and social tie during communication ABC routing algorithm in SANs. However, all of these solutions assume that nodes in the network are cooperative and never decline service to other nodes. Such assumption is not always true in a real social aware networks since the resources of a node, such as power, storage, and connection opportunities, are limited. As a result, a node might not be willing to provide free service to others unless they are rewarded or get service from other nodes. Therefore, the provision of incentive is imperative to stimulate the cooperation among the nodes.

2.1.4 Routing and Forwarding with Selfishness

The algorithms mentioned in Section 2.1.3, assume that all nodes in the network are cooperative and altruistic to all nodes in the network and are willing to help forward messages for other nodes. However, in reality, many nodes exhibit non-cooperative behaviors, such as selfish nodes or even malicious nodes, in order to conserve limited resources (like power and buffer) and increase their own benefits. As a result, selfish node always acts for its own interest, meaning selfish nodes may not be willing to provide services for others in order to conserve their limited buffer or power resources. Whereas, a malicious node acts maliciously with the intention to disrupt the main functionality of the networks, so it might possibly drop packets, jam the wireless channel, and even forge false packets. This behavior of nodes have in impact on data management activities such as data routing and forwarding, replication and dissemination. Therefore, data management process particularly data forwarding is affected by some misbehaving individuals in the networks because there is no end to end connectivity because of dynamic topology. The impact of selfishness behavior on the performance of data forwarding algorithms in opportunistic networks explored in [1][8][16][45][46][47]. Consiquently, different researchers proposed forwarding and routing algorithms without considering the existence of selfish users in the network [48]-[51].

However, in real scenario some nodes may not be cooperate in order to conserve their resource and should be tackle them to improve network performance through proposing novel incentive scheme. In addition to this there are also studies that are proposed routing algorithms that able to tackle individual selfishness of nodes in the network. Many efforts have been made to evaluate the effects of cooperation in opportunistic networks from different aspects for different wireless networks. For instances, in [45] there is a mechanism of combing the concept of social trust and quality of services (QoS) trust for trust metric for determining the best node among the encounters node for message forwarding to next node. Honesty and unselfishness are considered as metric to measure the social trust level the node in this study. And for QoS trust level of node measure by considering the connectivity of node in which connectivity for QoS trust to account for node capability to quickly deliver the message to the destination node. In this approach the behavior of node is describe in terms of energy level, location, degree of honesty and degree of selfishness. The other study in [46] explored the effect of nodes selfishness behavior in the networks in data forwarding activity in DTN. In this work cooperation is captured in terms of node's probability to drop message copy up on reception and forward the message copy up on node encounter which means node that receives copy of message drop or maintain in its buffer and forward. Opportunistic networking mainly governed by devices which carried by human as relays node to transfer data across the network. This also witnessed by [16] in which human altruistic behavior is an important factor in the performance in such networks by employing two approaches, social network topological models and experimental human mobility traces. The other study [8] again explored that the effect of altruistic behavior in opportunistic network. Helgason *et al.* [9] deliberated the performance of opportunistic content distribution in a delay tolerant network with node cooperation. The main interest in their work is the benefit of node cooperation on the content dissemination and investigate how different levels of cooperation affect the content delivery delay in the network. As result they proved that cooperation among nodes is dramatically improves network performance compared to non-cooperation even if cooperation is limited. There is research effort that investigate on the problem of how the non-cooperation behaviors of nodes influence the performance of DTN routing algorithms of two-hop relay and epidemic routing and verified that even if non-cooperation nodes have impact on network performances they may have opposite impacts on different routing algorithms [11][20].

However, these studies are failed to use full advantage of social properties to design more stable connectivity among nodes in the network. In proposing and designing routing and forwarding algorithms for opportunistic networks Of course, there are some works that show the impact of social selfishness in social aware networks such as [12][21][22] proposed mechanism to stimulate those nodes in data forwarding using social properties as social metrics in social aware networks which review detail in related work section of this chapter. It has been proved that node collaboration (even limited collaboration) can dramatically improve performance compared to non-cooperation scenarios and different non-cooperation behaviors may have opposite impacts on different routing algorithms by considering selfishness behavior of nodes as individual selfishness. There are individual selfishness which is node that forwards only packets which are generated by itself and drop packets from other node. Also there are social selfishness behavior of nodes that are willing to forward packets for other nodes with whom they have social connection but drop packets from which is not social connection these studies are not considered social selfishness behavior of nodes. Social selfish nodes have cooperation behavior for data buffering and forwarding activity between strong social relationships. Furthermore, more relationship of nodes also trust to each other and implies a stronger social tie between nodes, which can be used in effective relay node selections during the course of forwarding.

However, social selfishness behavior of nodes in the network and their impact is first introduced in [12] as socially selfishness aware routing (SSAR) for delay tolerant networks. In social perspective, a selfish user is usually willing to help others with whom he/she has social relationships (e.g., friends, coworkers, roommates) or in same community. He/she will provide better service to those with stronger social ties than those with weaker ties, especially when there are resource. In SSAR, it allowed nodes to be social selfish and it considered two important factors, user willingness and contact opportunity to select relay node. Then by combining these two factors through mathematical model and machine learning techniques they obtain new forwarding capability of relay node. The forwarding process of nodes in SSAR formulated as Multiple Knapsack Assignment Restriction (MKAR) and heuristic based solution to design the algorithm. There are some literature reviews who use some advantages of social properties and proposed and presented cooperation mechanism [6][7][21][22][52] in data forwarding. These protocols proposed to enforce the nodes' social selfishness in routing meanwhile maintains acceptable routing performance. However, there is no stimulation mechanism in these schemes.

Generally, the related works categorized into four section such as reputation based, credit based, tit for tat and game theory strategies. In section 2.2 explored detail of these approaches with what different studies proposed and present for selfishness behavior of nodes. But most work are more concentrated with individual selfishness than social selfishness behavior of nodes.

CHAPTER 3
RELATED WORK

In this chapter, we will present review of previous works that have been made related to our proposed scheme with four different sections based on the approaches those studies followed in their mechanisms.

3.1 Reputation-Based Strategy

In reputation-based incentive schemes is a scheme that give reputation to the node which provides services to the other node specifically to which it forwards messages. So, node with good reputation value can receives services from other nodes in the network. Generally, reputation incentive scheme is a mechanism in which node indicates the trust of other nodes about the degree of cooperation with other nodes. For instance, Dini and Duca [13] proposed decentralized system Reputaion Context Aware Routing (RCAR) by referring Context Aware Routing (CAR) protocol for selecting best carriers or intermediate node with reputation mechanism in DTNs. In RCAR each nodes estimates the misbehaving nodes and record the reputation value. If node considered as misbehavior its reputation value is decrease and it might not be choose for carrier and helps each nodes to establish whether a carrier is misbehavior or not. RCAR used acknowledgement-based and step-by-step techniques for updating reputation value of carrier node to determine misbehaving carrier for forwarding message. If a sender does not receive an acknowledgement within a certain time, it means that there is at least one misbehaving carrier in the path from sender to destination or from destination to sender. According to RCAR scheme each nodes estimates the misbehaving nodes and record reputation value. If node considered as misbehavior its reputation value is decrease and it might not be choose for carrier and helps each nodes to establish whether carrier is misbehavior or not. Carrier node periodically computes an estimation of its delivery probability and broadcasts it into the partition the carrier belongs to. The carrier context is defined as set of attributes such as mobility of host and battery level and delivery probability of carrier estimates by means of utility function from its attributes. However, RCAR did not considered social selfishness behavior of users which is a big issue in SANs and did not use any advantage of social properties.

On the other hand, Bigwood and Henderson [6] proposed scheme called IRONMAN mechanism to detect and take counter measure for selfish nodes in opportunistic networks. In IRONMAN selfish nodes detect by using preexisting social network information which stored history of encounter times and messages exchanged when nodes encounter to each other. When reputation value of node less than the threshold value it should be punished. So, this selfish node should have to forward packets for other nodes to improve its trust rating or reputation value. If it is not do this the other nodes would not forward packets for it. Since IRONMAN model assume that only node of the same member of social network which is not considered across multiple group of social network, the approach couldn't tackle spreading of selfishness issue across multiple social network which lead a new incentive challenge for network. And it is not considered social selfishness issue in the networks. Generally, IRONMAN indicate that the importance of social network information whether online or offline data for researchers to come with incentive scheme for different type of networks. Therefore, IRONMAN is reputation based incentive scheme which developed by considering social network information recorded when nodes encounter to each other for selecting rely node for message forwarding for opportunistic networks.

The store-carry-and-forward bundles in DTNs violation is also indicated by Wei *et al*. [7], due to the selfishness behavior of individuals with User-Centric and Social-Aware Reputation Based Incentive Scheme (SUCCESS) for DTNs. Since SUCCESS is dynamic reputation system each node able to maintain, update and keeps its forwarding evidence for its reputation. Therefore, sender node able to check directly the reputation value of the node when it need to forward data. The main problem with reputation based incentive scheme is that most of the time nodes may increase its reputation value by cheating the system because of attacks such as Sybil and whitewashing. For this issue SUCCESS proposed user centric, secure and social aware incentive scheme for stimulating cooperation among DTNs nodes in effective, secure and efficiency manner. In general a big contribution of SUCCESS is that designing user centric and social aware reputation incentive scheme with secure reputation ticket (value) from some malicious node in the network because most of the time in the reputation based incentive scheme malicious nodes able to compromise it reputation value and able to extract social relationship among nodes to design incentive scheme. Therefore, it follows creating cooperation among nodes instead of detecting and punishing principles. However, SUCCESS didn't considered social selfishness issue which again challenge for social aware networks which has big importance in social aware networks to maintain end to end connectivity between sources to destination.

3.2 Credit Based Strategy

There had been different studies that are conducted to tackle the selfishness behavior of users based on credit incentive mechanism. The credit-based schemes is a mechanism that virtual currency would be provide to nodes in the network to handle selfishness behavior of users. So, nodes may get virtual currency when it forwards packets for others.

For instance, MobiCent proposed by Chen and Chan [53] for replication based routing protocols in DTNs. MobiCent is credit based incentive scheme utilizes Multiplicative Decreasing Reward (MDR) algorithm to calculate the payment for nodes through two clients such as client to minimize cost and client to minimize delay. MobiCent employed Trusted Third Party (TTP) to stores key information for all nodes and provides verification and payment services.

Also Wang *et al.* [54] proposed Multi-Receiver Incentive-Based Dissemination (MuRIS) scheme for delay tolerant mobile networks. In this study proposed credit based incentive scheme which helps to improve data deliver from source to destination in collaborative way among nodes. It designed multi-receiver based incentive scheme for data dissemination for delay tolerant mobile network. MuRIS designed using local history path among nodes and user interest information maintained by each nodes in the network setting. In addition, MuRIS also apply rewarding function to nodes which are willing to share data in the network. This study contribute by proposing MuRIS incentive scheme to improve network performance in DTNs data sharing among different nodes in the networks. This MuRIS designed by local history path and user interest information which are maintained by each node when they encounter to each other. Therefore, the main contribution of MuRIS is encouraging of nodes to cooperate in data sharing process with path choosing which reaches for many subscribers within fewer transmission cost.

The other credit based incentive scheme proposed by Xia *et al.*[21] is community based incentive scheme, CIS, to handle selfishness behavior of users in social aware networks. The scheme focus on community to community communication and nodes awarded when relay messages. In general, the main contribution of this study is to introduced the community based incentivizing of selfish nodes to promote cooperation among them for data forwarding process to improve network performances. Therefore, CIS allows the nodesto take selfish action to a community when credit values of corrresponding community is greater than the minimum credit value of other community.

Ning *et al*. [55] proposed a copy adjustable incentive scheme in Community-Based Socially Aware Networking (CAIS) scheme. This study considered social relationship of individuals and social credit and non-social credit to decide the willingness of nodes in buffering and forwarding message generated by other nodes in the network.

The other credit based incentive scheme proposed by Ning *et al.*[56] incentive aware data dissemination which incorporate reluctant nodes to consume buffer for other nodes with considering multiple interest of nodes in which node may wish to receive data in one or multiple interest types. In this mechanism cooperation of nodes made through interest of nodes which means types of data wishes by nodes to acquire and reward nodes rewarded when data forwarded to destination. However, credit based incentive scheme is not scalable and requires higher investment for implementation for DTNs [33]. On the other hand, as [1] there are two significant difficulties to implement credit-based incentive schemes. These are the management of nodes and credits distribution among nodes and cheating attacks from selfish nodes which will try to cheat the system to maximize their welfare through injecting or deleting some relay nodes to achieve more credits.

3.3 Tit For Tat Strategy

RELICS proposed in [32] to call selfish users for sharing their energy with other users which follow tit for tat strategy. In RELICS node spend more energy if it wants arise its delivery ratio during forwarding. Each node get realization from other nodes based on the rank stored when it expend energy for data forwarding for other nodes in DTNs. This scheme also allows nodes to limit their resource usage equivalent with the achieved service from the network. Therefore, the main contribution of RELICS is proposing energy aware in-network realization incentive scheme to tackle selfishness behavior of nodes for DTNs. RELICS presented to tackle users that exhibit selfishness behavior because of energy constraints to expend for others. RELICS reward a value for node which are willing to relay message created by other nodes and sharing their energy. Then nodes get rank by accumulating their rewards and get message priority for forwarding based on the rank value accumulated. Generally, RELICS introduce physical rewarding to nodes through realization of network instead of virtual currency payment.

The other study in Zhou *et al.* [33] proposed scheme called incentive-driven and freshness-aware pub/sub content dissemination scheme, called Content Dissemination (ConDis), for selfish opportunistic mobile networks. This scheme chooses the Tid For Tat (TFT) strategy to stimulate selfish nodes in opportunistic mobile networks. ConDis, is incentive-driven and freshness-aware mechanism that employed TFT approach to stimulate nodes in the network and publish/subscribe content dissemination paradigm for stimulating selfish nodes in opportunistic mobile network. Nodes manage its buffer based on content utility stored in node and new content will be placed into the buffer corresponding to its content is high or low.

One of the challenge for opportunistic networks is how to collect, store and share network contents among selfish nodes. Thus, Zhou *et al.* [22] proposed incentive based pub/sub scheme, ConSub, to promote cooperation for data dissemination for opportunistic networks based on interest of node for content. And also ConSub encourages nodes to carry content of network to satisfy the other's interest. In addition to this this study proposed novel content exchange protocol among nodes when they are encounter to each other. ConSub employed TFT incentive scheme strategy to satisfy its objective in stimulating node for cooperation in data dissemination process.

In social aware networks Liu *et al.*[57] ComBIS scheme which introduced that exchanging the same amount of information between nodes in the same community whereas and exchanging of information node with node of outside its community. In ComBIS nodes balances their contribution they provide for the others and benefit get from others within community and outside the community. According to ComBIS contribution of nodes must be greater than the benefit it get from other nodes and each nodes records its contribution and benefits in a unit time interval. In ComBIS to forward data first source node send message to encounter node and the encounter node check its contribution and benefit, contact history of data and threshold which are minSize and maxSize. Then this encounter node decide based on this result to forward or refuse data based on difference between contribution and benefit. Generally, ComBIS node considered set of jointly history encounter information value and current value and converts stimulation issue to resource optimal allocation model and obtains approximate optimal solutions by using 0-1 knapsack algorithm.

3.4 Game Theory Strategy

Game theory approach provide analytical tools to predict the outcome of complex interactions among rational nodes. Each individual player participates with a payoff depending upon the other players. Therefore, as the previous strategies objectives of game theory also to motivate and stimulate selfish users in the network. Most of the time game theory scheme used for analysis of distributed protocols. For instance wireless nodes are energy constrained, it may not always accept relay request in the best interest of nodes.

On the other hand, Multicent proposed by Chen and Shen [47], which is promote cooperation among nodes based on game theory approach by realizing the performance of nodes. Multicent incentive scheme also proposed to encourages the node to follow defined rules to realize the desired performance of network.

Srinivasan *et al.*[58] proposed Generous TIT-FOR-TAT (GTFT) game theory based incentive scheme for selfish nodes that decide not expend their energy in relaying for others. According to GTFT investigation, the two extreme scenarios which are complete cooperation and complete noncooperation are harmful to the interests of a user. Thus, GTFT was proposed that used by the intermediate nodes to decide whether to accept or reject a relay request based on the past history of the node. The contribution of GTFT is applying of game theory to the problem of cooperation among nodes in an ad hoc network for relaying message with Nash equilibrium mechanism.

In the work [59] analyze different game theory based incentive schemes interms of their algorithm, advantages and disadvantages of those algorithms. Also Yu *et al.* [60] proposed Node Dependence-Based (NDI) game theory based mechanism in which node relay for message forwarding by exploiting dynamic game repeating and node dependency degree of reward and punish which means node rely for message from other node depends of the dependency degree of this node to relay node.

The other study in [61] that proposed game theory based incentive scheme for social aware routing in selfish mobile social networks (GISSO) to tackle social selfishness behavior of nodes. GISSO followed bargaining game theory strategy to promote cooperation for mobile social networks. The bargaining mechanism applies bargaining game approach in way of sender of message as buyer with bargain another node seller node.

Generally even if game theory based incentive scheme is good approach to stimulate and make cooperation among nodes in data forwarding process in the network it is not as good as other approaches. This is due to the number of node constraints which means it is not appropriate approach when the number of nodes in the network becoming very high. So, it is the only approach for network with limited number of nodes participation. Here we sumerized those different studies for incentive schemes with different strategies as follows.

Table 3.1 Reputation based incentive schemes

Algorithms	Approaches/techniques	Contributions	Drawback
IRONMAN [6]	• Employed reputation based strategy and preexisting information of social network and social tie as social metric.	• Shows importance of social network information to design incentive scheme	• Assume only the same group of nodes and not considered social selfishness behavior of individuals
SUCCESS [7]	• It apply dynamic reputation system and self and community check algorithms and cryptography	• Designing user centric and social aware reputation incentive. • Creating cooperation among nodes instead of punishing principles.	• SUCCESS only for individual selfishness
RCAR [13]	• It employed reputation based approach with context aware routing and synchronous and asynchronous routing scheme.	• Proposed context aware routing algorithm with reputation based incentive scheme for promoting cooperation.	• Acknowledgement technique is vulnerable for security issuses. • Not considered socially selfish nodes because RCAR did not used any advantage of social properties

Table 3.2 Credit based incentive schemes

Algorithm	Approaches/techniques	Contributions	Drawback
CIS [21]	• Followed credit based strategy incentive scheme and social community structure as social metrics components	• Used advantage of social properties which is community structure and considered social selfishness	• difficult to provide centralized credit bank incentive scheme
MobiCent [53]	• Followed credit based strategy to implement multiplicative decreasing reward (MDR) algorithm to incentivize nodes. • used Trusted Third Party (TTP) technique to stores key information	• allows the underlying routing protocol to discover the most efficient paths, • Tried to improved rational nodes that waste transfer opportunity or cheat by creating non-existing contacts to increase their rewards.	• Since node encounter opportunistically it is difficult to assign nodes as Trusted Third Party (TTP) to stores key information • Didn't considered social selfishness issues
MuRIS[54]	• Employed credit based approach. • It designed multi-receiver using local history path among nodes	• Contributes MuRIS incentive scheme in DTNs. • Used local history path and user interest information which maintained by nodes.	• Didn't considered social selfishness issue which is challenge for new paradigm networks such as social aware.
CAIS [55]	• Employed credit based incentive scheme. • Used social relationship of individuals nodes	• Proposed CAIS scheme using credit based approach and advantage of social relationship.	• CAIS also difficult to provide centralized credit bank incentive scheme

Table 3.3 Tit for Tat based incentive schemes

Algorithm	Approaches/techniques	Contribution	Drawback
ConSub [22]	• Is employed TFT with publish/subscribe incentive scheme (ConSub) with based on interest of node for content	• Proposed data dissemination scheme for opportunistic networks with incentive scheme	• The scheme considered only individual selfishness
RELICS[32]	• It involves physical realization instead of virtual currency payment for relying nodes. • Employed TFT strategy make cooperation among nodes	• presented energy aware network realization incentive scheme. • Introduce physical realization of network for nodes instead of virtual currency payment.	• Considered energy constraints of nodes but not buffer space is also a big issue • Concentrated with individual selfishness only
ConDis[33]	• ConDis employed TFT approach to stimulate nodes in the network and publish/subscribe content dissemination paradigm for	• Presented pub/sub content dissemination in opportunistic networks which considered freshness of content and content utility to manage its buffer	• didn’t considered social behavior of individual nodes to tackle social selfishness behavior of nodes
ComBIS[57]	• Employed barter incentive scheme with 0-1 knapsack algorithm for buffer allocation	• Introduce barter based incentive and presented ComBIS scheme for SANs	• Still there is overhead and delivery probability improvement issues in the network.

Table 3.4 Game theory based routing schemes

Algorithm	Approach/techniques	Contribution	Drawback
Multicent[47]	• It follow game theory strategy for promoting cooperation	• Contributed Multicent incentive based forwarding algorithm for providing the quality of service of packet routing.	• Not considered social selfishness behavior individuals in the network.
GTFT[58]	• Employed game theory approach among nodes in an ad hoc network for relaying traffic and apply Nash equilibrium mechanism	• Proposed GTFT algorithm that is used by the intermediate nodes to decide whether to accept or reject a relay request based on the past history of the node	• Is not used any advantage of social characteristic of individuals • Not considered social selfishness behavior
NDI[60]	• followed game theory based incentive strategy • exploiting dynamic game repeating	• Proposed NDI scheme and promoting cooperation among opportunistic nodes	• It designed for individual selfishness but not social selfishness behavior.
GISSO[61]	• Employeed bargaining game theory and social tie strength to design GISSO	• Proposed GISSO incentive schme for mobile social network using advantage of social tie as social properties with game theory strategy	• Has difficulty to implement in real world and is not use the advantage of community structure

3.5 Summary

In general, these all different incentive schemes were proposed for tackling selfishness behavior of users. Even if some studies employed social properties most of these works strive to encourage sharing from an individual selfish node perspective which are considered individual selfishness and failed in taking full advantage of social characteristics such as community, similarity and betweenness centrality which are more stable than individual mobility to design different algorithms. That are help to encourage social selfish nodes in the network. Therefore, Xia *et al.* [1] in their study, assured that still social selfishness is open issue and a challenge that need to further investigation for tackling such behavior in the network which dramatically affect the overall network performance. These issues needs further study for more network performances by tackling such issues through incentive schemes.

Therefore, in this study we proposed Community Recognition Incentive Scheme (CRIS) for social selfishness in social aware networks which give recognition value for nodes which cooperate by buffering message originated from other node of different community, based on TFT strategy as mutual benefit. As social relationship nodes within the same community they have similar interest and altruistic to each other since they have strong social ties. CRIS uses selfish nodes to build unselfish behavior to each other specially inter community (among different community). This will be incentivize selfishness behavior of users in better way than the previous works which is able to employee community structure of social properties to group node of according to their affiliation. Consequently, in this work instead of individual selfishness behavior of nodes, we considered social selfishness of nodes which is a current issues for social aware opportunistic networks because many research efforts have been made for tackling individual selfishness of nodes.

CHAPTER 4

PROPOSED SYSTEM

In the proposed system we have an assumptions that we have to discuss before going to modeling. So, before designing proposed scheme we have to consider those as follows.

4.1 Assumptions

In this study we make the following assumptions to state some statements that we have to take as assumptions accordingly.

- Assume that nodes have buffer space for their own benefit but not for other nodes which are located in different community.
- Nodes are not selfish to the nodes inside the community because they have strong relationship or strong social tie in the community but they are selfish to outside of its communities.
- If nodes are act as selfish, then their recognition value is less than threshold value and they could not get any buffering and forwarding service from nodes of outsid their community but able to get from nodes of the same community.
- There is no consideration of security issue in this study because there is probability of occurring some malicious nodes in the networks that affect the network performance and security issues.
- We consider buffer space constrain of nodes to become selfish node to conserve their own storage space.
- We assume that nodes in the community contact to each other via Bluetooth which enable devices opportunistically communicate when they are in the same communication range i.e. that is when they are 10 meters apart.
- It is not expected to propose forwarding algorithm from this study instead develope incentive scheme on the top existing opportuniscally forwarding algorithm.

4.2 CRIS Scheme Model

In this study to tackle selfishness behavior of users in the network we proposed CRIS used community structure as the advantage of social property to grouped nodes based on their interest. CRIS combined seven different components such as community formation, computing threshold value, modeling selfishness behavior of nodes, computing recognition value, buffering of messages, determination of nodes forwarding capability and updating recognition value.

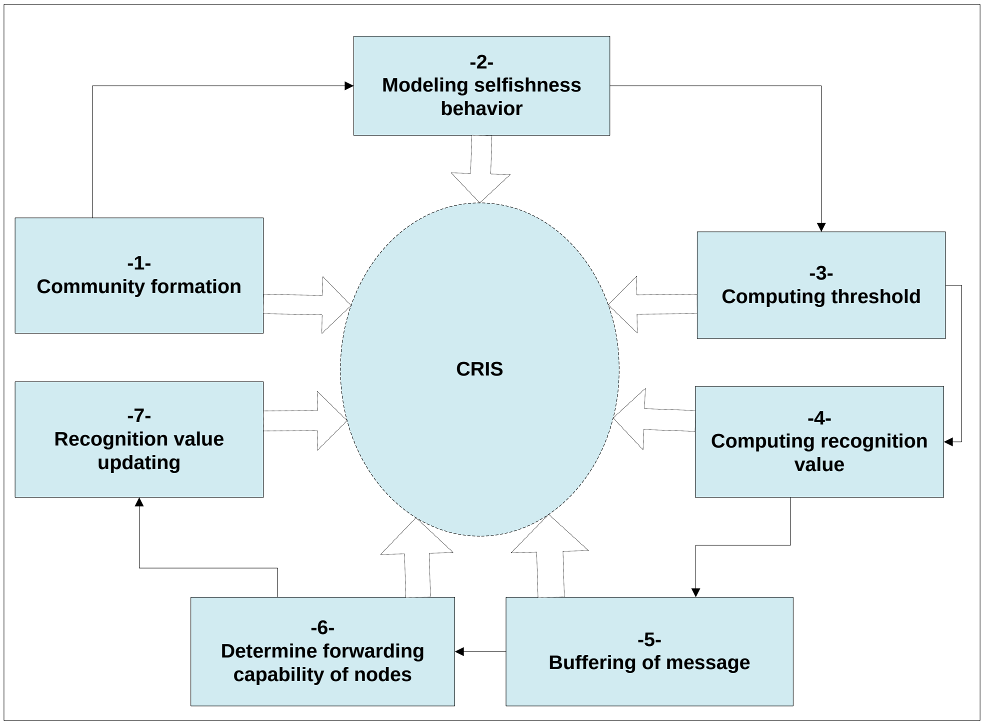


Figure 4.1 Proposed CRIS Model

In this proposed model first we grouping nodes into different communities according to their interest as we have discussed more detail in Chapter 1, Section 1.4.3. Then after grouping nodes we design and distribute selfishness behavior of nodes in the network to realize the impact of social selfishness behavior of individuals on the performances of the network. After realizing impact of selfishness behaviors of nodes we proposed mechanism to tackle such issue by cooperating those nodes to improve the performances of the network in terms of different performance evaluation metrics. The third component of CRIS is computation of threshold value. The computation of threshold value is depend on whether nodes are in the same or different community. This computed threshold value helps to identify the previous willingness behavior of nodes in buffering message originated from node of different community.

The fourh activitiy that have done in this model is computation of recognition value that helps to determine the forwarding capability of nodes among different community. Initially each node gets the recognition value which is 2 from configuration file. This value set in the file and helps them to get buffering forwarding services atleast one time message. Consiquently, this value determines the forwarding capability of nodes and updating recognition value as gaining and giving services to each other. In Figure 4.1 above reveals that the proposed model of CRIS incentive scheme which contains seven different components. The fith and the sixth components of CRIS scheme are buffering of message and determining of forwarding capability of nodes respectively. The last component is updating of recognition value of nodes. Social selfishness behavior of users in the network affect the performance of network in terms of decreasing delivery ratio while increasing delivery delay and overhead. So, proposing incentive scheme that enables us to tackle such misbehaving nodes by calling them for cooperation as mutual benefit. The system model for the proposed incentive scheme for inter-community communication by giving recognition for nodes which are willing to cooperate as mutual benefit as follows. When node givse a services for others its recognition value increase while it gets services from others its recognition value decreases. At the beginning two nodes encounter to each other by exchanging some information about nodes such as message size, current recognition value, location of node (community), current buffer space. At this time the incentive scheme starts its work to promote cooperation among selfish nodes. And then the two nodes check to each other their current status whether the current recognition value is greater than some threshold value or not. If recognition value of source node is greater than threshold then intermediate node buffered it message otherwise drop and inform to source node to maximize its recognition by giving service for node outside its community.

Generally, at time ***t*** relay node **RN** give services by buffering message originated from source node **SN** that locate in different community then the recognition value of node **RN** will increase and with the same value the recognition value of node **SN** will decrease because it get service from node **RN**. The increment of recognition value for relay node **RN** which cooperate by sharing its buffer space is store in its buffer. This distribution of recognition value of cooperator node among all other nodes enable to increase the probability of getting forwarding services from other individual nodes or from other community.

On the other hand, if buffer space left for intermediate nodes is less than size of message received then relay node check recognition value of source node. Consequently, message with lowest recognition value will be dropped and buffered new incoming message. This new incoming message will buffer if it has greater recognition value than previously buffered message. Here nodes drop messages based on two criteria. The first criteria is when time to live (TTL) of message is expired and the second criteria is when incoming message information shows the recognition value of source node is greater than previously buffered message. The other thing that we have to consider here is that the system checks the **TTL** of message already buffered and if **TTL** of all messages are not expired then the system follows the next criteria which is recognition value of node to drop message.This recognition value of each node indicates the willingness capability to other nodes in the network to buffer messages.

In addition to this the recognition value stored in terms of recognition value for each node.Then based on this recognition value of source node the forwarding capability of each node is determined. This means source nodes with high recognition value will have high priority to buffer their message even if they are member of different community from relay node. For instance, if node **SN** which found in community 1 need to forward message to destionation node **DN** which is located in community 2 by using node **RN** as relay node which is also located in community 2. The relay node **RN** check the recognition value of node **SN** whether it is less than or greater than the threshold value. If its recognition value is greater than threshold value then node **RN** cooperate in buffering message originated from node **SN**. Otherwise introduce to this node in order to maximize its recognition value by giving service for other node with buffering message from other community.

4.2.1 Community Formation

In the research challenges especially in data forwarding in opportunistic network nowaday employing social properties become crucial solution. As a result, community is one of social properties of human mobility. Community is structure which is inspired from gregarious property of society, in which mobile nodes contact frequently [5][14].

For research challenges especially in data forwarding in opportunistic network now a day employing social properties become crucial solution. As a result, community is one of social properties of human mobility. Community is structure which inspired from gregarious property of society, in which mobile nodes contact frequently [4][14] to be member of same group. Individuals have more social connections with other individuals inside their own community than with individuals outside. In general, individuals in the same community may meet each other more frequently. Therefore, community structure has significant impact on people’s mobility patterns and thus is beneficial for choosing appropriate forwarding path and designing different forwarding and cooperation mechanism for social aware networks. In socially-aware networks one of the most important properties of human mobility is the community structure, which means people move in certain tracks and form closely related groups.

The work in Hui and Crowcroft [3] exploits, the fact that people in the same community meet each other more frequently. Thus it uses small labels and forwards data to the nodes that belongs to the same community as the destination nodes, in order to achieve high delivery probability. It presented that the importance of forming community that will reduce the amount of traffic created when forwarding message and improve forwarding opportunity of nodes by identifying users according to their affiliation and achieve better forwarding result performance. In addition to that, the work in [23] presents friendship routing mechanism by forming community of nodes based on link computing between nodes which makes community in which when nodes are frequently encounter to each other. In this study nodes determine its friendship community in each period using mainly its own contact history computed and social ties between nodes when nodes has close friendships among themselves. Likewise, Xia *et al*. [24] present a community-based epidemic forwarding algorithm, LocalCom, which utilizes community social property to reduce the overload of the epidemic. Zhang *et al*. [25] proposed and presented SOCKER, a dynamic community creation mechanism in opportunistic mobile social networks. Based on social broker selection strategy with similar characteristic of individuals SOCKER was presented.

Therefore, now we create community of nodes in our model based on interests of individuals. As discussed detail in chapter 1 section 1.4.3 individual nodes have more social connections with other individuals inside their own community than with individuals outside of their community. It emplies that individual nodes within the same community may meet each other more frequently than outside its community.

Generally, community structure has significant impact on people's mobility patterns and thus is beneficial for choosing appropriate forwarding path through designing better forwarding and cooperation mechanisms for social-aware networks. Therefore, in socially-aware networks one of the most important properties of human mobility is the community structure, which means people move in certain tracks and form closely related groups. However, when we create communites we have to set properties to nodes to identify its community and we set this properties for nodes. Therefore, nodes formed community dynamically based on their interest. In this case if two node share same interest, they belong in the same community otherwise they are in different communities. Here nodes' interest information are extracted from dataset that is integrated in the configuration files.

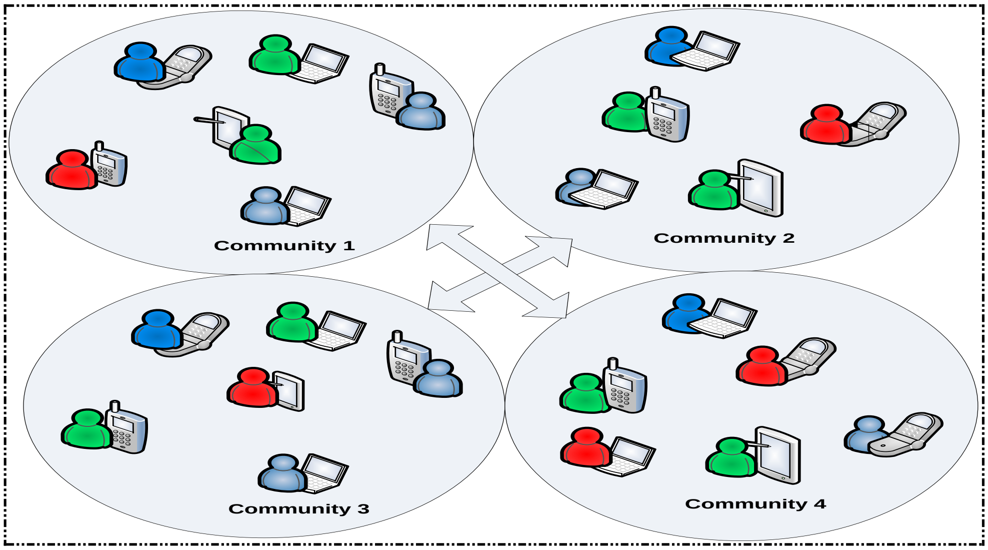


Figure 4.2 Community Formation of nodes

4.2.2 Modeling Selfishness Behavior in the Network

Many efforts have been done to represent and predict nodes behavior in opportunistic networks. Most of them concentrate and proposed mechanism on individual selfishness behavior of nodes. However, they ignore social selfishness behavior in which nodes that have strong social tie willing to forward to each other than weak tie among nodes in the network. A node acts selfishly when it is not willing to carry messages in beneath of others. In order to model a selfishness behavior in social aware networks, we considered the total number of nodes that participate in external data set that we integrate in the configuration file to evaluate our work and the router extracts from participant node from dataset as indicated pseudo code 1.

As a result external real traces dataset used for this work has 98 total participants with iMotes devices. The number of selfish nodes presented in the network dynamic which means there is no fixed number of selfish nodes from total number of nodes because node may belongs into different communities. The distribution of selfishness behavior of nodes in the network to allow nodes to act as selfishness behavior because in reality a node will usually not be totally selfish or altruistic. Nodes that are randomly selected from dataset will assign random value 0 or 1 to determine their altruistic behaviors for buffering messages originated from other nodes which have not social relationship. In this proposed scheme node behavior determined by its value, 0 or 1, which assigned randomly to node address. According to this when node gets 0 it is not selfish and if it gets 1 it is selfish to nodes outside its community and have lack of cooperation by sharing its buffer space and forwarding copy of messages for them. Therefore, node with random value 1 will not accept any message unless it is the final destination node or in the same community. When the CRIS router starts to runs, nodes behavior checked whether with value 0 or 1 and starts to make them cooperate with other by recognizing their community and improve network performances. The way how CRIS compute and update the recognition of nodes in the network to tackle selfishness behavior is discussed in section 4.2.4 and 4.2.5 respectively.

Algorithm 4.1 pseudo code for creating and generating selfish nodes in the network

```
Total number of Hosts  HostList = hosts get from dataset
    For (int Node=0; Node<Total number of Hosts; Node++)  do
    Node = getAddress(from dataset)
    If (random Number(Host-ID)) Then
    While (Initial Number < Count total nodes from dataset)
    CreateNewlist = getRand(0, Random node counts)
    End if
    Else if (Is not isRanNode(CreateNewNodeList )) Then
    RanNodes.add(CreateNewNodeList)
    End if
    Each  hosts assign randomly number 0 or 1
    If (hosts get number =1) Then
    Node is selfish
    Else if (hosts get random number = 0) Then
    Node is not selfish
    End if
    End for
```

4.2.3 Threshold Value Computing in the Network

In this study to tackle selfishness behavior of nodes in the network the CRIS compare the recognition value of source node with the threshold value setted in the network. Each nodes has its own recognition value and threshold value. Then when source node and relay nodes encounter they exchange their utility data. These data contains their community id that indicate their community member and their recognition value that indicate their willingness behavior to other. This value indicates whether this node buffered or not message originated from other node of different community. Then if nodes are altruistic to other node it maximize its recognition value as message buffered for other. This is checked by computing threshold value as Equation (1) and comparing with its recognition value. The nodes will have greater recognition value than threshold if they have willingness behavior in previous buffering and forwarding activities.

$$\forall \boldsymbol{Thv}_{c(node)t} = \frac{(\boldsymbol{Thv}_{ini(t)} + \boldsymbol{Rv}_{c(node)t})}{\boldsymbol{Thv}_{ini(t)}} ------------------(1)$$

$$where\ as\ \forall \boldsymbol{Tv}_{\mathbf{c(node)}t} - is\ current\ threshodl\ value\ of\ node\ at\ time\ \boldsymbol{t}$$

$$\boldsymbol{Rv}_{C(node)t} - is\ current\ recognition\ value\ of\ nodes\ at\ time\ \boldsymbol{t}$$

$$(\boldsymbol{Thv}_{ini(t)} - is\ initial\ threshold\ value\ of\ nodes\ at\ time\ \boldsymbol{t}$$

Generally in the Equation (1) from the initial threshold value and current recognition value of nodes the threshold value is computed. As indicated by pseudo code in Agorithm 4.2 the threshold value for each node computed from the initial threshold value and the current recognition value of nodes after message delivered or dropped. The current threshold value (Thvc) is computed as Equation (1) above. This computation of threshold value depends on the community of source and relay nodes whether in the same or different community. If the two nodes are in the same community, there is no need any computation of threshold value because assume that they have strong relationship. However, if nodes are from different community, the threshold value should be compute from initial threshold value and the current recognition value of nodes. This computed threshold value helps to identify the previous willingness behavior of nodes in buffering message originated from node of different community.

Algorithm 4.2 Pseudo code for computing threshold value of nodes

```
If (RN and SN or DN in the same Community) Then
  //no update threshold value of nodes
  Thvc = initThresholdValue;
End if
Else if RN and SN in different community and
RN buffered and forward message successfully to DN Then
  //Update the threshold value of nodes with (1);
  Thvc = ((CRV+ initThresholdValue)/ initThresholdValue);
End if
Else if
RN not buffer message for node of other community Then
  Threshold value of each nodes is their current threshold value;
End if
End if
```

4.2.4 Computing of Recognition Value

Recognition value is calculated and maintained as follows. When a message is successfully delivered to the destination, then all relay nodes that participated in forwarding of that message rewards a recognition value. Initially all nodes in the network have equal recognition value distributed that helps to gain service from other node at least once in running the algorithm. Therefore, each nodes populated initial recognition value in the message header as the message traverses from one hop to the next as follows:

$$\forall \boldsymbol{Rv}_{\boldsymbol{c(rn)t}} = \boldsymbol{Rv}_{\boldsymbol{i(rn)t}} \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} (\mathbf{2})$$

$$where\ as\ \forall \boldsymbol{Rv}_{\mathbf{c(rn)}\boldsymbol{t}} - is\ recogn\_value\ for\ all\ \boldsymbol{R}\ relay\ nodes\ get\ initially\ at\ time\ \boldsymbol{t}$$

$$\boldsymbol{Rv}_{\boldsymbol{i(rn)t}} - is\ initial\ recognition\ value\ for\ all\ \boldsymbol{R}\ relay\ nodes\ at\ time\ \boldsymbol{t}$$

In this computing of the recognition value we assume that all nodes have, $\boldsymbol{Rv_i}$, initial recognition which helps to forward to all nodes initially within different communities and call initiate cooperation among nodes and buffer message originated from different community. Until the recognition value of source node becomes less than its threshold value, it gets service from nodes of outside its community member and decrease its recognition value while it gains services and increase the recognition value of nodes while it gives services.

The scheme inforces nodes which have less forwarding capability in terms of recognition value to contribute thier forwarding resource, buffer space, for others to increase their recognition value and accumulate this value to get forwarding services from other altruistic nodes in the network which grouped in different community. Of course nodes are altruistic to nodes which grouped in the same community based on their interest. This means no need to compute the forwarding capability value because we assume that they are willing to each other since they have more strong social tie strength than nodes in different community that have weak social tie among nodes. Therefore, if source and in the same community and have hop to each other, no relay node between them, then destination have direct contact with source node that able to get its respective message directly. On the other hand, if source and destination node are in the same community and are not direct contact then they needs relay node. As a result relay node buffered and forward for source node even though its recognition value less than the threshold value.

4.2.5 Recognition Value Update

The recognition values of source node **SN** and relay node **RN** will update when relay node **RN** forwards message for node **SN** and **SN** and **RN** are in located in different. If destination node **DN**, source node **SN** and relay node **RN** are on the same community they have strong relationship and they are willing to buffer and forward message to each other. is an intermediate node. However, if **SN** node in community 1 and source node **RN** in community 2 and **RN** buffer message for **SN** then **SN** gets service from outside of its community. On the other hand node **RN** provides service to node **SN** for outside of its community then after the recognition value of node **SN** and **RN** will update. Thus, the recognition value of node **SN** is reduced with constant value α while recognition value of node **RN** is increased with constant value β. However, if **SN** and **RN** are encounter directly to each other then they will provide service to each other. Therefore the recognition value of both nodes will not increase which means no change of recognition value. After message transmitted successfully to respective destinations node, the recognition value of relay nodes increase. In this update module the recognition value will increase with constant value α for relay nodes. On the other hand the recognition value of source node decrease by constant value β while no change of recognition value of destination node because at this circumstances it considered as node which get forwarding service from other node grouped in different community or at the same community. The recognition value will computed with equation (2) below as follows for all relay nodes except source and destination nodes because they are service gained users in the network at this time and if source and relay nodes are belongs in different community.

$$\forall \boldsymbol{Rv}_{\boldsymbol{u(rn)t}} = \forall \boldsymbol{Rv}_{\boldsymbol{c(rn)t}} + \boldsymbol{\alpha} \text{---} (3)$$

Where $\forall \boldsymbol{Rv}_{\boldsymbol{u(rn)t}}$ $is\ updated\ recognition\ value\ for\ all\ relay\ nodes\ at\ time\ t$
$\forall \boldsymbol{Rv}_{\boldsymbol{c(rn)t}}$ $is\ current\ recognition\ value\ for\ all\ relay\ nodes\ at\ time\ t\ and\ \boldsymbol{\alpha}\ is\ constant\ value$
On the other hand, recognition value of source node should be update when message successfully delivered at destination node **D**. Therefore, the recognition value of source node decrease per it gains service from other nodes with constant value $\boldsymbol{\beta}$ at time $\boldsymbol{t}$ as follows:

$$\boldsymbol{Rv}_{\boldsymbol{u(sn)t}} = \boldsymbol{Rv}_{\boldsymbol{c(sn)t}} - \boldsymbol{\beta} \text{---} (4)$$

Where $\boldsymbol{Rv}_{\boldsymbol{u(sn)t}}$ $is\ updated\ recognition\ value\ of\ source\ node\ at\ time\ t$
$\boldsymbol{Rv}_{\boldsymbol{c(sn)t}}$ $is\ current\ recognition\ value\ of source\ node\ at\ time\ t\ and\ \boldsymbol{\beta}\ \ is\ constant\ value.$
Forwarding management and buffering message depends on the recognition value and community communication. This means when communication between the nodes is intra-community (nodes within the same community) we assume that nodes are willing to each other and give priority to buffer and forward message than inter-community communication. Since this study employee community structure social properties or metrics to develop this scheme it follows both intra-community and inter-community communication. When messages buffered for intra-community communication no change recognition value of relay nodes. Generally, nodes in the same community will trust and they are not selfish to each other but selfish to outside its communities. The pseudo code in Algorithm 4.3 that reveals recognition value update while message delivered successfully to respective destination within node of different communities. This is considered the delivery of message from source to destination node to maximize or minimize the recognition value of nodes in the community. In this algorithm when message successfully delivered to respective destination nodes the recognition value of both source node and all relay nodes updated to new value unless both source and relay nodes in the same community.

Algorithm 4.3 Pseudo code for computing and updating Recog-Value while message delivery successfully to respective destination.

```
//Node SN and RN encounter and exchange utilities
If (SN and RN in the same community) Then
    RN and SN have strong social tie Then
    //no update the recognition value of both SN and RN nodes
    Recognition value of RN Rv(RN) = Rcvr and recognition value of SN  Rv(SN) = Rcvs;
End if
Else if node SN and RN in different community and (RN buffering for node SN)
    //Update recognition value of both RN and SN
    // decrease recognition value of source node with (4)
    $Rv(SN) = Rcvs - \beta$
    // increase recognition value of relay node with (3)
    $Rv(RN) = Rcvr + \alpha$
End if
End if
```

On the other hand, relay and source nodes might be in different community. If so relay node, RN, check the previous cooperation capability of source node. If source node has accumulative enough value as recognition value that enables to get services from other node of different community that allowed by CRIS algorithm then relay node RN willing to cooperate otherwise the algorithm enforces SN to maximize the value by sharing its communication resource such as buffer. This helps to get services from other that equal to services it gives. This is done as when message generated by source node it holds the recognition value of source node and travels across the network through different relay nodes until it received by destination node. During traveling of generated message in the network each relay nodes check this recognition value before buffering and forwarding it. This means relay nodes will not buffer message with lower recognition value than threshold of source node and if source and relay nodes are member of different community.

4.2.6 Message Buffer

One of the task in this approach is how to nodes share their buffer space to each other whether in same or different community among nodes. Therefore, in proposed scheme, CRIS, when two nodes encounter, the relay node check the previous node cooperation capability of source node in terms of recognition value it holds. However, this is done if relay node and source node encounter from different community. Then this relay node cooperate to source node if its recognition value computed in process of previous forwarding activity is greater than or equal to threshold value.

However, message originated from other nodes will buffered without checking it recognition value, if both source and relay nodes are in the same community. This checking the recognition value of source node helps to promote cooperation among nodes. For instance, when node that have less recognition value then it is not get any forwarding services for nodes of outside its community. Of course this unwillingness of node reveals to this node to maximize its recognition value by buffering and forwarding message to nodes of different community because forwarding to nodes in the same community there is no computing and increment of recognition value unless forward for node of different groups.

Generally if this value is enough that enables nodes to get service from other node of different community the relay node buffer the message show cooperation. In CRIS, after grouping nodes in to different community, nodes generate messages and forward to encounter nodes. However, the receiver node check buffering and forwarding capability of the source node by cheking its recognition value with comparing the it threshold value set in the configuration file that each nodes access when the algorithm starts to run. In the following pseudo code 2 depicts that how nodes willing and buffer message generated by nodes of different community and decide to cooperate to each other in the forwarding activites. This pseudo code 2 to reveals that buffering of message originated from other node. When the node encounter to each other they exchange their utility to decide buffering and forwarding originated from other node. At the beginning each node check community member of each encountered node. If both nodes are in the same community they node to check their recognition value to buffer and forward because they have strong relationship which meanse have strong tie to each other.

On the other hand if relay (intermediate) node **RN** and source node **SN** are member of the different community the node **RN** check the recognition value of **SN** whether it accumalte enough value to get buffering service from node of out side its community. Consequently, if this node have enough recognition value that able to get service then the relay node **RN** willing to cooperate and buffer message for it. This checking recognition value of out side its community helps to identify the selfishness and altruistic behavior of individuals in the network.

Algorithm 4.4 Pseudo code for buffering and forwarding message

```
Source node SN and relay node RN exchange utility
If Node  RN and Node  SN in the same community Then
    //Node RN and SN have strong social tie, relationship
    Node RN willing to buffer for Node source node SN
End if
Else if RN and SN in different community
    //RN Compare recognition value of SN with its threshold value;
    If Recog-Value of  SN ≥ ThresholdValue of SN Then
        Node RN Willing to buffer message for Node SN;
    End if
    Else if
        Recog-Value of  SN < ThresholdValue SN Then
        Node  RN refuse to buffer message for Node  SN
    End if
```

In any way source nodes should have satisfy the condition that set in the algorithm that enable them to bring cooperation mechanism in the network by buffering message originated from node of different community. The recognition value of nodes compute with Equation (2) in Section 4.2.4 then update this value for relay node and source node with Equation (3) in Section 4.2.5 when message delivered successfully to its destination this value for all relay node update.

4.2.7 Determination of forwarding capability of nodes

Here to determine forwarding capability of each node for outside its community we have to calculate the recognition value of each node and stored in its buffer. Since message contains current recognition value of source nodes, relay node may be willing or not to buffer its message. So, this value is calculated from the current recognition value of node. Then current recognition value will compute and determine the selfishness behavior of source node by comparing this value with the threshold set. The recognition value of relay node will increase with constant number ***α*** and recognition value of source node decrease ***β*** with time *t* as follows: *(where as* ***α = β****)* as it give service for other nodes outside its community. Generally in this study we employee **Tit For Tat (TFT**) approach to promote cooperation among nodes of different community based on recognition value of source node to each relay node of different communities. In TFT approach, each nodes have to give services for other node of different community to get proportional reward in the form recognition value to increase its probability to get forwarding service from the outside its community when needed. Nodes increase its recognition value when it is willing and relay message originated from other community but if both relay and source nodes are in the same community there is no any change of recognition value because node in the same community have willing to each other since they have strong relationship or social tie. This means even if source node have zero recognition value, nodes are buffer message for source node because of they are in the same community. Therefore, determining the nodes' buffering and forwarding capability is helps to identify node that give service to other nodes of outside its community which act altruistic behavior

Let see simple scenario with two communities namely **community 1** and **community 2** with **49** nodes in each of communities. Node **SN** found in community **community 1** and **RN** and **DN** are in community **2**. Source node **S** create message and need to forward to destination node **DN** which member of community **2**. However, node **SN** is not directly connect to destination node **DN**. Therefore, message originated from node of community **1**, **SN**, should pass through node **RN** as relay node because source node and destination nodes have direct contact to each other. Then node **RN** check recognition value of node **SN** whether it is less than threshold value or not. As a result, if it is greater than threshold value node **RN** cooperate with node **SN** to relay otherwise it is refuse cooperation and this informs to this node in order to increase its recognition value by giving forwarding service to nodes of other group.

Generally, node relay nodes such as **RN** get the source node's forwarding capability information from nodes that originated message in the network because message created contains lists of information such as community id (**CID**), source node (**SN**), relay node (**RN**), destination node (**DN**), message size (**MS**), current recognition value (**CRV**) for both source and relay nodes and time to live (**TTL**). This contents are list in the header of message when source node create message in the network and each relay nodes read this content list and compare the current recognition value with threshold.

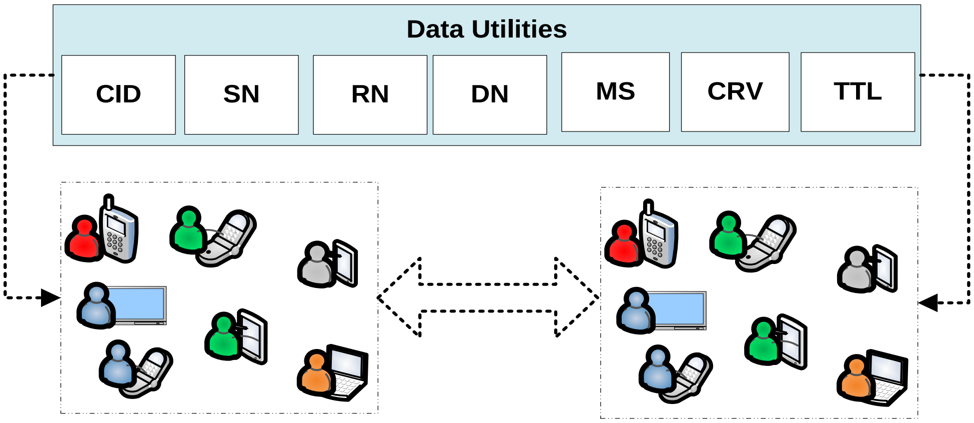


Figure 4.3 Example of CRIS communication between community 1 and 2

In the Figure 4.3 above when node let source nodes **SN** and relay node **RN,** encounter they share community id (**CID**), source node and relay information such as current recognition and decide to be selfish or altruistic to each other. In the configuration initially **CRV** is **2** which assign to each nodes and able to buffered and forward at least one message to each other. For instance, if the current recognition value of **(**$\mathbf{CRV_{sn}}$ **)** is greater than or equal to threshold value (**Tv**), $\mathbf{CRV_{sn}} >=$ **Tv** then **RN** willing to cooperate with **SN** by buffering message for it and the recognition value of relay node ($\mathbf{CRV_{rn}}$) increasevwhile decrease recognition value of source node. If the current recognition value of source node is less than threshold value **(**$\mathbf{CRV_{rs} < T_v}$ **)** then this nodes considered as socially selfish node and then **RN** refuse to cooperate with this **SN**. Each generate message with size of 1 megabytes and the buffere size in our model is 10 megabytes. The proble here is that even if **RN** willing to buffer message and if it has no storage space for buffering message that has size of 10 megabytes, it cannot buffer and overflow issue will happen. However, this not our concern because we have stated that node with buffer space but for future use they may not willing to spend for others advantage because such users have not altruistic behavior. Therefore, our proposed scheme concerned with such kinds of behavior of nodes and promote cooperation. Generally the work process of CRIS scheme in Figure 4.4 reveals its flow of activity in which the how nodes cooperate and shows altruistic behavior to each other for better network performances in terms of performance evaluation metrics as discus detail in chapter 6.

Consequently, nodes get forwarding service from node of outside its community by giving equivalent amount of service for other. This have been done through relaying message and maximize its recognition value while decreasing from node that get service from other community. These all have been done based on community structure of node what grouped together according to their affiliation.

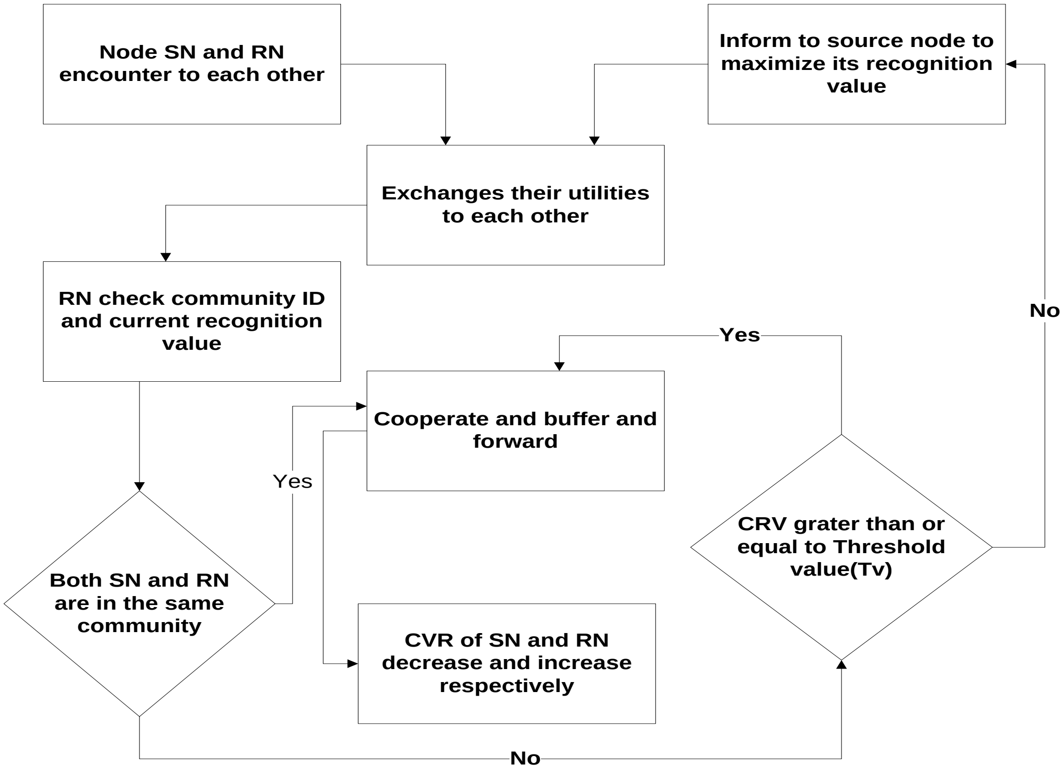


Figure 4.4 Working process of proposed scheme between SN and RN nodes

Let see the proposed scheme flow of work in Figure 4.4 to tackle selfishness behavior among nodes in the network. In this Figure 4.4, **SN** as source node, **RN** as relay node, **CID** as community id, **CRV** as current recognition value and **T_v** as threshold value. Assume that node **SN** and **RN** are member of different community and node **RN** will be relay message for node **SN** which is source node. When the two node encounter to each other they exchange their community id, current recognition value, size of message as well. Then node **RN** check the current status of node if it fulfil the criteria that the network allow for it to get buffering message from node of different community. Thus, node **RN** decide to buffer or refuse based on the recognition value of node **SN** whether it has greater than threshold value or not. If the current recognition value of node permit for it to get service from other community such as node **RN** in community **2** then source node **SN** will get message buffering service from node **RN** by buffering its message as relay node. Then the recognition value of both nodes should be update by increasing with some constant value for node **RN** and by decreasing from node **SN** with such constant number when message delivered to destination. In general, the flow activity of proposed scheme will summarized as follows. When node **SN** and **RN** encounter in the same radio range (through Bluetooth interface as simple broadcast) they exchange community Id (**CID**), Message size (**MS**) and also its current recognition value (**CRV**). Then:

1. Node **SN** and **RN** check the **CID** and **CRV** to each other whether their **CID** is differ from each other or not and.
2. Also check the **CRV** to each other whether less than some threshold value $\boldsymbol{T_v}$ or greater than $\mathbf{T}_v$.
3. If source node and relay nodes are member of different community relay nodes check the recognition value if source node and cooperate and willing to buffer message originated from **S** if and only if its **CRV** is greater than threshold value. Then it indicate that previously this node is give service to other nodes of different community.
4. However, if **CRV** is less than some threshold value then the scheme inform to source node in order to maximize its recognition value by giving service (buffering message) for node outside its community to get cooperation from other instead of buffering its message.
5. But if both source and relay node or destination node are in the same community they have strong relationship to each other.

Therefore, they are willing and buffer message without checking its recognition value to each other. This means if they are in the same community it is intra-community communication in which nodes have strong social tie and willing to each other and no need to check recognition value.

Generally this proposed mechanism work on the top non-selfishness routing algorithm to improve routing performance in terms of delivery ratio, overhead ratio, hopcount and delivery delay. So the main objective of the work is to design incentive scheme for tackling selfishness behavior of nodes to improve forwarding performances.

CHAPTER 5

IMPLEMENTATION AND EXPERMENTAL RESULT

5.1 CRIS Incentive Scheme

In order to implement the proposed CRIS incentive scheme, which has capability discourage selfishness behavior of nodes and call them for cooperation is begin with grouping nodes into different communities. First we suppose that nodes grouped into different communities according to some social relationships. They maintain recognition value of relay and source node with each community. This recognition value indicate that level of willingness to forward for others which means in **CRIS** incentive scheme, the recognition value will reduce from a community which gets buffering and forwarding services from other community. Similarly, the recognition value of community which gives buffering service will increase. This means nodes in community 1 get service from nodes in community 2 then the recognition value of nodes in community 1 will reduce while community 2's will increase. This is done by identifying community by their community Id. Every node records recognition value (**Rv**) for communities in a unit time interval. In the Figure 4.3 node **SN** and **RN** are in contact and need to decide whether to take cooperative behavior or not between them. Node **RN** check recognition value of node **SN** which is source node in this example and if it is enough value to get buffer from node **RN** then node **SN** get service from node **RN**. This done if the two nodes locate in different community but if in the same community according to **CRIS** they are willing to each other. Then **CRIS** have better network performance than both non-incentive and social selfishness scheme based forwarding. However, in the case when node in the source community have lower recognition value which compared with threshold value which set in the configuration file, then relay node in other community inform to source node of other community to increase its recognition value by buffering and forwarding message originated from other community. This indicate that there is Tit for Tat incentive strategy to form cooperation among nodes of different communities to buffer and forward message to each other to improve netwok performance in terms of performace evaluation mechanism.

5.2 Implementation of CRIS

In this study first we define selfishness in opportunistic networks which have an impact on the network performances. A node acts selfishly when it is not willing to carry messages in beneath of others. In this study we model selfishness behavior to nodes in the network by considering some subset of nodes within the network that will present some degree of selfishness by randomly selecting nodes from total dataset. Therefore, some of nodes represent the willingness of nodes to accept and buffer message sent by other nodes while some of them are not buffer message. Thus, we model selfishness of node randomly from total number of nodes in real traces dataset which is INFOCOM2006. Which means node will assign 0 or 1 by selecting node from dataset randomly. This indicates that when assign with 0 this nodes is non-selfishness behavior, while 1 is indicates selfishness behavior of nodes. So, we distribute selfishness behavior of nodes in the network and in this way we prove that selfishness behavior of nodes decrease network performance in terms of packet delivery ratio, overhead ratio, and average latency as well as hope count metrics. Generally we have generate selfishness behavior in the network and prove their impact on the performance of the network and evaluate the scheme with ONE simulation and external real trace dataset that collected by Haggle project in laboratory of Cambridge University. Generally to implement and evaluate our proposed scheme. After modeling and implementing selfishness behavior of node to other nodes in different community to indicate the impact of this behavior on the performances of the network in terms of performance evaluation metrics finding the solution for this selfishness issue is the main work of this study. Therefore, the study modeled and implemented the cooperation mechanism to tackle this selfishness behavior of node in the network improve the network performance that influenced by selfish nodes. Based on Tit for Tat incentive scheme strategy we proposed and implement CRIS incentive scheme with community structure for grouping nodes based on their interest that extracted from external dataset.

Consequently, when recognition value holds in message indicates that it is enough value to get service then the current relay node willing to assign buffer space and forward message. This node also carry the received message until it encounters another node that is able to forwards to other node. In this scheme, each nodes have current recognition value with their community id to identify from which community message is originated. As a result, nodes in the same community have strong social tie to each other they are willing to cooperate to each other.

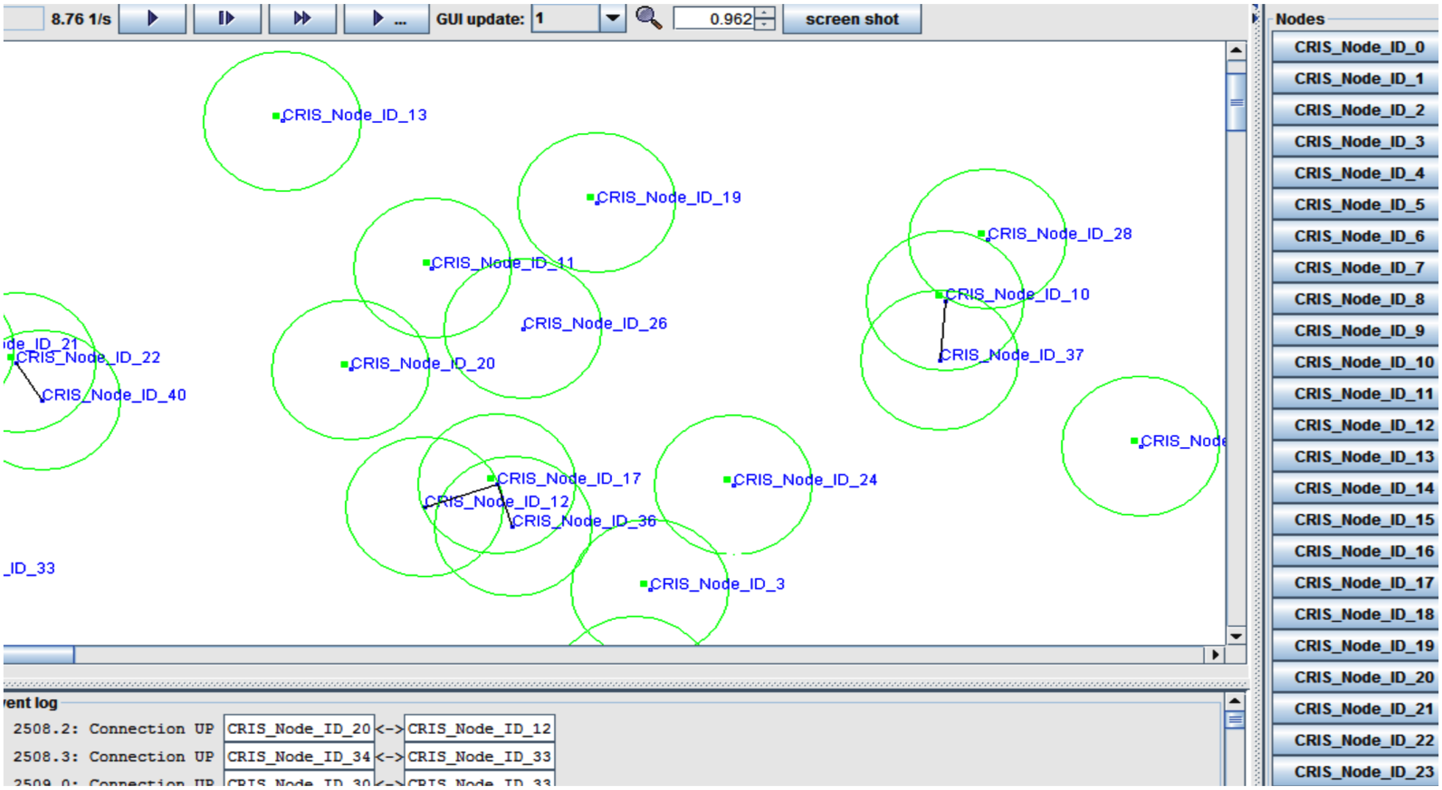
However, if two nodes encounter to each other as source and relay node from different community, then the realy node check previous history of source node in giving and gaining forwarding services. Consequently, if the source node have high capability to get service by having greater recognition value than threshold the relay node willing to buffer the message for it. Otherwise, relay node inform to the node to maximize its recognition value by giving service to other nodes of different community to gain equivalent service. When message delivered successfully then recognition value should be update for source nodes and all relay node in which decrease for source node while increase for relay nodes. This because the principle of CRIS scheme is decrease recognition value when it gain service while increase when it gives services to other nodes in the inter-community communication. Therefore, the proposed scheme CRIS, implemented on the top of spray and wait routing algorithm. We explored that the distributed selfishness behavior of nodes in the network decrease the performance of Spray and Wait routing algorithm which is not consider the existence and impact of selfishness behavior of node in forwarding activity. As a result, selfish nodes decrease routing performance in the network in terms of delivery ratio, overhead ratio, delivery latency and hopcount of message created.

The time for which the scenario is to be simulated is simulation end time which is 12,000 seconds according to our scenario in proposed scheme as optimal simulation end time. The connection of simulation time in the configuration file should be true because we use external trace dataset INFOCOM2006 from CRAWDAD. The movement model for our scenario is external movement model for all communities because we employeed external dataset. The buffer size for out scenario is set to 10M that enable nodes to buffer message to each other. The other parameter is wait time which is the minimum and maximum wait times (in seconds) after reaching destination which set to 100,200 seconds respectively for our scenario as optimal wait time for our scheme. It defines how long nodes should stay in the same place after reaching the destination of the current path. For this scenario we use Bluetooth features for interface types of nodes and TTL time to live in which determine the expiration time of message created. Field of number of host specifies the number of nodes that get from dataset which 98 hosts. Since we employed Bluetooth interface, node communicate at range of 10 metre appart. The initial threshold value set in our scenario is 2 which compare with initial recognition value of each nodes to compute the buffering history of nodes. The recognition value of nodes updated after gaining and giving service with alpha and beta values set in the configuration file respectively. Similarly, the threshold value of nodes update by computing it from its initial value and the current recognition value of node. The message generation time interval is time frequency in which nodes create message in the network when the algorithm start to run which is [600,800] seconds in our proposed scheme scenario as optimal message generation frequency.

Generally this study reveals the mechanism to improve the network perfromances specifically in the presence of social selfishness behavior of nodes in the network and tackle such behavior of nodes in different communities and make them cooperate to each other through the proposed scheme, community recognition incentive scheme. An the end we evaluate the perfromances of our scheme with different evaluation metrcis such as delivery ratio, overhead ratio, hopcount and delivery latency and achieve good result as discussed in the following sections.

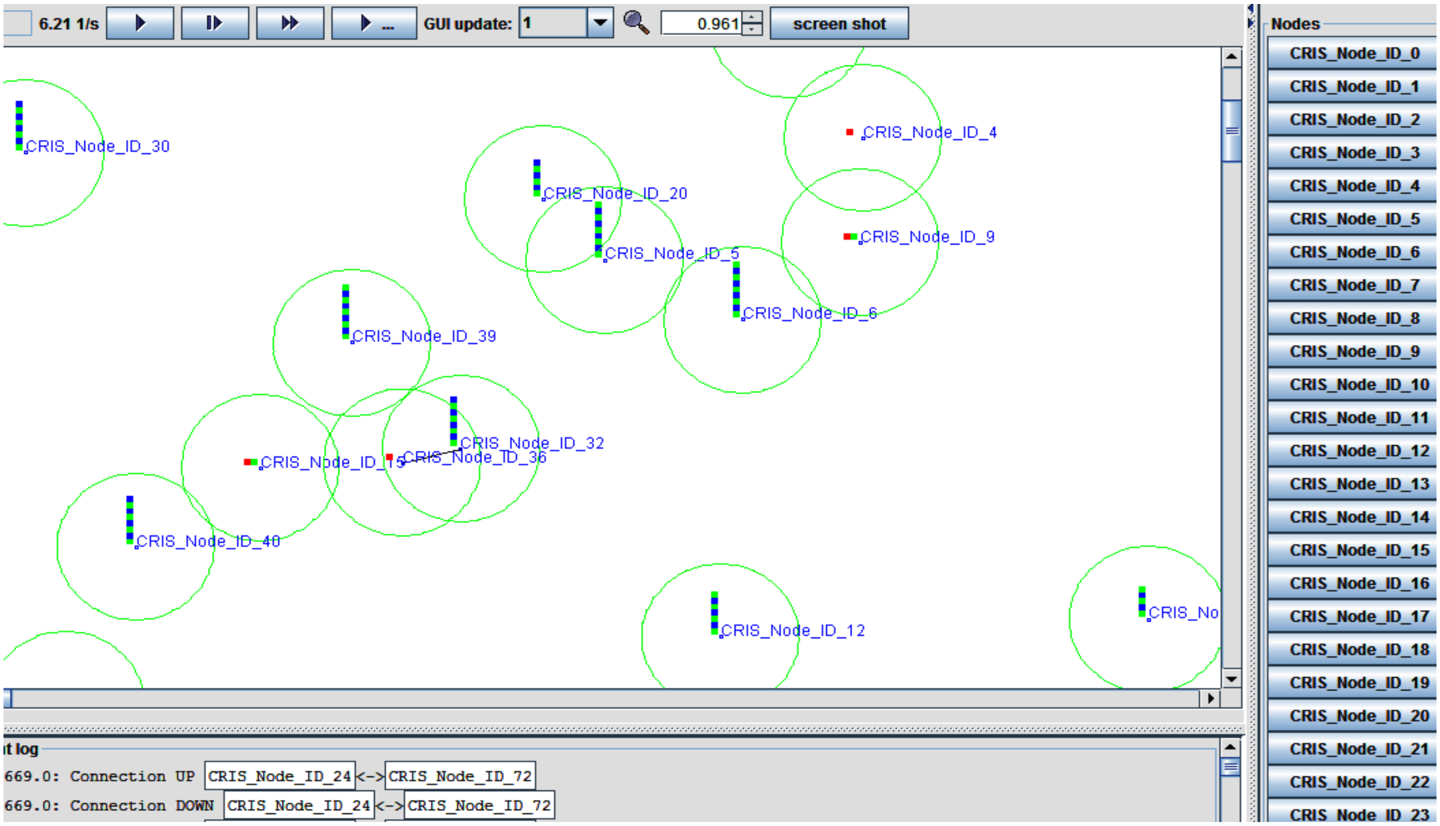
5.3 Simulation Setup Information

In this work we employed tool and real external traces dataset for simulation setup. To evaluate the proposed and designed system we have been using opportunistic network environment (ONE) simulator tool. It is developed for simulating and evaluating DTN protocols. Since its inception, the ONE simulator has become largely popular in the research community and is being widely used. Apart from providing implementations of several well-known routing protocols and mobility models, the ONE simulator makes integration of real-life traces such as, mobility and connection information into simulation a simple and easy task. To evaluate the proposed scheme we use real trace dataset INFOCOM2006. In this simulation we have four community of nodes based on their common interest community of nodes created from dataset and based on nodes interest they grouped into different community. Also in this simulation setup we set different parameters listed in Table 5.1 and evaluate the proposed scheme based on performance evaluation metrics such as delivery ratio, overhead ratio, average latency and hopcount. In the Table 5.1 we set 18 parameters in the configuration text file. Movement models govern the way nodes move in the simulation. Movement model of nodes govern the way nodes move in the simulation and provide coordinates, speeds and pause times for the nodes. There are different movement models available as discussed in section 1.4.8 above detail. However we employee external movement model for our work because we use INFOCOM2006 external real trace dataset for simulation. The other parameters are alpha and beta value which need to increase and decrease recognition value of community respectively to provide cooperation among nodes of different community. Which means if node willing to forward for nodes in other community the recognition value will increase by this alpha value whereas decrease beta value and CRIS inform to increase its recognition value by cooperating with other nodes of different community to get as much as it gives service from other which indicate that Tit for Tat strategy as mutual benefit among nodes in the network which initiated by CRIS scheme.



```
2508.2: Connection UP CRIS_Node_ID_20<->CRIS_Node_ID_12
2508.3: Connection UP CRIS_Node_ID_34<->CRIS_Node_ID_33
```

Figure 5.1 At the beginning of simulating CRIS graphical with ONE simulator(a)



```
669.0: Connection UP CRIS_Node_ID_24<->CRIS_Node_ID_72
669.0: Connection DOWN CRIS_Node_ID_24<->CRIS_Node_ID_72
```

Figure 5.2 At the end of simulating CRIS graphical with ONE simulator (b)

5.4 Simulation Parameters

The parameters employed for these work and setup the simulation in the configuration will be here. In the configuration setting for our scenario depicts the parameters that employeed to evaluate and compare the result achived in the evaluation of our proposed scheme,CRIS.

Simulation End Time: Determine that how many seconds need to simulate the simulation. For our work we set 12000 seconds as an optimal simulation duration.

Simulation Connection: It is a parameter that should connections among nodes and determine their movement model when which its value set to true or false based on dataset used. For this work we set true because we employed real trace dataset INFOCOM2006.

Scenario Update Interval: This indicates that how many seconds are stepped on every update of routing. While increase this value simulation is faster, but then we will lose some precision result. Therefore, it should be 0.1 is good for simulation of our work.

Message Generation time interval: When the message generated there is frequency interval time at which message should be generated. This means as the algorithm start to run with the given simulation end time (e.g. 12,000 seconds) there time at which message start to create (e.g. 600,800 interval). Therefore, this message creation time interval is assume that in the real scenario allowed to create message in the network instead of automatically generating which indicate us there is message generation time.

Waiting Time: On the other hand, there is waiting time which means how long nodes should stay in the same place after reaching the destination of the current path. As increasing this time the delivery delay and overhead increase. So, for our work we used (100,200) as optimal waiting time for all nodes.

Interface type: It is interface type all nodes to have to communicate to each other. Since dataset we employed is external real trace dataset which gather using Bluetooth we employed Bluetooth for our simulation.

Transmit Range: The range at which nodes able to communicate to each other in meters since we employed Bluetooth we set it to 10M value.

Movement Model: This is the movement model that all hosts in the community should use. Since we used external real trace dataset from CRAWDAD we employed external movement model for all nodes.

Buffer Size: is size of the nodes' message buffer space at initially have with megabytes. We use 10M for our simulation because

Message TTL: is message time to live at which message expired time in simulated time of the messages created by the host. This indicate that the TTL of each message check every time set and drop such messages if TTL expired and we set its value for our work 5000 seconds optimal time.

Number of Nodes: is total number of nodes participate in the simulation. We eployed 98 node from external dataset integrated.

Alpha Value: is the value that helps to update the recognition value when message delivered to respective destination successfully**.** We set to 2 which is enough to get service from nodes of outside its community atleast once to maximize the recognition value of all relay nodes.

Beta Value: is the value that helps again to update the recognition value when message delivered to respective destination successfully. Also its value is 2 helps to minimize the recognition value by 2 when message delivered.

Threshold Value: is parameter that helps nodes to gain and give service to nodes of outside their community. By comparing this threshold value with the recognition value nodes gain buffering and forwarding services. Initially, we used 2 for simulation which helps all nodes to get service from each nodes at the beginning. Then we compute from its initially recognition value and current recognition value of each nodes get to forwarding in inter-community communication. Generaaly we show those parameters with their optimal value we used our evaluation of our proposed scheme in the Table 5.1.

Table 5.1 Simulation parameters

Parameters	Value
Simulation End Time	12,000 (~4hr)
Message TTL	5000 (~2hr)
Simulatation Connection	True
Waiting Time	100, 200
Number Of Nodes	98
Interface Type	Bluetooth
Buffer Size	10M
Transmit Range	10metre
Update Interval	0.1
Movement Model	External Movement
Message Size	500K,1M
Event Interval	600,800
Threshold	2
Alpha	2
Beta	2
Dataset	INFOCOM2006

5.5 Comparisions Forwarding Mechanisms

In this work we consider forwarding mechanisms with and without incentive scheme in addition to selfishness routing. At the beginning we evaluate the performance of network in non-incentive and selfishness based routing mechanisms in the network. Both selfishness based routing and CRIS scheme are implemented and evaluated on the top of Spray and Wait routing algorithm. Spray and Wait routing algorithm is not considered the impact of selfishness behavior of nodes in the network in its forwarding activities.

5.5.1 Non-incentive Forwarding

In this mechanism since there is no any kind of incentive mechanism, the forwarding algorithms do not consider the selfishness behavior of nodes to each other. So that previously forwarding algorithms blindly forward packet to destination without considering this selfishness issue in the network. However, as stated in the statement of problem section of the study, this behavior of nodes has an impact on the performance of network in terms of performances evaluation metrics such as delivery ratio, overhead ratio, average latency and hopcount. We examine the existence of selfish nodes and their effect on the network performance by allowing nodes to be selfish to each other and not buffer message originated from other. Spray and wait routing algorithm performs data forwarding activity as “sprays” a number of copies into the network, and then waits till one of these nodes meets the destination [40]. Spray and wait routing algorithm has two phase which are spray phase and wait phase. In spray phase source node forward the packet to different node. If destination is found then the message or packet transfer is successfully terminated. If not than wait phase is started. When the destination is encounter it will perform the direct transmission that means source node itself send the data to destination node. However, this routing algorithm did not use any advantage of social properties and also not considered selfishness behavior that affect the forwarding activity in terms of performance evaluation metrics such as delivery ratio, overhead ratio, delivery latency and hopcount. Therefore, we proposed CRIS scheme to tackle such behavior and improve the network performances with such evaluation metrics by calling selfish nodes to cooperate and incentivize to each other in the network.

5.5.2 Social Selfishness Forwarding

In this routing mechanism we evaluate that social selfishness behavior of node impact on the social aware routing algorithm in opportunistic networks. Since we grouped nodes in the network into different communities, only nodes in the same community are willing to forward to each other. But are selfish to node of outside their community. This depict as social selfishness behavior in social aware networks have influence on the performance of routing activity in the network in terms of different routing metrics such as delivery ratio, overhead ratio, delivery delay hopcount. We will discuss more detail of these metrics in the next Section 5.6. To make clear these paragraph if source node and destination as well as relay node in the same community, relay node is willing to receive and buffered message from source node and forwarding to respective destination when they are in the same communication range.

5.5.3 Cooperation Based Forwarding

In the social aware routing network protocols, the routing mechanisms are dependent on social properties to make more stable network connectivity. Even though, different social aware routing algorithms are proposed, most of the them did not consider social selfishness behavior of nodes.

Therefore, the proposed cooperation mechanism, CRIS scheme, community recognition incentive scheme has better network performance in terms of routing metrics such as delivery ratio, delivery delay and hop count while better performances achievement in terms of overhead ratio than selfishness based routing. This section describe the CRIS mechanism which is show better network performances because nodes are willing to forward for all other nodes among different communities which performed by this CRIS cooperation mechanism.

5.6 Comparison and Evaluation Metrics

The performance evaluation metrics computed as follows. This computing techniques for messages traverse in the network from source to destination is described in detail in the following sections according to [62]. Therefore, before evaluating our scheme let discus the performance evaluation metrics.

5.6.1 Delivery Ratio

It is the ratio of successfully delivered messages to the total number of unique messages created in a given period. The average delivery ratio of the messages is evaluated as **| Md| / | M|** where **M** and **Md** are message generated and message delivered to destination successfully respectively but not include redundant messages. This is one of the primary metrics used to evaluate the performance under a given scenario or using a particular protocol. Since we proposed to increase the performances of the network in terms of this metrics as well we use delivery ratio of message to evaluate CRIS incentive scheme [62].

5.6.2 Overhead Ratio

Routing in opportunistic type of networks, is usually replication based which cause for existence of multiple copies of a message in the network. This has impact on the storage capacities of the nodes. Generally the overhead ratio is computed as$\left(\sum_{i=1}^{|M|} ri - |Md|\right)/|Md|$ where M, ri, and Md are total message created, relayed message and delivered message respectively. So, it is a ratio of delivered messages to the total number of unique messages created in a given period. This metrics also didn’t include the redundant messages [62].

5.6.3 Average Latency

The delivery delay of message to reach its destination includes waiting time, queuing time, and transmission time of message until arrive its respective destination. This metric gives an indication of an average time required to deliver a message from its source to its corresponding destination. This is evaluated as $\sum_{\boldsymbol{i=1}}^{|\boldsymbol{Md}|}(\boldsymbol{ti'} - \boldsymbol{ti})/|\boldsymbol{Md}|$ where is $\boldsymbol{ti'}$ **and** $\boldsymbol{ti}$ the time instants when a message is created and delivered to its destination respectively. The average delivery latency of a message in opportunistic network is high but is should be few seconds even thousand seconds. Therefore, usually one of the objectives should be minimizing the delivery latency [62].

5.6.4 Average Hopcount

The hopcount is the number of hop counts that message pass through to reach its destination. Therefore, average hopcount is the total of hop counts when messages are received successfully by respective destination. Therefore, the average hopcount information show us how challenging the evaluation scenarios was and how well routing scheme managed and used network resources. Let $\boldsymbol{hc}$ be the hop count for the delivered message and Md is delivered message then average hopcount is computed as$\sum_{\boldsymbol{i=1}}^{|\boldsymbol{Md}|} \boldsymbol{hc}/|\boldsymbol{Md}|$. It may be noted that the above defined metrics are generic in nature and can be used in any scenario [62].

However, in [62] delivery ratio of the messages, delivery latency, and overhead ratio are three tightly intertwined metrics. In practice, whenever one of them improves, another one fails to achieve what planned. For example, having large number of replicas of a message is helpful to improve its delivery chances. But, at the same time, it also incurs high overhead in the network.

5.7 Result and Discussion

In this section we discussed the simulation result, detail incomparison with performances of the three mechanisms with each evaluation metrics. For instances, Table 5.2 below reveals that the simulation result with four metrics such as delivery ratio, overhead ratio, hopcount and delivery latency with 10 different simulation end times for the three routing mechanisms. However, in social selfishness forwarding mechanism since node of one community have selfishness behavior to other community messages created from one community will drop instead of buffering. This bring to decrease performance on the network in terms of those metrics. As indicated in Table 5.2, social selfishness forwarding mechanism reduce the delivery ratio. This indicate that the impact of selfishness behavior on the opportunistic network especially on the data forwarding activities in data management framework. So, to cope this selfishness issue in the network proposing incentive scheme which call node for cooperation among nodes of different community and willing to forward between neighbors communities. The delivery ratio of CRIS incentive scheme is better than both Non_Incentive and Selfish_Routing scheme at different simulation end time. For example, at the 6000, 8000, 10000, 14000, 16000, 18000, 20000, 22000 and 24000 seconds the proposed scheme is achieved 75.00%, 81.81%, 92.86%, 94.44%, 85.71%, 79.17, 73.08% , 86.21%, 90.63% and 82.86% delivery ratio respectively with 600-800 message generation time interval. Even if delivery ratio of CRIS decreases as increasing simulation end time its delivery ratio is higher than both mechanisms as explored in Table 5.2. At 2nd hour (8000s) the delivery ratio of CRIS incentive scheme based routing is better than both selfishness and Non_incentive scheme routing but its overhead ratio is higher than both mechanisms. The result indicate that the delivery ratio of CRIS incentive scheme (81.81%) is better delivery probability which means from total number of created messages, 81.81% of messages are delivered successfully to corresponding destination.

However, at 3rd simulation end time the delivery ratio of the three mechanism are 71%, 50% and 92.86% for non-incentive, selfishness and CRIS routing mechanisms respectively. The delivery ratio result of selfishness routing mechanism (50%) which is less than non-incentive routing indicates that network performances in terms of delivery ratio is influenced by such selfish nodes. In addition to this, in terms of overhead ratio the non_incentive scheme routing is achieved better result as shown in the Table 5.2. Even if the overhead ratio of CRIS is higher than non_incentive scheme, it less tesult obtained than selfishness based routing. In terms of overhead ratio CRIS has high remarkable result as compared to selfishness routing mechanisms. But in the case of hopcount both non-incentive and selfishness touting mechanisms perform marginally. However, CRIS still outperforms both of them in all simulation end time as result presented in Table 5.2. This higher number of hopcount indicate that there cooperation among nodes to buffered and forward message originated from other node of different community.

Evaluation result of the three forwarding mechanism, CRIS has better network performance in terms of some of the metrics except that delivery latency is higher than other schemes. However, in terms of overhead ratio non_incentive scheme is less than both of CRIS and selfishness routing schemes. For example, the proposed study resulted higher delivery latency than non-incentive routing mechanism at 6th, 8th, 11th, 13th and 14th hour of simulation time. However, at 2nd and 3rd hour the delivery latency of CRIS less than non-incentive scheme.

On the other hand the delivery latency of selfishness routing mechanism is higher than cooperation (CRIS) mechanism in all the simulation end time. Generally this enable as to conclude CRIS has better network performance than those mechanisms. More detail graphically, also we tried to explore the performance of these mechanisms in terms of different evaluation metrics.

For instance, in Figure 5.3-5.6 reveals the performance of proposed scheme with other mechanisms with performance evaluation metrics such as delivery ratio, overhead ratio, hopcount and delivery delay of message generated by each mechanism with different simulation end time and different message generation time interval (message generation frequency). Let first explored detail of the performances of the three mechanisms with different simulation end time and different performance evaluation metrics in Table 5.2. The result discussed in this table, each mechanisms have evaluated with their own setting scenario in the configuration files. But all mechanism implemented and evaluated with real trace dataset infocom2006 as recommended by different researcher for evaluating opportunistic types of networks.

As a result, we found that CRIS have outperforms of the two mechanisms with delivery ratio, delivery delay and hopcount. Of course there is intertwined of these metrics which means is difficult to achieve everything what planned because when we improve network performance in terms of one of these metrics the other may failed which is challenge in such type of networks.

Table 5.2 Simulation result for three mechanisms

Simulation_ Time(s)	Evaluation Metrics	**The Three Mechanisms**		
		Non_Incentive_Scheme_Routing	Social_Selfish_ Routing	Incentive_Scheme_ Routing
6000	Delivery ratio	75.00	67.00	75
	Overhead ratio	9.50	59.33	71
	Hopcount	1.33	1.50	8
	Delivery latency	610.36	232.13	558
8000	Delivery ratio	72.73	63.64	81
	Overhead ratio	9.88	61.14	80
	Hopcount	1.25	1.57	8
	Delivery latency	501.74	202.59	568
10000	Delivery ratio	71.43	50.00	92
	Overhead ratio	9.60	72.00	80
	Hopcount	1.20	1.57	7
	Delivery latency	401.96	202.59	698
12000	Delivery ratio	70.59	50.00	94
	Overhead ratio	9.08	64.89	63
	Hopcount	1.17	1.56	7
	Delivery latency	335.38	831.73	784
14000	Delivery ratio	68.42	52.38	86
	Overhead ratio	9.69	59.73	109
	Hopcount	1.15	1.72	6
	Delivery latency	309.86	1104.72	1031
16000	Delivery ratio	63.64	54.17	79
	Overhead ratio	10.57	182.34	189
	Hopcount	1.14	1.61	6
	Delivery latency	287.97	635.34	976
18000	Delivery ratio	64.00	51.85	73
	Overhead ratio	10.633	1027	216
	Hopcount	1.31	1.64	6
	Delivery latency	314.79	869.01	976
20000	Delivery ratio	67.86	50.00	86
	Overhead ratio	9.84	1761	211
	Hopcount	1.32	1.67	5
	Delivery latency	283.20	811.79	987
22000	Delivery ratio	67.74	48.48	91
	Overhead ratio	9.95	2405	226
	Hopcount	1.33	1.69	4
	Delivery latency	566.30	763.18	1041
24000	Delivery ratio	76.47	44.44	82
	Overhead ratio	8.89	3165	266
	Hopcount	1.58	1.69	4
	Delivery latency	2209.13	763.18	1154

5.8 Factors affect the result of evaluation of CRIS scheme

5.8.1 Influence of message generation

To evaluate our work and get better result during simulation of the proposed scheme, CRIS, we evaluate with different message generation frequency in terms of different performance evaluation metrics. In the configuration file we set different message generation interval time in second that determine amount of message should generate when the proposed algorithm start to run. These generation time intervals such as 600-700, 600-800, 700-800 and 800-900 are generated different amount of message in the network as reveals in Table 5.3. These message generation time intervals indicate that as message generation frequency increase the amount of message generated in the network decrease.

On the other hand smaller message generation frequency will generate more amount of message in the network. For instance, at the simulation time of 8000second (3hr) in the Table 5.3 below reveals different results of delivery ratio, overhead ratio, hopcount and delivery delay with different simulation time in different message generation frequency. In Table 5.3 we find that different delivery ratio for different message generation time intervals. For instance, with 600-700 second message generation time interval resulted 55%, 50%, 66%, 77%, 80%, 75%, 70%, 86%, 84%, 73%, and 86% delivery ratio for 6000, 8000, 10000, 12000, 14000, 16000, 18000, 20000, 22000 and 24000 simulation end time respectively. Also the table shows different delivery ratio results from other different message generation time interval such as 600-800, 700-8000 and 800-900 with different simulation end time. For example at event interval of (600-800) delivery ratio for 6000, 8000, 10000, 12000, 14000, 16000, 18000, 20000, 22000 and 24000 are 75%, 81, 92, 94, 86, 80, 78, 86, 90 and 83 respectively. From these result we concluded that message generation time interval has its own impact on the evaluation of proposed CRIS scheme in terms of this metric. And as the result in the show that 600,800 message generation frequency is better event interval to acheve better delivery probability. In addition to this from the results we also concluded that as message generation time increase the delivery ratio of messages decrease. Therefore at the (600-800) message generation time interval the delivery ratio is better than other message creation time intervals for all simulation end time. As a result, at the (600-800) event interval CRIS have capability of 94.4% delivery ratio at 12,000 seconds simulation end time which means that 94.4% of messages delivered to respective destination from total message created during the simulation time . Here when we simulate with above and below 600-800 time interval, the delivery ratio decrease.

At the same time we evaluate this work in terms of overhead ration with different message generation time interval. In the Table 5.3 also we show that evaluation result of CRIS in terms of overhead ratio at different message generation time interval with different simulation time. Here the overhead ratio is less at (800-900) message generation time intervals. In this table we find better result in terms of overhead ratio at (800-900) event interval. However, at (600-800) interval time at 12,000 simulation end time there is less overhead ratio than all intervals time and all simulation end time which is 63. So, from this result we concluded that CRIS achieve better performance in terms of overhead ratio at (800-900) message generation interval. When message generation time interval is less then number of message creates in the network is high. As a result when message creates in the network is high, the probability of overhead ratio is high. Generally, the message creation time interval has an impact on CRIS in terms of overhead ratio.

The indication of the impact of message generation time interval is not limited with delivery ratio and overhead ratio but also continue to hopcount and delivery delay metrics. Message generation frequency also has an impact on th hopcount metric which is numerically show in the Table 5.3 below from different message creation time interval and simulation of our scenario. As indicate in this table the hopcount of message until it reaches to respective destination is high at message creation time interval of (600-800) which is better event interval than other that enumerated in the table. Therefore, when compared hopcount of all message generation time interval with each other to indicate the impact of the average result of (600-800) interval is higher than other intervals. Consequently, the message generation event intervals have performance evaluation impact on the CRIS in terms of hopcount because the increment of hopcount designates that there is high cooperation among nodes in the network in which message travers through a number of relay nodes to arrive at destination. At the time this events interval has an impact on the delivery delay which time that message take until it reaches its destination.

Table 5.3 Influence of message generation on the performance of CRIS

Simulation time	Evaluation metrics	Message generation time interval			
		600-700	600-800	700-800	800-900
6000	Delivery ratio	56	75	62	70
	Overhead ratio	95	71	83	67
	Hopcount	3	8	6	8
	Delivery latency	762	558	2039	1439
8000	Delivery ratio	50	81	70	76
	Overhead ratio	105	80	77	72
	Hopcount	4	8	6	8
	Delivery latency	695	568	2044	1381
10000	Delivery ratio	66	92	76	81
	Overhead ratio	90	78	76	65
	Hopcount	4	7	5	7
	Delivery latency	755	698	2002	1297
12000	Delivery ratio	77	94	75	90
	Overhead ratio	93	63	79	73
	Hopcount	4	7	4	6
	Delivery latency	904	784	1988	1128
14000	Delivery ratio	80	85	80	81
	Overhead ratio	127	109	64	66
	Hopcount	4	6	4	6
	Delivery latency	1142	1031	2083	1518
16000	Delivery ratio	75	84	75	73
	Overhead ratio	160	189	123	72
	Hopcount	4	6	4	5
	Delivery latency	1078	976	1973	1355
18000	Delivery ratio	70	82	70	78
	Overhead ratio	160	216	190	70
	Hopcount	4	6	4	4
	Delivery latency	1030	976	1875	1447
20000	Delivery ratio	80	86	76	70
	Overhead ratio	160	211	176	87
	Hopcount	3	4	3	4
	Delivery latency	1044	987	1993	1544

The message generation time interval also has an impact on the performance of the study in terms of delivery delay. As Table 5.3 presented that different message generation time intervals, CRIS shows different delivery delay result. As the result depicts on the Table 5.3, at 600-800 event intervals CRIS has less delivery delay than other generation intervals. In general, the performance of CRIS also explored with graphs to indicate the overall difference among message generation time intervals in terms of evaluation metrics. In the Figure 5.3 the delivery ratio of CRIS degrade as increasing the number of messages generated in the network because of increasing message generation time interval. For instances, the delivery ratio of CRIS scheme is better at 600-800 interval with different simulation end time than 600-700, 700-800 and 800-900 message generation frequencies. Also the overhead ratio of CRIS increase as decreasing message creation frequency as in Figure 5.4. For instance, at 600-700 event interval time, is higher than 800-900. In Figure 5.5 also shows the impact of message generation frequency on the performance of CRIS in terms of hopcount. At the end we evaluate this work with delivery latency of message generated in the network to delivered respective destination. Therefore, the performance of CRIS also influenced by the message generation frequency. Generally, CRIS performed effectively at message generation frequency of 600-800 seconds in terms of all metrics except overhead ratio which less at 800-900 intervals which is an optimal message generation frequency for this work.

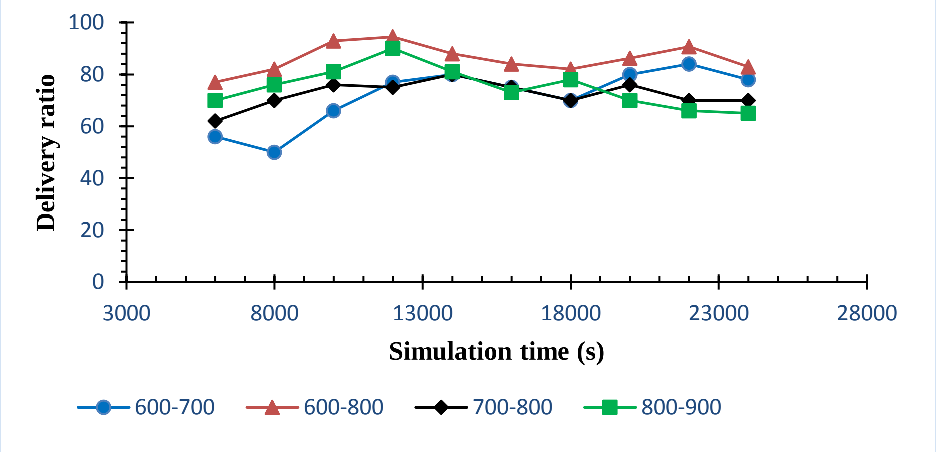


Figure 5.3 Influence of message generation time interval on delivery ratio

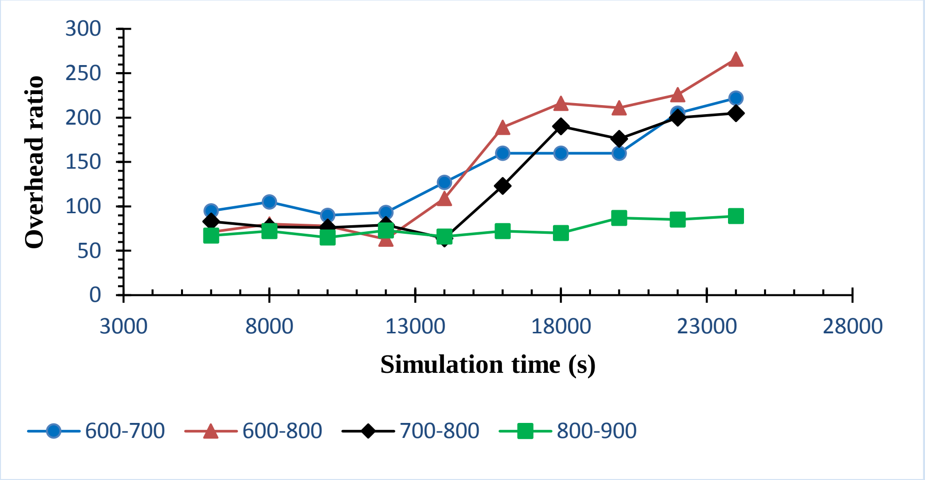


Figure 5.4 Influence of message generation time interval on overhead ratio

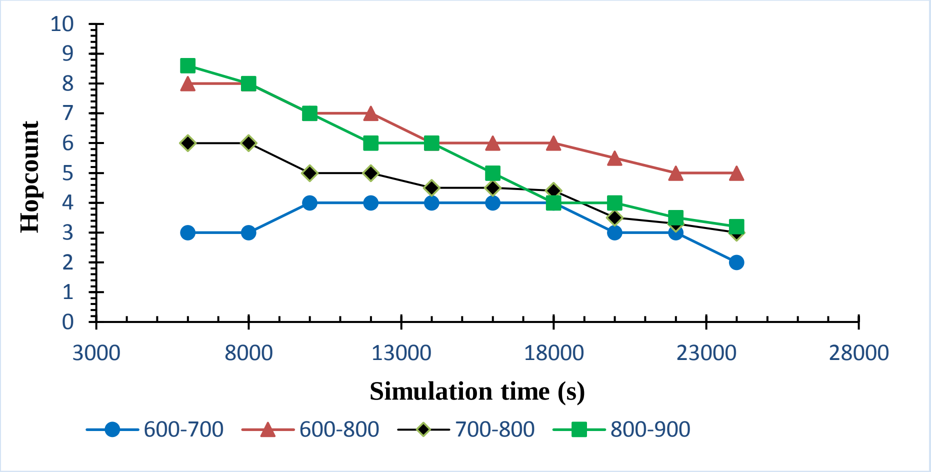


Figure 5.5 Influence of message generation time interval on hopcount

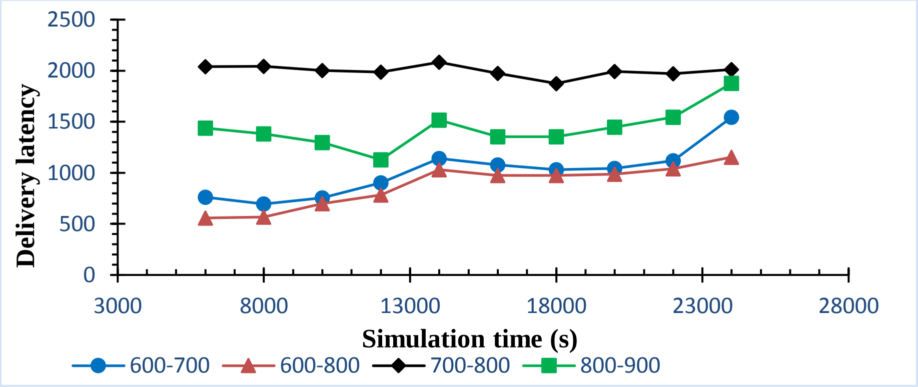


Figure 5.6 Influence of message generation time interval on delivery latency

5.8.2 Influence of simulation time on CRIS

In addition to message generation time intervals the simulation end time has also its own impact on the performance CRIS with different evaluation metrics such as delivery ratio, overhead ratio, hopcount and delivery latency. The simulation time is measured in second and we tried to simulate 10 different simulation end time from 6,000 to 24000 or [2hr, 7hr] at message generation frequency time 600-800 seconds (10-13mins) which optimal message generation time interval for this work. For example, as Figure 5.7-5.10 show that we evaluate the proposed scheme CRIS with different simulation end time. Consequently, the delivery ratio decrease as simulation time increases from 6000 to 12000 seconds. Then after the delivery ratio decrease as simulation time end increase. This indicate that when simulation time of the scenario is high the delivery probability of generated message decrease because message will be expire before arrive its destionation. As result, since there is simulation result differences for different simulation end time it has an impact on the evaluation of the performance of CRIS. For instance, in the Table 5.2 below the delivery ratio of CRIS is 94% at simulation time 12000 but at the simulation time 24000 seconds it is reduced to 82%. In terms of overhead ratio, the performance of CRIS increase as increasing simulation time. Numerically at simulation time 6000 seconds overhead ratio is 71 whereas 266 at 24000 simulation end time. However, at 12000 seconds CRIS resulted 63 which is optimal messagae generation interval of (600-800) seconds and optimal simulation end time of 12000 seconds. Overhead ratio which is better result than other evaluation result. The performance of this work also influenced in terms of hopcount metric by simulation time. Also in Figure 5.9, the hopcount of message decrease as increasing simulation time. For example, the hopcount at simulation time 6000 is 8 but at 24000 seconds the hopcount of CRIS is 4. Therefore, as simulation time increase the hopcount of messages in CRIS scheme decrease. At the same time delivery latency also affected by simulation end time. On the other hand, as simulation end time increase, the delivery delay of message to reach its destination is increase. This indicate that message take long time to arrive its destinations. For example, as Figure 5.10 show that, at the 2nd hour of the simulation end time the delivery delay of CRIS scheme is higher than at 7th hour.

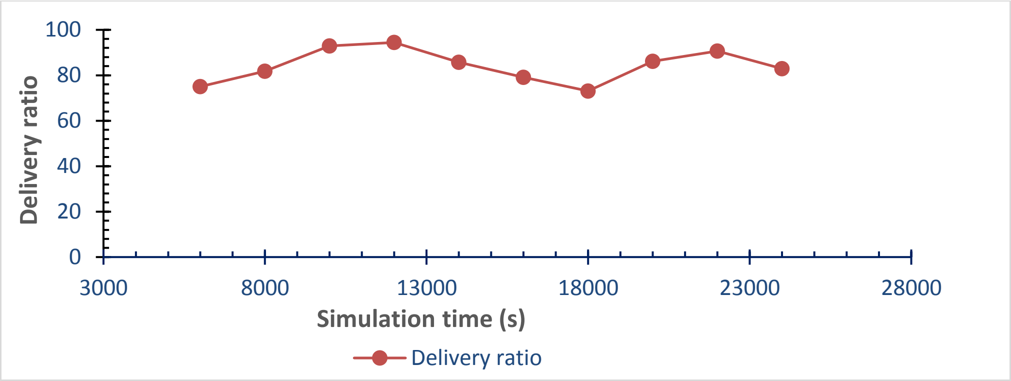


Figure 5.7 Simulation time effect on CRIS delivery ratio

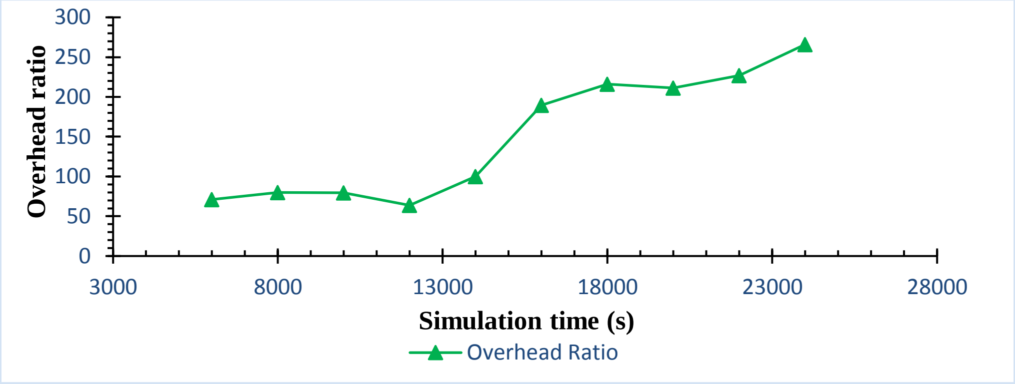


Figure 5.8 Simulation time effect on CRIS overhead ratio

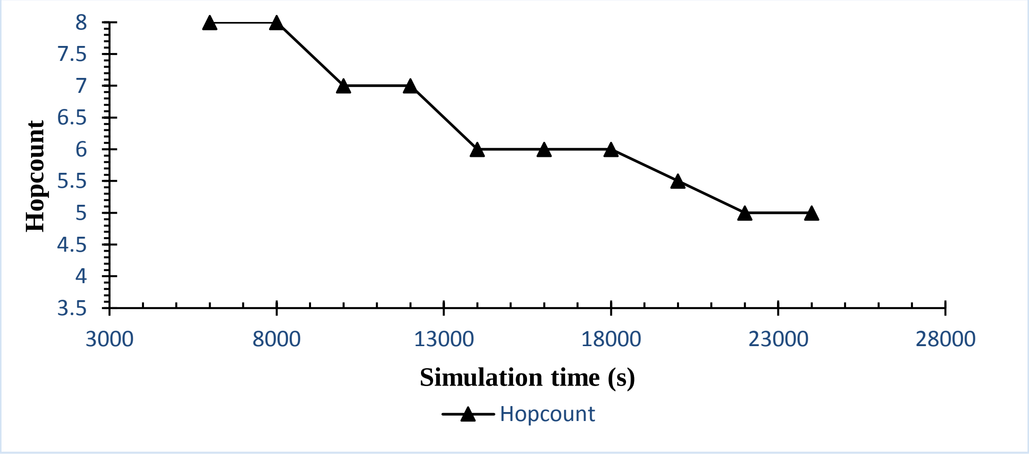


Figure 5.9 Simulation time effect on CRIS hop count

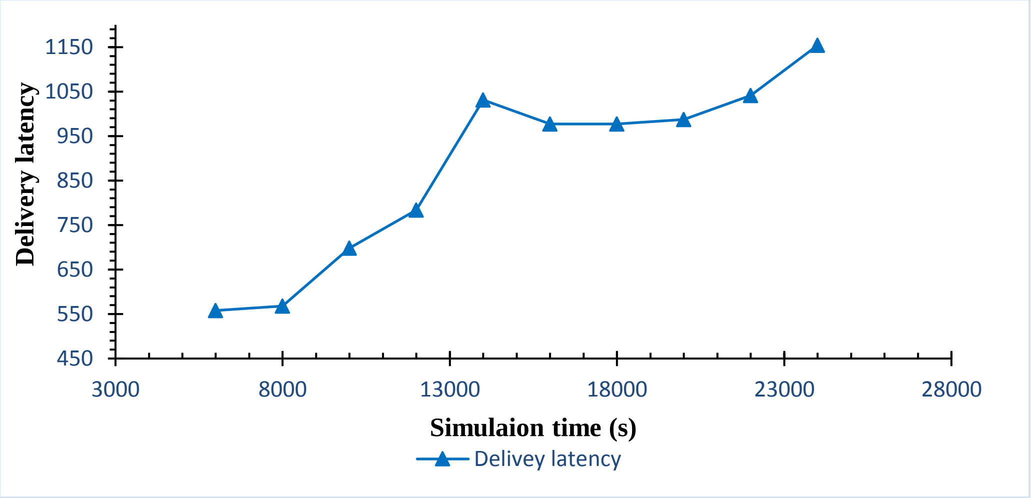


Figure 5.10 Simulation time effect on CRIS delivery latency

5.8.3 Why these factor affect the expermental evaluation CRIS

In general as decreasing message generation time interval the message created in the network is increase which leads increasing of overhead ratio and delivery delay while decrease delivery ratio and hopcount of message. The reason behind this why these factor affect performance evaluation of CRIS incentive scheme is the way how the forwarding algorithm (Spray and Wait) is performed. Because of Spray and Wait routing algorithm follows **sprays** a number of copies into the network and **waits** till one of the nodes meets the destination that hold message. In **spray** phase source node forward the packet to different node. If destination is found then the message or packet transfer is successfully terminated. If not then **wait** phase is started. Of course it is not the part of this study to decide way of forwarding activity of this routing algorithm. However, way of its forwarding activity has an impact on the evaluation of proposed incentive scheme CRIS in terms of those performance evaluation metrics. Therefore, we conclude that factors that affect the performance of our proposed scheme such as simulation end time and message generation frequency is because of spray and wait routing algorithm. Even if these facters have an impact till the CRIS outperforms Sray and Wait routing algorithm in terms of delivery ratio, hopcount and delivery delay, while spary and wait(Non_incentive scheme) outperforms in terms of overhead ratio as reveals in Figure 5.11 to 5.14. Of course in terms of delivery delay CRIS has marginal to non_incentive scheme while CRIS outperforms both scheme in terms of delivery ratio while CRIS, better in terms of hopcount metrics than both non_incentive and selfishness based routing scheme.

5.9 Performance Comparison

5.9.1 Comparison of the result of this study

In this part, we compare the proposed incentive scheme, CRIS, with INFOCOM2006 using ONE simulator tool and it outperforms other two non-incentive routing and selfish routing schemes in terms of delivery ratio, hopcount and delivery latency. This is due to the fact that in CRIS scheme, nodes are cooperate to each other when nodes start to run this scheme and tackle selfishness behavior of nodes in the network. By simulating three of these mechanisms with different simulation end time and different message generation frequency interval our proposed scheme has better performance with those performance evaluation metrics discussed beforehand. For instance, in the Table 5.2, reveal that the performance of the three mechanisms in terms delivery ratio, overhead ratio, hopcount and delivery delay. In the Table 5.2 the delivery ratio of CRIS incentive scheme is better than both Non_Incentive and Selfish_Routing scheme which achieved 94% of delivery ratio at the 3rd simulation hour. In this table delivery ratio of non-selfish routing scheme is 71% whereas 50 % for selfishness routing mechanism. This result show that the delivery ratio of proposed scheme CRIS is 23% and 44% higher than non-incentive and selfishness routing mechanisms respectively at optimal message generation time intervals and simulation end time. Similarly, CRIS is better scheme in terms of all metrics with different simulation end time ven if the delivery ratio for all mechanism decrease while increasing simulation end time, CRIS achieved better performances than these mechanisms at different end time. For instances, for different simulation end time, the overhead ratio of non-incentive scheme at 6000, 8000, 10000, 12000, 14000, 16000, 18000, 20000, 22000 and 24000 simulation end time respectively have less overhead ratio than both mechanisms. However, in selfishness routing scheme the overhead ratio is higher than non-incentive routing which but less overhead than CRIS. In contrast, the proposed incenitive scheme, CRIS, exhibits a little bit higher overhead ratio than both mechanisms. In addition to delivery and overhead ratio also we compared the proposed scheme in terms of hopcount metrics. Consequently, at 6000, 8000, 10000, 12000, 14000, 16000, 18000, 20000, 22000 and 24000 simulation end time the hopcount of CRIS is higher than both mechanisms while non_incentive and selfishness routing mechanisms have marginal hopcount. In the case of non-incentive scheme hopcounts are 133, 1.25, 1.20, 1.17, 1.15, 1.14, 1.31, 1.32 and 1.58 at 6000, 8000, 10000, 12000, 14000, 16000, 18000, 20000, 22000 and 24000 simulation time respectively. Also in the case of selfishness routing mechanism the hopcounts are 1.50, 1.57, 1.57, 1.56, 1.72, 1.62, 1.64, 1.76, 1.69, and 1.69 at 6000, 8000, 10000, 12000, 14000, 16000, 18000, 20000, 22000 and 24000 simulation end time respectively which is marginal hopcount to non-incentive routing scheme. On the other hand, CRIS outperforms other two mechanisms in terms of hopcount which indicates that message able to reach at destination through many relay nodes. More detail, the hopcount of CRIS scheme at 6000, 8000, 10000, 12000, 14000, 16000, 18000, 20000, 22000 and 24000 simulation end time respectively are 8, 8, 7, 7, 6, 6, 6, 4, and 4. This increasing of hopcount of messages shows the cooperation capability of nodes in the network. Even though delivery delay of messages tolerates than other metrics in opportunistic networks, selfish_routing mechanism is higher than non_incentive routing mechanisms while less delay than CRIS scheme. However, CRIS outperforms selfishness based routing mechanism in terms of delivery delay at 4rd hour (14000 seconds) of simulation end time. For instance, in Figure 5.11 after the 4th hour of simulation end time the delivery latency of CRIS is increase with increasing simulation time. In addition to the result reveals in the Table 5.2, the performance evaluation of the three mechanisms explored with Figures 5.11-5.14. As in the Figure 5.11 depicts, CRIS achieved better delivery ratio than both mechanisms. Figure 5.12 is presented that the overhead ratio of selfishness based routing is higher than both mechanisms. But non_incentive scheme resulted less overead ratio than both schemes. Also Figure 5.13 and 5.14 indicate the performance of all mechanisms in terms of hopcount and delivery latency respectively. Thus, message able to travers higher number of hops to arrive its destination in CRIS. But in terms of hopcount selfishness routing is marginal to non_incentive scheme. On the other hand the deliver delay of message in CRIS scheme is lower than selfishness based routing before the 4th hour of simulation end time while higher after 4th hour of simulation end time. Non-incentive based routing is lower delivery latency of message to arrive its destination than both schemes. At the end we take 10 different result that achieved at 10 different simulation end time for those three routing scheme to compare their performances in terms of evaluation metrics. As result, the average delivery ratio for non_incentive scheme, selfishness routing and CRIS scheme are 70%, 53% and 84% respectively. On the other hand, in terms of average overhead for these scheme are 10.1, 886, 151 for non_incentive scheme, selfishness routing and CRIS scheme respectively. Similarly, in terms of average hopcount 1.28, 1.6 and 6 for non_incentive scheme, selfishness routing and CRIS scheme respectively. And in terms of average delivery latency 581, 641 and 761 seconds are for non_incentive scheme, selfishness routing and CRIS scheme respectively.

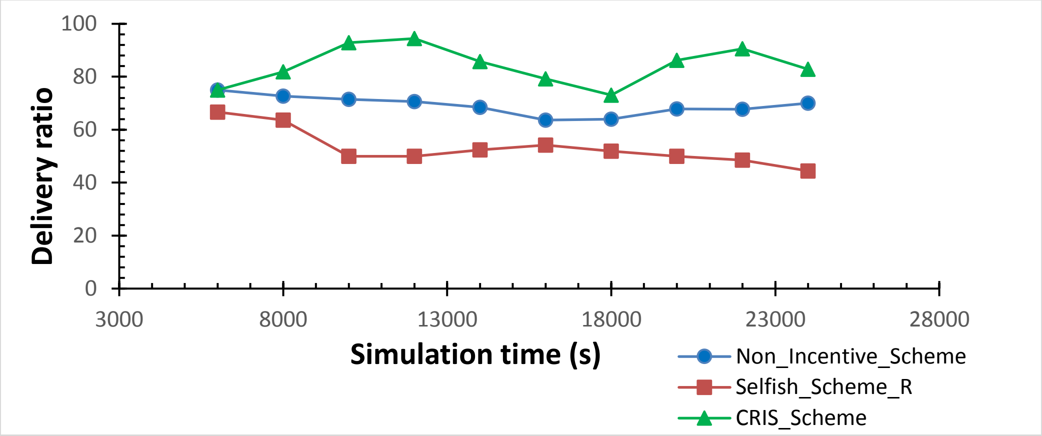


Figure 5.11 Comparison the three mechanisms in terms of delivery ratio.

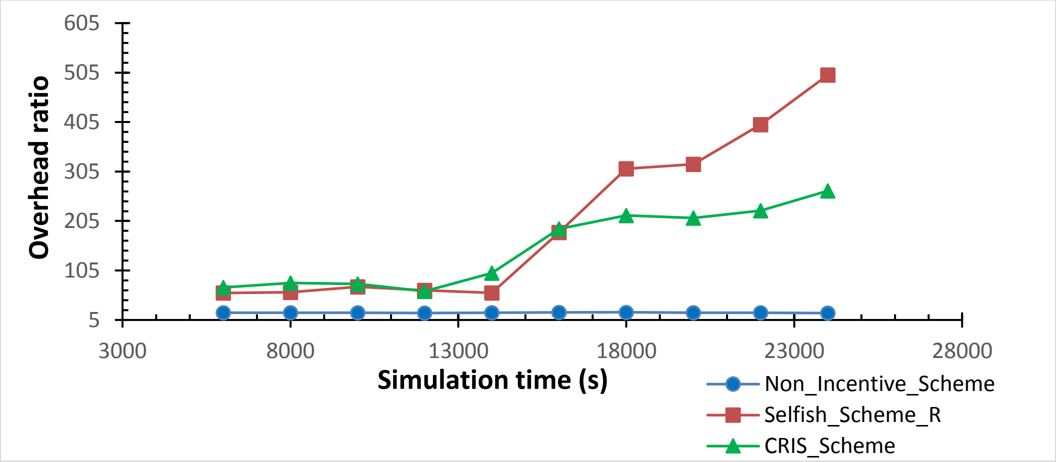


Figure 5.12 Comparison the three mechanisms in terms of overhead ratio

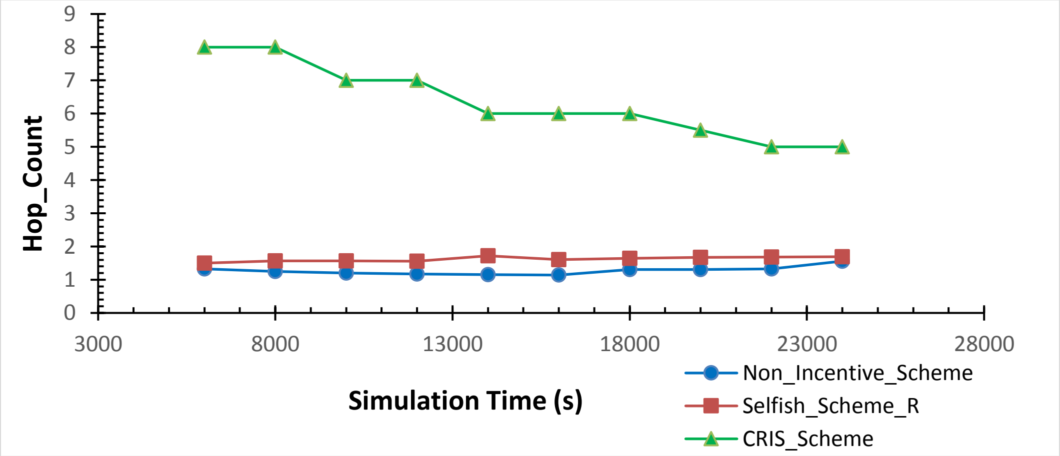


Figure 5.13 Comparison the three mechanisms in terms of hopcount

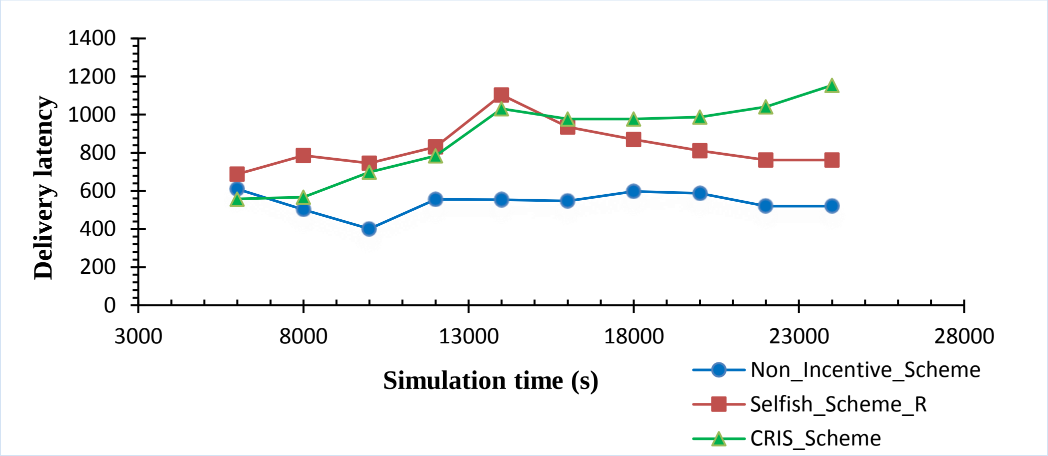


Figure 5.14 Comparison the three mechanisms in terms of delivery latency

Generally, CRIS scheme outperforms both scheme in terms of average delivery ratio and average hopcount while non_incentive scheme outperforms both schemes in terms of average overhead ratio and delivery delay. This indicate that selfishness behavior of nodes affect the performance of the network in terms of delivery ratio, overhead ratio, hopcount and delivery delay. And the proposed scheme, CRIS incentivize those selfish nodes and improve network performance in terms of delivery rati, overhead ratio and hopcount.

CHAPTER 6

CONCLUSION AND FUTURE WORK

6.1 Conclusion

This study set out to investigate the CRIS scheme to tackle selfishness behavior of node to improve network performances in data forwarding. In this final chapter, we reviewed that the research contributions of this work, as well as discuss the directions for future research.

- In this study first we use advantage of social community as social properties to group nodes according to their interest for better understanding of social selfishness behavior of individuals.
- Then after we have presented a community recognition incentive scheme for SANs paradigm, CRIS, that employed tit for tat approach for calling nodes to cooperate and willing in the data forwarding activity for improving network performances.
- CRIS ables to make nodes to forward data for node of outside its community and accumulate recognition value which helps to get forwarding service from node of its outside community. When nodes' recognition value decrease or increase to make balance service gains and provides to other respectively. This means when nodes gain forwarding services from nodes outside its community its recognition value decrease and make balance recognition to nodes give services.
- On the other hand, when it provides forwarding services for nodes outside its community it gains recognition from that community and its recognition value increases. The simulation results demonstrate that CRIS not only stimulates selfish nodes to cooperate in data delivery for other nodes effectively but also improves the forwarding performance considerably in terms of performance evaluation metrics such data delivery. Overhead ratio, latency and hop count.

➢ **Delivery ratio:** the result of this study evaluation in terms of delivery ratio, 94% of total message created is delivered successfully to its respective destination at optimal message genenarion time intervals. This means, for instance, from total of 80 messages generated in the network during simulation time interval, 75.2 messages are delivered to destination successfully. With this metric CRIS has better delivery ratio than both mechanisms at optimal message generation time intevals and and simulation end time. Even though above and below this optimal simulation end time.

- **Overhead ratio:** we evaluate the three routing mechanism in terms of overhead ratio and compare them then both non-incentive routing and selfish based routing mechanisms reveals higher than CRIS. Numerically CRIS resulted less overhead ratio than than selfishness routing mechanism which is 63 while 65 for selfishness routing mechanism. However, non-incentive routing is less overhead ratio than both schemes.
- **Latency:** again the delivery delay of CRIS scheme is marginal with selfishness routing while non incentive scheme routing mechanism is less delivery latency than both schemes. The result show that the delivery delay of selfish routing mechanism is higher than non-incentive routing mechanisms whereas non-incentive's delivery delay is less than selfishness and CRIS scheme. Of course latency of message acceptable result for different application of delay tolerance opportunistic networks.
- **Hop count:** as message travers through in the network to arrive its destination is high depict that the cooperation among nodes is high and there is better delivery probability of message to destination. As result, CRIS has more number of hop counts than both mechanisms. Evidently, CRIS scheme has resulted the average hopcount of 6.1 which is higher result than non-incentive (1.28) and selfishness routing mechanisms (1.62).

Generally in this paper, we discuss CRIS incentive scheme scenario and concentrate on the relationships between two contact nodes both itra-community and inter-community contact. As the result, the evaluation reveals that CRIS proposed scheme makes node cooperate and performs better network performance than both mechanisms with higher delivery ratio, less overhead ratio, short delivery latency and more hopcount.

6.2 Future work

However, some social selfish nodes may exhibit and act maliciously with intention to disturb the function of the networks and it might drop packets. Therefore, it needs again further investigation which is security issue in future. Also for this study selfishness behavior of node we considered is about buffer space constraints. But nodes also exhibit selfishness behavior because of energy constraints, so in future it needs further study on the area. In addition to this, in the future, we recommended to continue to examine the efficiency of CRIS in data dissemination scenario.

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APPENDIX: Configuration Settings Scenarios

Appendix I: Non_Incentive Scheme scenario

```
Scenario.name = Non_Incentive_Scenario
Scenario.simulateConnections = true
Scenario.updateInterval = 0.1
NonIncentiveRouter.binaryMode = true
Scenario.updateInterval = 0.1
Scenario.nrofHostCommunity = 1
Community.CommunityID = NodeC1_
Community.router = NonIncentiveRouter
NonIncentiveRouter.nrofCopies = 10
NonIncentiveRouter.timeInterval =8
Report.warmup = 500
Community.msgTtl = 5000
Community.waitTime = 100,200
Community.nrofInterfaces = 1
btInterface.type= SimpleBroadcastInterface
Community.interface1 = btInterface
btInterface.transmitSpeed = 250k
btInterface.transmitRange = 60
Community.nodeLocation = 744, 135
Community.bufferSize = 10M
Community.transmitRange = 10
MovementModel.worldSize = 10000, 8000
Report.nrofReports = 1
Report.reportDir =      Non_Incentive_Report/
Report.report1 = MessageStatsReport
Community.nrofHosts = 98
#Scenario.endTime =  6000
#Scenario.endTime =  8000
#Scenario.endTime =  10000
#Scenario.endTime =  12000
#Scenario.endTime =  14000
#Scenario.endTime =  16000
#Scenario.endTime =  18000
Scenario.endTime =  20000
#Scenario.endTime =  22000
#Scenario.endTime =  24000
Community.movementModel = ExternalMovement
Events.nrof = 2
Events1.class = ExternalEventsQueue
Events1.filePath = RealDataset/infocom6.csv
ExternalMovement.file = RealDataset/infocom2006.txt
Events2.class =  MessageEventGenerator
Events2.size = 500k,1M
```

```
### Message generation time intervals #####
Events2.interval= 600,800
#Events2.interval= 600,700
#Events2.interval= 700,800
#Events2.interval= 800,1000
Events2.hosts = 0,97
Events2.prefix = Non_In_Message_
```

Appendix II: selfishness behavior routing mechanism scenario

```
Scenario.name = Selfishness_Routing_scenario
Scenario.simulateConnections = true
Scenario.updateInterval = 0.1
Scenario.nrofHostCommunity = 1
####### SelfishnessRouter settings ##########
SelfishnessRouter.binaryMode = true
Community.CommunityID = Node_
Community.router = SelfishnessRouter
SelfishnessRouter.nrofCopies = 10
SelfishnessRouter.timeInterval =8
Report.warmup = 500
Community.msgTtl = 5000
Community.waitTime = 100,200
Community.nrofInterfaces = 1
btInterface.type= SimpleBroadcastInterface
Community.interface1 = btInterface
btInterface.transmitSpeed = 250k
#####Range of transmission (in meter) #############
btInterface.transmitRange = 10
Community.nodeLocation = 744, 135
Community.bufferSize = 10M
Community.transmitRange = 10
# World's size for Movement Models without implicit size (width, height; meters)
#MovementModel.worldSize = 500, 200
MovementModel.worldSize = 10000, 8000
#### How many reports to load ########################
Report.nrofReports = 1
Report.reportDir = SelfishReport/
Report.report1 = MessageStatsReport
Community.nrofHosts = 98
##Different Simulation end times ########
#Scenario.endTime =  6000
#Scenario.endTime =  8000
#Scenario.endTime =  10000
#Scenario.endTime =  12000
#Scenario.endTime =  14000
#Scenario.endTime =  16000
```

```
#Scenario.endTime =  18000
Scenario.endTime =  20000
#Scenario.endTime =  22000
#Scenario.endTime =  24000

Community.movementModel = ExternalMovement
Events.nrof = 2
#Events1.class = StandardEventsReader
Events1.class = ExternalEventsQueue
Events1.filePath = RealDataset/infocom6.csv
ExternalMovement.file = RealDataset/infocom2006.txt
Events2.class =  MessageEventGenerator
Events2.size = 500k,1M
### Message generation time intervals #####
#Events2.interval= 600,700
Events2.interval= 600,800
#Events2.interval= 700,800
#Events2.interval= 800,1000
Events2.hosts = 0,97
Events2.prefix = Selfish_Message_
```

Appendix III: CRIS incentive scheme routing mechanism scenario

```
Scenario.name = CRIS_INCENTIVE_SCHEME Evaluation With BUFFER_SIZE 10M
Scenario.simulateConnections = true
Scenario.updateInterval = 0.1
## CRIS routers settings #################
CRISRouter.threshold = 2
CRISRouter.alpha = 2
CRISRouter.beta = 2
Community.router = CRISRouter
CRISRouter.nrofCopies = 10
CRISRouter.binaryMode = true
Community.CommunityID = CRIS_Node_ID =
######### Community ID ######################
Scenario.nrofHostCommunity = 1
Community.nrofInterfaces = 1
btInterface.type= SimpleBroadcastInterface
Community.interface1 = btInterface
btInterface.transmitSpeed = 250k
#### Range of transmission (in meter)########
btInterface.transmitRange = 60
Community.nodeLocation = 744, 135
Community.bufferSize = 10M
Community.transmitRange = 10
ExternalEvents.nrofPreload = 500
# World's size for Movement Models without implicit size (width, height; meters)
```

```
MovementModel.worldSize = 1000, 800
Report.nrofReports = 1
Report.reportDir = CRIS_Evaluation_Report/
Report.report1 = MessageStatsReport
Events.nrof = 2
Community.nrofHosts = 98
Community.movementModel = ExternalMovement
Report.warmup = 500
Community.msgTtl = 5000
Community.waitTime = 100,200
#Scenario.endTime =  6000
#Scenario.endTime =  8000
#Scenario.endTime =  10000
#Scenario.endTime =  12000
#Scenario.endTime =  14000
#Scenario.endTime =  16000
#Scenario.endTime =  18000
Scenario.endTime =  20000
#Scenario.endTime =  22000
#Scenario.endTime =  24000
Events1.class = ExternalEventsQueue
Events1.filePath = RealDataset/infocom6.csv
ExternalMovement.file = RealDataset/infocom2006.txt
Events2.class =  MessageEventGenerator
Events2.size = 500k,1M
#Events2.interval= 600,700
Events2.interval= 600,800
#Events2.interval= 700,800
#Events2.interval= 800,1000
Events2.hosts = 0,97
Events2.prefix = CRISR_Message_
```