

## **A Minimum Residual Energy Model On Social Network Using Source Instigate Multi-Cast Assembly**

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### **ABSTRACT**

Multi-cast is an inter network service that offers efficient data delivery from a source to multiple destinations. Recent work in multi-casting on social networking has concentrated on packet delivery ratio to increase the rate of throughput. However, the mean bandwidth under different networks and the rate of energy consumption varies according to different destination points. Increasing the quality of video and decreasing the consumption of energy though applied Polynomial Time Approximation (PTA) algorithm failed to limit the energy usage on mobile subscribers. In this paper, we investigate the operation of limiting the energy usage on multi-casting the packets from the source to destination, called as Source Instigate Multi-cast Assembly (SIMA) mechanism. SIMA in social network multi-cast group of packets from the source (i.e.,) single point to more than one destination node. In order to reduce the energy consumption in SIMA, the set of nodes that support a multi-cast session uses a multi-cast tree. SIMA is designed on the social network to operate under the minimal transmission energy as well as on higher bandwidth rate. We also study the problem of reducing the delay time by designing maintenance of an assembly that efficiently forwards the packets to each participating node in the social network. For this problem, the assembly maintenance minimizes the delay time on multi-casting using the multi-cast tree in SIMA mechanism. Furthermore, the SIMA mechanism provides high multi-cast efficiency with prolonged network lifetime on the social networking. We conduct experiments using the NS2 simulator that accounts for energy expenditure, bandwidth rate and multi-cast transmission efficiency. The results demonstrate that SIMA mechanism provides better packet delivery ratio for different nodes under different network range and provides better multi-cast transmission efficiency for different number of users in social network.

**Keywords:** Social networking, Multi-casting, Source Instigate Multi-cast Assembly, Transmission Energy, Bandwidth Rate.

## 1. INTRODUCTION

With the massive growth of the Social Network, we have been provided with an outpouring of information, and hence multi-casting have become one of the most significant methods for broadcasting desired information from a source node to multiple destination nodes. The method based on multi-casting has been the most popular method in the Social Network as it limits the energy usage and improves the packet delivery ratio.

Wireless mesh networks (WMNs) has substantially grown as a significant methodology that provides low-cost high-bandwidth services. Recent research works concentrated on multi-cast routing for WMN measures the quality of link in order to increase the level of throughput. In Measurement-based Attack Detection and Accusation-based Reaction (MAD-AR) [1], certain types of novel attacks were identified with respect to throughput multi-cast protocols in WMN that used both the measure of local variables and the aggregation of global values and proved to be efficient against multi-cast protocols. Though high-throughput was provided, the mean bandwidth for varied types of networks and the energy consumption varied largely on the basis of several destination points.

With the increasing use of mobile multimedia streams, information delivery across large scale users has been a promising trend. In Sub-stream Selection Algorithm (SSA) [2], concentric focus was made on increasing the quality of video and reduces the energy consumption for mobile receivers. SSA was introduced to solve the sub-stream selection problem in order to enhance the quality of video using the algorithm, polynomial time approximation. However, it failed to limit the energy usage on mobile subscribers. Distributed MAC protocols with multi packet reception capability were introduced in [14] that resulted in the increased level of throughput.

One of the main advantages of using route discovery methodology is to identify the path to the destination node whereas using a route maintenance methodology a mobile node detects the changes in network topology. Both route discovery and maintenance highly relies on radio wave propagation. In [3], on demand ad hoc routing protocols were performed to analyze the results of mobility and fading. However, the disadvantage of this method was that it was less stable and unreliable links were not avoided.

Social Selfishness Aware Routing (SSAR) algorithm [4] was designed to provide mechanisms to user selfishness and ensure best routing performance using mathematical modeling. Though low transmission cost was also ensured, but at the cost of time. A distributed algorithm was introduced in [15] to increase the minimum residual energy of all the nodes present in the network during each multi-cast. In this model, transient type of multi-cast tree was used without the knowledge of global information to increase the minimum residual energy.

Mobile users carry highly significant mobile devices that include increasing processing capacity and memory for different sensors. SCAMPI (Service platform for

social-aware mobile and pervasive computing) [7] was structured to ensure the execution and processing of tasks in a distributed manner for opportunistic pervasive networks. SCAMPI provided opportunistic interaction between different types of sensors and the efficient types of resources that were embedded in local environment to provide flexibility. However, cooperation for complex ecosystems was unsolved.

Context- and social-aware middleware [8] studied the integrated context and social information in social network, in order to efficiently forecast the movement of the users or the nodes. The middleware and content sharing was combined for measuring the networks of opportunistic in nature. Though the model predicted the user movements in an efficient manner, but the resources used increased with the number of users in social network.

To summarize, the contributions of Source Instigate Multi-cast Assembly (SIMA) mechanism includes the following (i) to reduce the energy consumption using multi-cast tree that support a multi-cast session (ii) facilitating assembly maintenance in social network by efficiently forwarding the packets to each participating node and finally (iii) to limit the energy consumption and increase the packet delivery ratio in social network using SIMA probing model.

The structure of this paper is as follows. In Section 1, multi-casting in social network and other types of network is discussed. In Section 2, an eye view of increasing throughput with different types of existing work with their restrictions is presented. Section 3 describes in detail about the design considerations involved in Source Instigate Multi-cast Assembly (SIMA) mechanism with neat architecture and algorithm design. Section 4 and 5 elaborates the experimental settings datasets are outlined and provided analysis of results. Section 6 finally concludes with the concluding remark.

## **2. RELATED WORKS**

The fast and the ever increasing use of the Internet has made the research scholars to immediately shift their observation from conventional centralized types of network to the most non cooperative form of structures. The influence of graphs introduced in the social knowledge on the price of disorder and stability on multi-cast environment was introduced in [5] to improve the computational cost using Nash equilibrium theory. Though proved to be efficient in terms of cost, but high involvement of user decision deteriorated the model.

One of the most important services to be provided during multi-cast communication is ensuring QoS. A multi-cast routing algorithm was introduced in [6] that were based on the heuristic model to increase the bandwidth rate. The advantage of using the multi-cast routing algorithm was that it applied discrete particle swarm optimization for efficient searching using multi-cast tree. Though efficiency was improved but at the cost of time.

Home-cell Community-based Mobility Model (HCMM) [9], integrated users sociality including spatial properties under several user movement patterns to improve the rate of inter-contact time distribution. However, with the increase in the nodes and their mobile behavior, mobility and time distribution drastically increased. In order to

address this issue, HiBop [10], the behavior and pattern of the user was analyzed. In addition HiBop also evaluated the social relationships between the nodes to identify the mobile behavior even when mobility changed by using this knowledge for packet forwarding. Though scalability was addressed using packet forwarding, the two most important parameters, security and privacy were not taken into consideration.

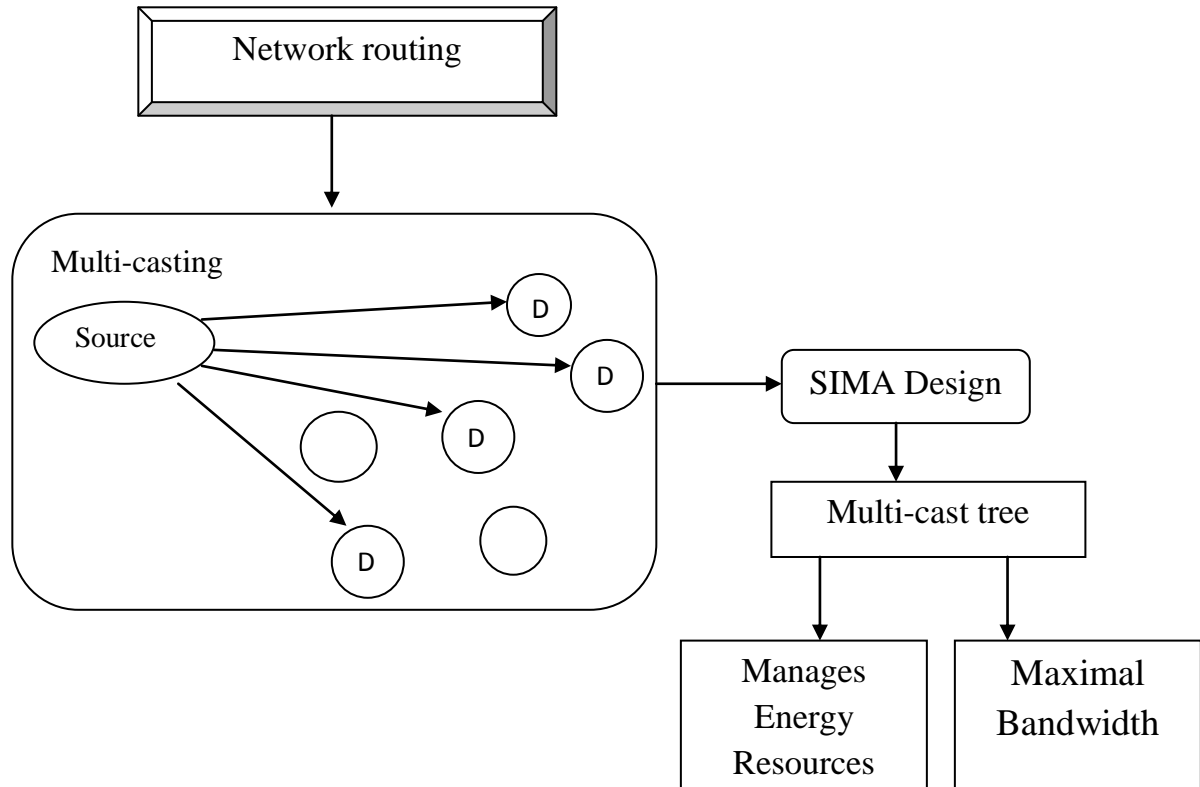
The fascinating use of Online Social Networks (OSN) has increased the process of communication to larger extent that is of significant use of studying the behavioral patterns of user. In [11], online social relationships were governed and maintained dynamically that highly reflected the user behavior pattern. Though dynamism was observed, the reflection of human behavior on the society was remains unaddressed.

Ego-net digger [12], a novel Facebook application was used for gathering the social data of the users' and also gave a clear picture of user behavior using Dunbar's circles model. Though user behavior pattern was analyzed, the application was limited only towards Facebook. Realistic jump sizes were included in [13] where the communication gets established with the devices in hand (i.e., with the users) and with the other devices in the receiving end. The traveling behavior of users was also analyzed using social-based mobility pattern.

Based on the aforementioned techniques, development of source instigate multi-cast assembly on social network is provided in the forthcoming section.

### **3. DEVELOPMENT OF SOURCE INSTIGATE MULTI-CAST ASSEMBLY ON SOCIAL NETWORK**

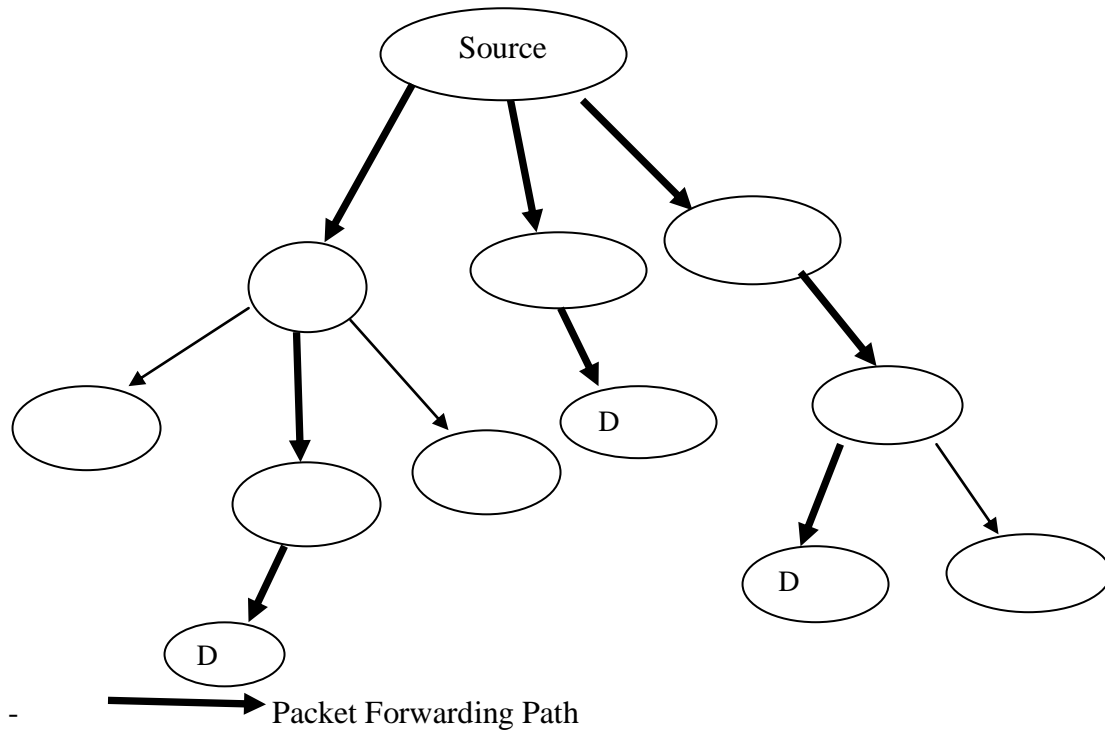
The main objective of SIMA mechanism is to limit the energy usage while performing multi-casting on social network. SIMA exclusively addresses the problem of multi-casting on the traffic network with the application of assembly that efficiently maintains the traffic with limited energy consumption. To start with, the SIMA mechanism predetermines the amount of energy required at each of the network nodes and evaluates the cost paths. The overall architecture diagram of SIMA mechanism is depicted in Figure 1.



**Figure 1 Architecture Diagram of SIMA**

The architecture diagram of SIMA mechanism is illustrated in Figure 1. As illustrated in figure 1, multi-casting refers to the delivery of a message or information to a group of destination computers or nodes in a simultaneous manner during single transmission from the source point. The design considerations of SIMA mechanism is structured in such a way that it includes, source instigate, route switched and multi-cast assembly. The SIMA mechanism is constructed using the multi-cast tree which is constructed to forward the nodes from the sender to the group of transceivers or destination nodes. The advantage of using multi-cast tree in SIMA mechanism is that it helps in building the transmission system with limited energy consumption and maximal bandwidth rate. In addition, the maintenance of an assembly requires a dedicated transceiver at each participating node throughout the duration of the transmission.

Let us consider a network consisting of ‘n’ nodes in social network, which are distributed in an arbitrary manner over a particular section. In SIMA mechanism, a node is transmitted and received simultaneously at different frequencies. In SIMA mechanism, a node is transmitted and received simultaneously at different frequencies. The packets are transmitted through the multi path with different transmit and receive frequencies. As a result, a total of ‘F’ frequencies are available in the social network to perform the multi-cast routing. The multi-cast tree construction is depicted in Figure 2.



**Figure 2 Multi-cast Tree construction in SIMA**

An example for multi-cast tree construction using SIMA mechanism is illustrated in figure 2 that briefly describes the movement of packets from the source to multiple destination points. As a result of these design considerations, an intermediate node in the tree takes different frequency range to transmit the packets. This means that an average of about  $2T$  frequencies is needed for each assembly of the node in the social networking to transmit the packets to different transceivers. The SIMA mechanism works with all the hard constraint on energy to create a drastically diverse networking environment in which even the option of a performance measure becomes unexpectedly very simple. The assembly is active on all the nodes of the social network. As a result, the frequency required to make use of the transceiver resources is easily evaluated at lesser amount of time.

### 3.1 SIMA Probing Model

With the basic assumptions that the connectivity of the network depends on the transmission energy in the social networking, let us assume that each node in social network selects its range of transmission energy to be  $E^{RT}$  (i.e.,  $E^{RT}$  refers to the range of transmission energy) such that  $E_{min} \leq E^{RT} \leq E_{max}$ . The nodes in any multi-cast tree need not use the same transmission energy levels but the node may require different transmission energy level in SIMA mechanism for different form of multi-cast tree.

The received energy level is equal to  $(E^{RT} \cdot d^{-\alpha})$  where 'd', is the distance from a single source to different destination nodes whereas the value of the parameter  $\alpha$

differs according to the communication media in social network (i.e., a node, a mobile device, I pad and so on). Based on the design considerations of SIMA, the transmission energy level required to support a link between two nodes (i.e., source and destination nodes) is separately evaluated by the distance, “d” which is directly proportional to  $d^\alpha$ . The received energy easily identify whether the energy level exceed threshold value or not. Without loss of generalization, set the threshold constant is equal to 1, resulting in,

$E_{ij}^{RT}$  = RT range of transmission required to establish a connection between two nodes i and j.

$$= \max\{d_{ij}^\alpha, E_{\min}\} \tag{1}$$

where  $d_{ij}$  is the distance between Node ‘i’ and Node ‘j’. The maximum allowable transmitter energy  $\max\{\}$  is significantly large, when the social network nodes are fully connected. The use of a numerical value of  $E_{\min}$  is a way to account for the fact that the  $d^\alpha$  confidence applies only in the specific network region. In addition to random waypoint propagation, energy is also required and propagated during broadcast and response which is given as below,

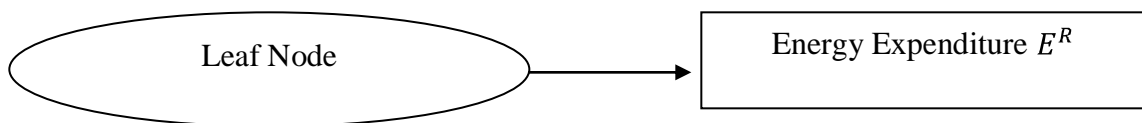
$$E^B = \text{Broadcast processing energy} \tag{2}$$

$$E^R = \text{Response processing energy} \tag{3}$$

The SIMA probing model further assumes that the quantities are the same at all nodes of the social network, and the level of energy consumption during the “idle” state is neglected i.e., whenever there is not transmission between the nodes. The notification of the idle condition is effectively performed using SIMA mechanism. The total energy expenditure required using SIMA probing model between Node i, and Node j, during broadcasting is given as below,

$$E_{i,j} = E_{i,j}^{RT} + E^B + E^R \tag{4}$$

Where,  $E_{i,j}$  is the total energy expenditure which is the summation of range of transmission required to establish a connection between two nodes i and j, the broadcast processing energy and response processing energy. A pointer function is included because during the processing stage, the response processing energy  $E^R$  is not required.



**Figure 3 Total Energy Computation**

The total energy consumption rate using SIMA is depicted through Figure 3. As

illustrated in the figure when a leaf node does not broadcast any nodes but only receive it, then the leaf node has a total energy expenditure of  $E^R$  in SIMA. The design of SIMA proceeds in a way with only limited amount of energy for each node in the social network. Let us consider that if a node 'i' in a social network consisting of any communication media has energy  $R_i(0)$  during the initial instance 0, then the residual energy at Node 'i' during time interval 't' is,

$$R_i(t) = R_i(0) - \int_0^t E_i(\tau) d\tau \quad (5)$$

where  $E_i(\tau)$  is the total energy consumed at Node 'i' at time  $\tau$ . The state of the node whether it is alive or dead is realized using the residual energy. The node in the social network is said to be alive when the residual energy is greater than zero whereas the state of the node is said to be dead when its residual energy decreases to zero. Based on these assumptions in SIMA mechanism, a "dead" node in the social network cannot participate, even as a receiver using multi-cast tree of SIMA mechanism. An important feature of SIMA mechanism is that the energy limitations is avoided using the assemble routing. The assembly routing in SIMA mechanism provide solution to energy limitations by selecting the shortest path to transfer the data packets from the source to multiple destination route.

### 3.2 Multi-cast tree Algorithmic Design

SIMA address the problem of determining an appropriate multi-cast tree for each arriving multi-cast assembly request using algorithm, so that the group of destination nodes are selected in a random manner using SIMA mechanism. The basic constructing of a multi-cast tree using SIMA requires the transmitted energy levels between the source and destination nodes, the distance between the source and destination nodes, and the required resources by the transceiver throughout a session during multi-cast assembly.

#### //Multi-cast Tree Construction

##### Begin

**Input:** Multi-cast Assembly requests arrive to each of the 'n' nodes at rate  $\lambda/n$  arrivals per unit time

**Output:** Destination reached with minimal energy resource usage.

Step 1: Set of preferred destinations is selected arbitrarily for each arrival.

Step 2: Path from the source to support the path which does not exceed  $E_{max}$  at any node

Step 3: Transceiver is obtainable at each node along the path 'l'

Step 4: Appropriate frequency 'F' assignment found to hold up the path link between each node pair in the social network

Step 5: Frequency assignments 'F' must not interfere with, or suffer interference from, ongoing assembly.

##### End

As described above through the algorithmic step, all multi-cast route node requests are expected to reach the destination with one or more route path in social network.

The paths are recognized for all available destinations using SIMA mechanism, regardless of the cost factor. The transmission cost is necessary to check whether the transmitted energy does not exceed  $E_{max}$  at any node in the social network. SIMA mechanism provide longer network lifetime, as several alternative paths are defined to transmit the packet from source to destination. As a result, the SIMA mechanism works until the performance degrades below the acceptable level.

#### 4. EXPERIMENTAL EVALUATION

Source Instigate Multi-cast Assembly (SIMA) mechanism in social networking performs the experimental work in NS2 simulator. SIMA mechanism is implemented using the Dolphin Social Network dataset extracted from UCI network data repository. The UCI Network Data Repository is an effort to facilitate the elaborate study of networks. Dolphin Social Network consists of 62 nodes using undirected edges. The undirected social network with frequent association's points consists of 62 dolphins in a community living off Doubtful Sound, New Zealand. The dolphin network range taken for the experimental work is about 900\*950 m.

The Random Waypoint model is developed to randomly group and move another node location point to correctly deploy the packets to multiple destination nodes. The RWM model shifts to an erratically chosen location to perform the effective transmission using multiple sink nodes. For each simulation, the Dolphin Social Network takes 20 milliseconds and on an average 62 nodes is considered for experimental evaluation. The chosen nodes randomly move with a selected velocity and speed.

The minimum moving speed of the sensor node is about 2.5.0 m/s of each node. The random movement of sensor nodes uses the Ad hoc On-Demand Distance Vector (AODV) Protocol for performing the experimental evaluation. The experiment is conducted on the factors such as energy consumption, packet transmission time, packet delivery ratio and multi-cast transmission efficiency.

The energy consumption  $Energy_{cons}$  using SIMA mechanism refers to the energy consumed over an interval of time between the source and destination nodes which is the ratio of packet delivery ratio  $PDR$  to the sum of energy level used by all the nodes  $Energy_n$  in the social network. The energy consumption is measured in terms of joules (J).

$$Energy_{cons} = \sum_{i=1}^n \frac{PDR}{Energy_n} \quad (6)$$

The Packet transmission time measures the time taken to transmit the packet from one source node to several destination nodes using SIMA mechanism. The packet transmission time  $PTT$  is the ratio of the size of the packet  $Packet_{size}$  to bandwidth rate  $Bandwidth$  with the distance between source and destination nodes  $Distance_{source \text{ and } destination \text{ nodes}}$  to the speed  $speed$  with which it travels between the nodes. The packet transmission time is measured in terms of milliseconds (ms).

$$PTT = \left( \frac{Packet_{size}}{Bandwidth} + \frac{Distance_{source \text{ and } destination \text{ nodes}}}{speed} \right) \quad (7)$$

Packet delivery ratio *PDR* measures the amount of packets delivered which includes both the number of destination nodes *Number of destination nodes* and the time taken to reach the destination *Time taken<sub>destination nodes</sub>*.

$$PDR = (\text{Number of destination nodes} * \text{Time taken}_{\text{destination nodes}}) \quad (8)$$

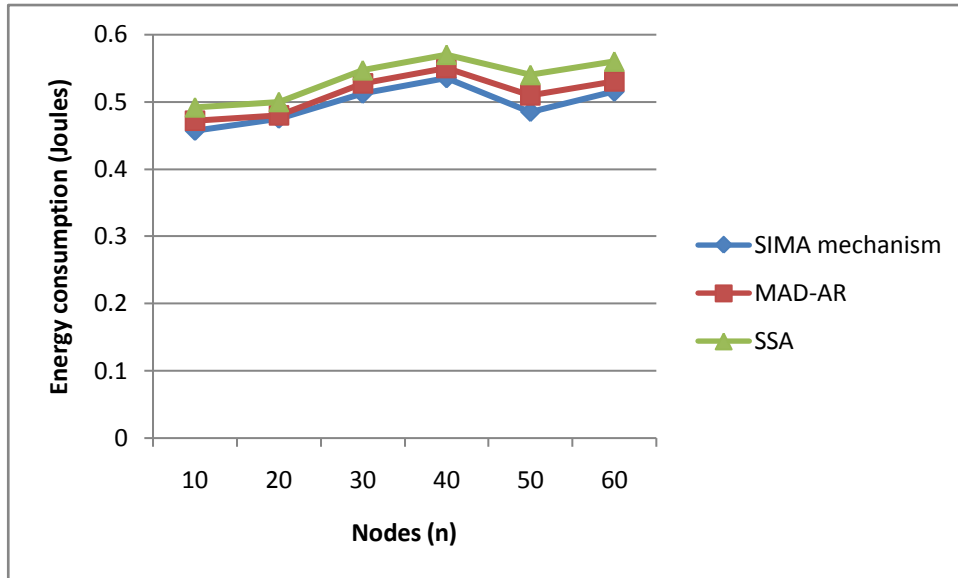
Finally the multi-cast transmission efficiency measures the rate at which the multi-cast transmission is performed using SIMA mechanism. The unit of measurement is percentage (%).

## 5. RESULTS ANALYSIS OF SIMA MECHANISM

The Source Instigate Multi-cast Assembly (SIMA) mechanism in social network is compared against the existing measurement-based attack detection and accusation-based reaction (MAD-AR) [1] and Sub-stream Selection Algorithm (SSA) [2]. Experimental results are analyzed with the help of table and graph representations. Table 1 represents the rate of energy consumption NS2 simulator and comparison is made with two other methods, namely MAD-AR [1] and SSA [2].

**Table 1 Tabulation for energy consumption**

Nodes (n)	Energy consumption (Joules)		
	SIMA mechanism	MAD-AR	SSA
10	0.457	0.472	0.492
20	0.475	0.480	0.500
30	0.512	0.527	0.547
40	0.535	0.550	0.570
50	0.485	0.510	0.540
60	0.515	0.530	0.560



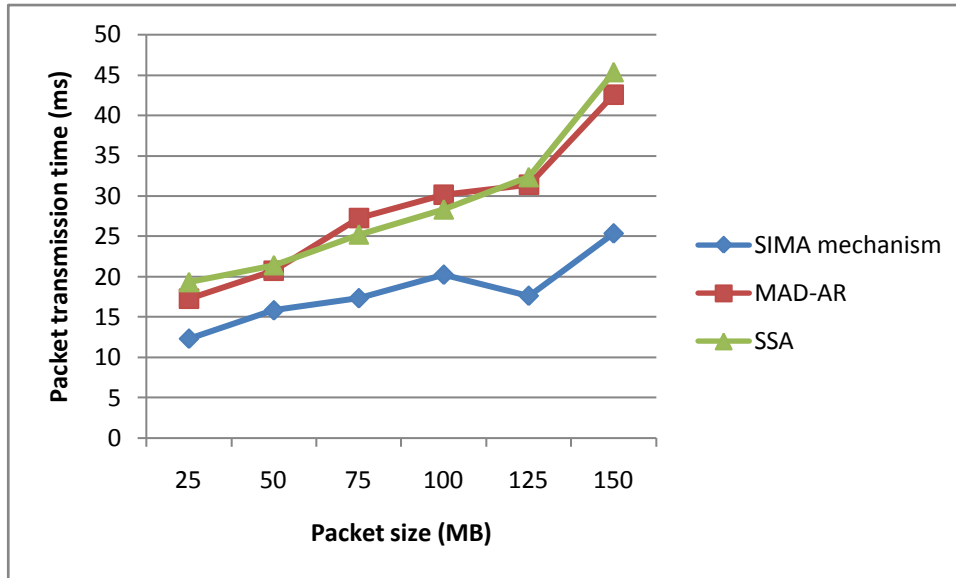
**Figure 4 Measure of energy consumption**

Figure 4 show that the proposed SMIA mechanism provides lower rate of energy consumption when compared to MAD-AR [1] and SSA [2]. This is because of the application of multi-cast tree that efficiently supports a multi-cast session by reducing the energy consumption by 1 – 5 % when compared to MAD-AR [1]. In addition, the idle state whenever the node is in idle condition using SIMA mechanism further reduces the energy consumption by 5 – 11 % when compared to SSA [2].

**Table 2 Tabulation for packet transmission time**

Packet size (MB)	Packet transmission time (ms)		
	SIMA mechanism	MAD-AR	SSA
25	12.35	17.25	19.35
50	15.85	20.75	21.45
75	17.35	27.25	25.25
100	20.25	30.15	28.35
125	17.65	31.35	32.35
150	25.35	42.55	45.35

The comparison of packet transmission time is presented in table 2 with respect to varying packet sizes of ranges 25 – 150 MB. With increase in the sizes of packet, the packet transmission time also gets increased.



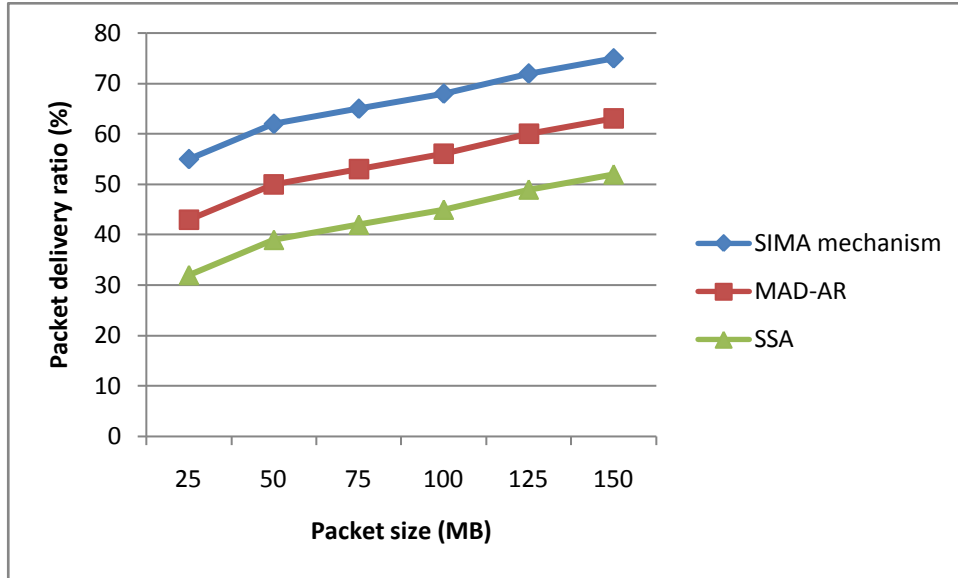
**Figure 5 Measure of packet transmission time**

To evaluate the performance of the packet transmission time, comparison is made with two other existing works measurement-based attack detection and accusation-based reaction (MAD-AR) [1] and Sub-stream Selection Algorithm (SSA) [2]. In figure 5, the size of packet is varied 25 and 150. From the figure it is illustrative that the packet transmission time is reduced using SIMA mechanism when compared to the two other existing works. This is because with the application of assembly maintenance, the SIMA mechanism significantly reduces the packet transmission time by 30 – 77% when compared to MAD-AR [1]. Furthermore, by efficient design of packet forwarding using assembly maintenance to each participating node in the social network, the packet transmission time gets reduced by 35 – 83 % when compared to SSA [2].

**Table 3 Tabulation for packet delivery ratio**

Packet size (MB)	Packet delivery ratio (%)		
	SIMA mechanism	MAD-AR	SSA
25	55	43	32
50	62	50	39
75	65	53	42
100	68	56	45
125	72	60	49
150	75	63	52

The packet delivery ratio for SIMA mechanism is elaborated in table 3. We consider the method with packet size of range 25 MB to 150 MB for experimental purpose using NS simulator.

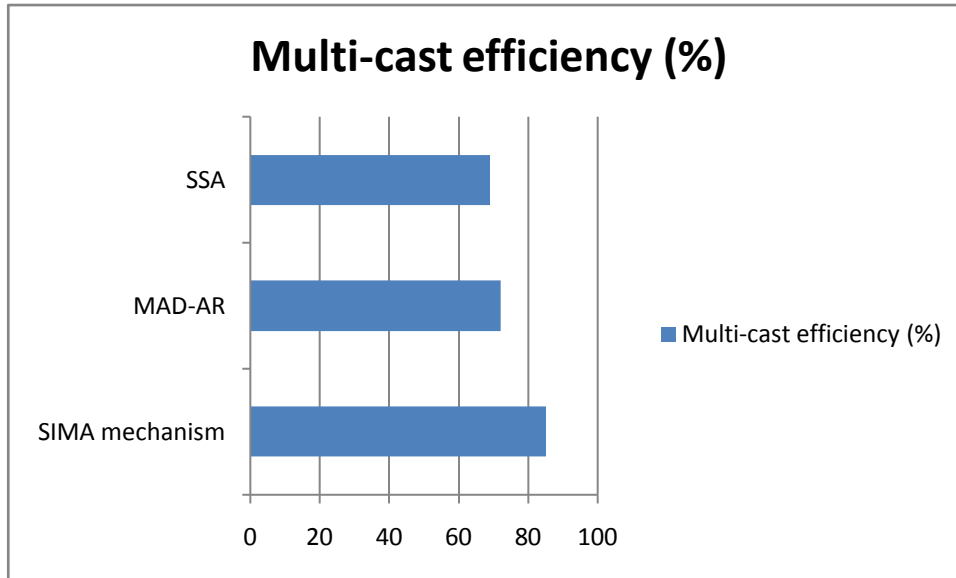


**Figure 6 Measure of packet delivery ratio**

In figure 6, we depict the packet delivery ratio obtained using varied packet sizes of range 25 to 150 for experimental purposes. From the figure, the value of packet delivery ratio achieved using the proposed SIMA mechanism is higher when compared to two other existing works MAD-AR and SSA respectively. Besides we can also observe that by increasing the size of the packets, the packet delivery ratio increases using all the methods. But comparatively, it is higher using SIMA mechanism because the maximum allowable transmitter energy  $\max\{ \}$  is significantly large to efficiently deliver the packets to the destination nodes. With the packets for destined nodes, the packet delivery ratio is improved by 16 – 21 % when compared to MAD-AR [1]. In addition with the application of separate broadcast processing and response processing, results in the increase of packet delivery ratio by 30 – 41 % when compared to SSA [2].

**Table 4 Tabulation for multi-cast efficiency**

Methods	Multi-cast efficiency (%)
SIMA mechanism	85
MAD-AR	72
SSA	69



**Figure 7 Measure of multi-cast efficiency**

Table 4 and Figure 7 illustrate the multi-cast efficiency versus the different methods uses for comparison with the proposed SIMA mechanism. From the figure we can note that the multi-cast efficiency attains 85 % whereas the existing method, MAD-AR and SSA achieves 72 % and 69 % respectively. This is because of the use of residual energy the node can be successfully differentiated as live or dead node. As a result, the dead node cannot event participate as the receiving node in the social network which improves the multi-cast efficiency by 13 % compared to MAD-AR [1] and 18 % when compared to SSA [2].

## 6. CONCLUSION

Multi-casting on social network has become the key for efficient data delivery between nodes to achieve better packet delivery ratio and improve the level of multi-cast efficiency with lesser amount of packet transmission time. In this work, we investigate the performance effects of limiting the energy usage during multi-casting from source to many destination nodes to reduce the energy consumption and propose a mechanism called Source Instigate Multi-cast Assembly (SIMA) mechanism. The SIMA mechanism based on multi-cast tree supporting a multi-cast session in social network reduces the delay time and greatly improves the multi-casting efficiency. First, we study the use of SIMA probing model that uses a separate broadcast processing and response processing energy for improving the packet delivery ratio use the residual energy model and assembly routing for differentiating alive or dead node and effective packet forwarding respectively. Second, we developed a multi-cast tree that efficiently recognizes the path for all available destinations using SIMA mechanism. The experiment conducted using Dolphin Social Network dataset

extracted from UCI network data repository shows that the SIMA mechanism achieves up to 75 percent improvement on packet delivery ratio compared to the state-of-the-art methods.

## REFERENCES

- [1] Jing Dong., Reza Curtmola., and Cristina Nita-Rotaru., “Secure High-Throughput Multi-cast Routing in Wireless Mesh Networks,” *IEEE TRANSACTIONS ON MOBILE COMPUTING*, VOL. 10, NO. 5, MAY 2011
- [2] Somsubhra Sharangi., Ramesh Krishnamurti., and Mohamed Hefeeda., “Energy-Efficient Multi-casting of Scalable Video Streams Over WiMAX Networks,” *IEEE TRANSACTIONS ON MULTIMEDIA*, VOL. 13, NO. 1, FEBRUARY 2011
- [3] L. Nassef,” On the effects of fading and mobility in on-demand routing protocols”, *Egyptian Informatics Journal*, Elsevier, Oct 2010
- [4] Qinghua Li, Wei Gao, Sencun Zhu, Guohong Cao,” A routing protocol for socially selfish delay tolerant networks”, *Ad Hoc Networks*, Elsevier, July 2011
- [5] Vittorio Bilòa, Angelo Fanelli, Michele Flammini, Luca Mosca,” When ignorance helps: Graphical multi-cast cost sharing games”, *Theoretical Computer Science*, Elsevier, Sep 2009
- [6] Rehab F. Abdel-Kader,” Hybrid discrete PSO with GA operators for efficient QoS-multi-cast routing”, *Ain Shams Engineering Journal*, Elsevier, June 2011
- [7] Mikko Pitkänen, Marco Conti, Silvia Giordano,” SCAMPI: Service Platform for Social Aware Mobile and Pervasive Computing”, *ACM*, Aug 2012
- [8] C. Boldrini, M.Conti, F.Delmastro n, A.Passarella,” Context- and social-aware middleware for opportunistic networks”, *Journal of Network and Computer Applications*, Elsevier, Mar 2010
- [9] Chiara Boldrini \*, Andrea Passarella,” HCMM: Modelling spatial and temporal properties of human mobility driven by users’ social relationships”, *Computer Communications*, Elsevier, Jan 2010
- [10] Chiara Boldrini, Marco Conti, Andrea Passarella,” Exploiting users’ social relations to forward data in opportunistic networks: The HiBOp solution”, *Pervasive and Mobile Computing*, Elsevier, Dec 2007
- [11] Valerio Arnaboldi, Marco Conti, Andrea Passarella,” Dynamics of Personal Social Relationships in Online Social Networks: a Study on Twitter”, *ACM*, Oct 2013
- [12] Massimiliano La Gala, Valerio Arnaboldi, Andrea Passarella,” Ego-net Digger: a New Way to Study Ego Networks in Online Social Networks”, *ACM*, Aug 2012
- [13] Chiara Boldrini, Marco Conti, Andrea Passarella, “The Sociable Traveller: Human Travelling Patterns in Social-Based Mobility”, *ACM*, Oct 2009

- [14] Guner D. Celik, Gil Zussman, Wajahat F. Khan, and Eytan Modiano,” MAC for Networks with Multipacket Reception Capability and Spatially Distributed Nodes”,IEEE TRANSACTIONS ON MOBILE COMPUTING, VOL. 9, NO. 2, FEBRUARY 2010
- [15] Pi-Cheng Hsiu, and Tei-Wei Kuo,” A Maximum-Residual Multi-cast Protocol for Large-Scale Mobile Ad Hoc Networks”, IEEE TRANSACTIONS ON MOBILE COMPUTING, VOL. 8, NO. 11, NOVEMBER 2009