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# Optimal Relay Selection In Empowered Cognitive Radio Ad-Hoc Networks

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**Abstract**
Cognitive radio systems are intelligent communication systems that can be established on the fly in difficult terrains. The prime features of the cognitive radio systems are adaptive carrier frequency, adjustable power and effective spectrum utilization. The entire system consists of nodes. The distance between the nodes becomes crucial for the communication process. The selection of relays becomes a bottle neck while the communication needs to be established between distant nodes. In this paper, a new relay selection scheme (NRSS) is implemented by the fuzzy logic for double hop cooperative transmission. With this proposed technique the user can increase the performance of the cooperative node. The requirements which are needed in the relay selection schemes are SNR (signal to noise ratio), cooperative gain and the gain of the channel are some of the parameters observed in fuzzy input for getting the best relay.

**Keywords**: Optimal selection approach, fuzzy logic, SNR ratio, MIMO-CR, Relay selection, NRSS.

## 1. Introduction

A good connection between individual nodes will establish an effective conversation. That conversation may be a wired conversation or wireless conversation. The Ad-Hoc wireless networks [1],[2]are defined as the decentralized form of networks. The Ad-Hoc networks are independent of the relay of the pre-presence framework. Every node is capable of routing in AD-Hoc networks. This routing process is nothing but every node forwards the data and information to the other node. The nodes in the Ad-Hoc networks identify the information dynamically and forward the data. Multi-Hop relaying is the main principle used for the Ad-Hoc networks. With the help of relaying the information is transferred from the source to the destination through the in-between nodes or hops. Mobile- Ad-Hoc networks are defined as the accumulation of two or more gadgets with the help of wireless communication and networking [3]. Without any assistance from the centralized administrator, the Mobile-Ad-Hoc networks are capable of communicating with one other. It is a self-governing system where the mobile moderators are associated through wireless connections and their handouts are vigorous. The mobile hosts even act as a router under some situations.

As the network topology is dynamic, the nodes of the wireless ad hoc network [4] function as a router and as a moderator even. It happens due to the association bounded by the nodes may change with respect to time because of the approach of some new nodes and distraction of some old nodes with respect to time. Because of these efficient characteristics present in the architecture of the Mobile Ad Hoc networks made this technology into existence for present generations, even though it is having some typical challenges. All the devices are subjected to coordinate themselves invigorated and broadcast between one another. The devices administer required network processes during the unavailability of fixed infrastructure. The above all functions should happen between all the devices. This functioning process is known as peer-level Multi Hooping and is mentioned as the main section in an Ad-Hoc network. At last, gives a conclusion as Ad-Hoc network routers are more complicated than other wireless communication networks.

The adorable aim in Ad-Hoc networks is to develop the routing capacity [5] and using the feasible bandwidth adequately. Making the adjacent nodes to make a parallel communication. The user can reach the aim by using the multiple channels in broadcasting as a substitute of a single channel. Exploiting the channel is nothing but exploiting the capacity of the channel when the channel is being used in the wireless communication. The best example of this type of channels is Cognitive radios. The cognitive radio provides the best platform for programmable radio, which is a base in wireless broadcast development.

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The multiple channel transmission approach is done by the MIMO. The space-time coding is a combination of numerous antennas which are present in the sender side with signal processing and coding methods. The MIMO technology [6] gives an efficient output. The other high efficient spectral technology is the spatial multiplexing or BLAST. The old MIMO wireless architecture is applicable to narrowband systems only. The MIMO is a spatial diversity broadband; it is also capable of providing a huge capacity and frequency diversity. With the help of Orthogonal Frequency Division Multiplexing (OFDM), the receiver complexity gets reduced. The efficient solution for upcoming generation broadband wireless systems is MIMO-OFDM.

If the MIMO technology is used along with OFDM, then there will be a high possibility of increasing the network capacity by joining MIMO with CR. Developing a spreading algorithm which simultaneously increases the activity of CR and MIMO. By this spare spectral channels and spatial degree of freedom (DoF) will be gained, and the delay gets reduced. Distinctive channels use distinctive antennas. So by using the MIMO array the spatial gain can be enhanced. The assignment of the transmission channels and the functioning of the antennas count on various factors like network topology, the condition of the physical channel, and their traffic arrangement. When there are fewer channels and if there is a presence of high node density in its neighbor then the MIMO starts functioning for supporting them. The MIMO works efficiently even during the typical channel conditions.

The aim of the proposed system is to architect a relay selection algorithm, which is used for determining the efficient relay nodes between the source and the target. The relay nodes are selected by using some criteria's, they are nodes energy and efficient way from source to destination. The increment in the weighted network throughput is the main aim of the relay selection algorithm. This algorithm also supports various transmission priorities. It reduces the transmission delay and makes sure to give a genuine transmission between the nodes. It gives an equal chance to all the nodes present in the structure. With help of some simulations and results, the user can understand how effectively the algorithm is working.

## 2. Related work

The research on MIMO with CRs for effective wireless communication [7] is happening for many years. This division associates an expanded survey on various wireless multi-channels communication and their lineaments. The single channel transmission nodes systematically follow to the similar channel while transferring in the single channel communication. For the better process in the multichannel transmission networks routers will switch among themselves for better parallel communication. Before going into the process of parallel transmission to begin, all the channels make an agreement and with the help of channel assignment mechanisms, they will coordinate with each other. The four generalized categorizations of multichannel communication are SISO (Single Input Single output), SIMO (Single input multi output), MISO (Multiple input Single Output), and finally MIMO. Among all these MIMO is the highly prioritized multi-channel communication network which is capable of transmitting an efficient data from transmitter to receiver. The assignment scheme where the radio interfaces will not vary the functioning of the channel during the process of transmission is fixed channel assignment scheme. The scheme which is capable of providing a fixed channel either to the sender or the receiver is known as semi-dynamic scheme. In the semi-dynamic scheme, the junctions relay their interfaces to a selected channel for transmission. Here the switching takes place between various recurrences. For the process of delivering the data, the channels communicate with one another dynamically. The transmission of data happens after the selection of a channel. The wireless sensor nodes (WSNs), Ad-Hoc networks, mesh networks etc are mainly experimented in this concept. The related work gives a brief explanation of various multi-channel communications by taking the help of cognitive radio in huge communication networks.

The dynamic channel sensing is supported by a Cognitive radio network. In every node of a cognitive Radio, a single half-duplex transceiver is observed. It helps in any of the two conditions either listening or transmitting, but only in a simultaneous manner. The sensing of the spectrum and assigning the adaptive frequencies for all the channels is the intelligent work done by the cognitive radios. The count of spectral holes can be reduced with it. Some of the important cognitive tasks are (a) Radio sense analysis (b) Channel state identification (c) dynamic spectrum support. The main aim of the cognitive radio is the signal processing and radio technology. The radio technology reconfigures the RF signals and switches to the desired frequency bands. As compared to the old multi-channel multi-radio technologies, it is the most powerful tool where the frequency can be molded easily according to the requirement. The cognitive radios with multi-hop networking are discussed. The collection of frequency bands are assigned for every node in the case of this type of networks. The size of the collection of bands is unequal. Bands can be partitioned into different sub-bands for the effective sharing. It specifies the working of multi-hop cognitive radio network by taking the considerations of multiple layers along with various constraints like scheduling, packets routing and errors. The

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programmer which is there for reducing the spectrum resources of network-wide radio is a mixed-integer non-linear program. A non-linear optimal algorithm is applied for correcting the errors of the MNLP problem.

By taking some network parameters the optimal channel selection is done. For making this process one should know about optimal opportunistic spectrum access (OSA). The characteristics of OSA are discussed here. OSA is observed at the transmitter section. The complete detection of the channel cannot be done by the transmitter. But with its techniques, it smartly determines some characteristics like time and energy. The main focus is to determine about the probing of the channel along with its sequence. The limited number of steps even at unlimited conditions, for computing the optimal strategy is gained from the dynamic program. These strategies are expressed as optimal under many real-life situations. This information is used for knowing the process where less complexity for computation and low space is achieved while doing the wireless communications. Wireless ad hoc networks are capable of providing a better transmission or communication between the two target points. By this the user can connect to huge wireless devices. These huge wireless connections make calculating and resourcing the various gadgets. The emerging technology where the communication needs are increasing more and more is MIMO. The MIMO can't able to handle the weak channels. If the condition of the channel gets degraded, then MIMO gives an efficient diversity transmission support. The MIMO gives a required multiplexing gain. The main target of the MIMO [8] is to develop the wireless technique using relay transmission, where the direct communication is a bit difficult. The relay transmission can be done efficiently in the scheduling scheme, without the involvement of significant signaling. By multiplexed relay transmission the effectively integrated relay transmission is done. The MIMO technical development activates the cellular or the wireless coverage which is impossible with the present proceeding technologies. The present running software for radio communication is innovated by the involvement of VANU Inc. This paper gives a better overview of the requirement of CR in present generation wireless world. The CR is capable of spreading the capacity of the frequency band to a vast extends. It gives a specification about the functioning of CR in the frequency band. How the partitioning of the spectrum is done between the various channels. How the spectrum is being utilized by this channels. This survey handles the functioning design and networking of MIMO.

## 3. Proposed method

In the previous year's different ways of relay selection algorithms came into existence. In the present architecture, multiple interfaces are combined with the Cognitive Radio Ad-hoc networks [9] for better results. The main target is to give an efficient wireless communication. For better results every node is considered as an intelligent node, each intelligent node consists of its unique functionalities. The spatial multiplexing can be achieved from the multiple interfaces. The CR is capable of sensing the channels and determining the white holes in a frequency band. By this, the system's outcome gets increased. The proposed algorithm is injected into the MIMO-CR framework [10]. During this condition, some of the junctions between the source and destination points may act as relay nodes. The relay node transfers the information present in the cellular communication in the form of packets from one junction to the other. But they all consist of some particular specifications. Some of the specifications like node's energy, the timing of the node, requirement or count of the hops from source to destination. For an efficient cooperative communication [11] and steady cooperative frequency, spectrum sensing can be obtained by a jointly optimized relay selection scheme. The computational burden can be reduced with it. One selection algorithm is taken for the functioning of the two tasks in the MIMO-CR networks. The computer simulations make the transmission and sensing performances.

Diagrammatic illustration:

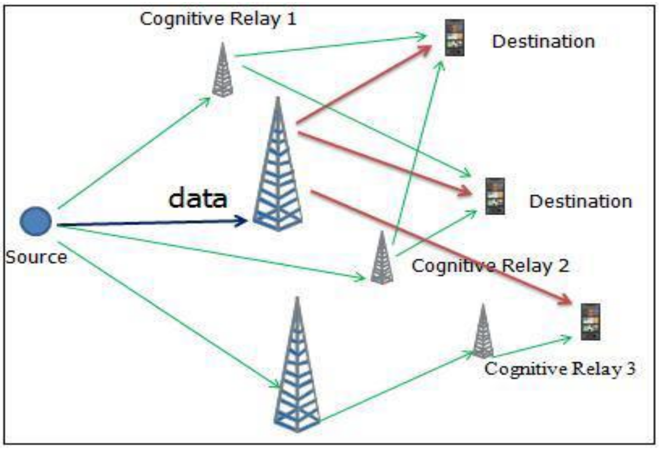

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**Fig1: MI-cognitive radio model**

### 3.1 proposed framework

Every gadget present in the network is taken as an Intelligent MIMO-CR junction [12]. The gadget communication and the sensing of the spectrum in multiple interfaces - Cognitive Radio networks is done by the optimal relay selection scheme. The complete algorithm consists of two steps

I. The best relay junction to be selected for the efficient junction to junction communication.
II. An efficient relay for sensing of the spectrum.

These two tasks are combined and functioned as a single task. The selected relay is worked as a sub- optimal for transmission or sense of the spectrum. The figure1 above explains about the complete multiple interfaces-Cognitive Radio network model [13] along with relay junctions. The performance of the proposed method is proved by the simulation results by taking the considerations like an end to end transmission, sensing of the spectrum and tasks of transmission. Its computational cost is low. It is a highly stable network, less noise.

The method by which the "best relay" for transmission is mentioned as:
If the transmitted signal is amplified and gives a high incoming instantaneous signal-to-noise ratio (SINR), then it is considered as the best relay in the secondary network transmission. The best relay is taken as
$B_{relay}$ = Average (max(SNR(destination signal)))

The spectrum sensing best relay:
The spectrum which is having a huge channel coefficient is considered as the best relay for spectrum sensing.
$B_{relay} = \arg \left[\frac{|hPT-SRi|^2}{\sigma^2 SRi-PD}\right]$
The fading variations in the channel from the transmitter to receiver is considered as $SRi - PD$
The complex Gauss fading coefficient is taken as $hPT - SRi$

### 3.2 flowchart of proposed system

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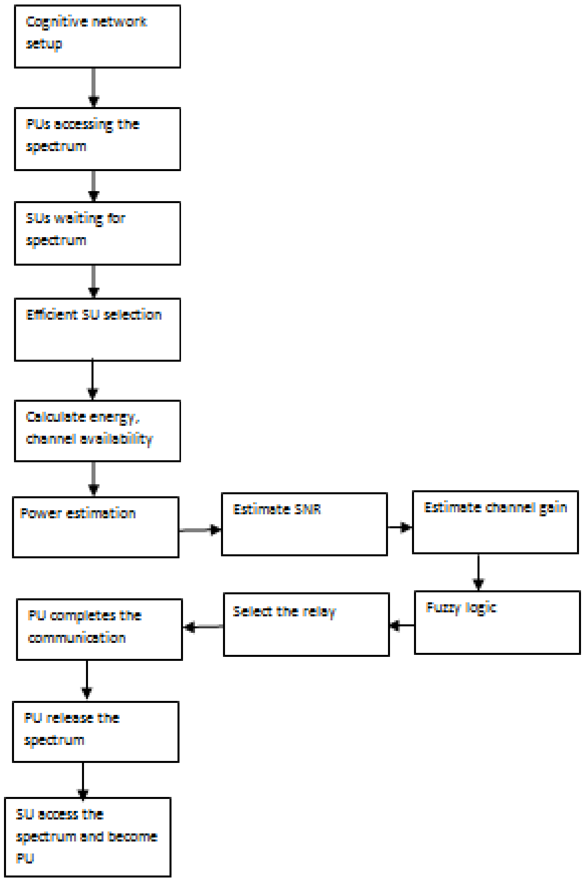


### 3.3 Algorithm:

Step 1: Initiate i=0
Step 2: Increment i by 1
Step 3: Calculate the fuzzy parameters for relay selection.
Step 4: Find out the fuzzy output of each relay
Step 5: If i= final, then jump to step 6, else jump to step 2.
Step 6: Select the relay which satisfies all fuzzy parame-

The new relay selection scheme (NRSS) is implemented by the fuzzy logic for double hop cooperative transmission [14]. With this proposed technique the user can increase the performance of the cooperative node. The requirements which are needed in the relay selection schemes are SNR (signal to noise ratio), cooperative gain and the gain of the channel are some of the parameters observed in fuzzy input for getting the best relay.

In this cooperative communication, it will have a source which transmits the signal to the destination by taking N relays. The model of the network is dual hop [15]. This consideration will not give any occurrence of inter-relay communication. The source point has an idea about the entire channel statics of both the switches used in the loop feedback. For avoiding the interferences two-time slots are considered, one- time slot is taken by the source point during the signal broadcasting, and it is used by destination and the relay simultaneously. The second time slot is used for sending the amplified copy of the received signal through the relay. The source signals multiple copies are received by the destination point and by using the optimal selection approach (OSA) those signals are combined by ignoring the occurrence of the time delay [16] during the process of communication. For an effective solution assume the value of the path loss component as 1. By applying the new relay selection algorithm, an efficient relay from the overall relays is selected for the purpose of cooperation by the destination and feedback transmission transfers the data (the best relay value) to all the relays even for the source point.

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## 4. Result and discussion

With the help of the parameters used in the below tables 1 and 2, the result of the NRSS can be obtained. The optimal channel networking parameters are compared with the present communication approaches. The result gives an analysis of less consumption of energy, minimum delay value, and efficient throughput algorithms. The different network scale configurations are observed in table 1. The nodes traffic is applied during the communication process. The applicability of various variables during the process is observed in the second table. The most of the nodes random movement happen at an average speed of 10m/s. 150s is the simulation time, it verifies the information of the primary users and the spectrum availability. The random way communications area is set to 500x500. TCP connection is the connections observed between the mobile nodes and file transfer protocol is sent as traffic in every communication channel. The connections FTP rate is 512Kb/s, and the user's threshold value is 1M/s, so when any two primary users want to send the traffic for the same destination point, then the user will not get any alert but the alert is given to the secondary user. The scenario field's size is 1000m X 1000m. The Ad-Hoc On-Demand Distance Vector (AODV) is the routing protocol applied for integrating the user's optimal selection method.

**Table 1: Network Scale Configuration**

| Node number | Field size (MXM) | Number of primary and secondary users | Number of channels |
|---|---|---|---|
| 2 | 100x100 | 1,1 | 1 |
| 4 | 250x250 | 2,2 | 2 |
| 8 | 500x500 | 2,4 | 5 |
| 16 | 1000x1000 | 6,8 | 8 |
| 32 | 1500x1500 | 12,14 | 14 |

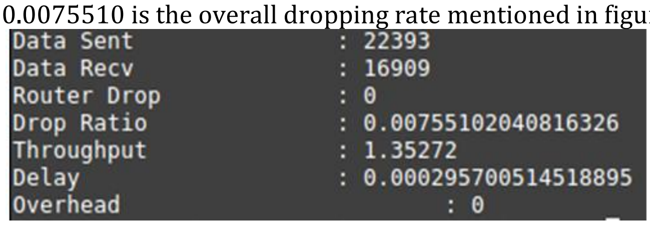
**Table 2: Simulation parameters**

| PARAMETERS | VALUE |
|---|---|
| Application traffic | FTP |
| Radio range | 250m |
| Packet range | 512 bytes |
| Maximum speed | 10m/s |
| Simulation time | 150s |
| Number of nodes | 10 |
| Area | 1000x1000 |
| Channels/radio | 5 |
| Maximum number of packets | 10000 |
| Total packets in the node | 50 |

The three metrics are:

- Packet propagation delay: the time taken by one packet for propagating from the source to destination.
- Energy levels of node: The energy levels used by the nodes per second.
- Network performance: The count of the packets transmitted mathematicized in megabits per second.

After getting an efficient output, the results observed are 22393 are the total count of the packets sent, where 16909 are the packets delivered. The user can observe that the spectrum is having the zero dropping packets. But 0.0075510 is the overall dropping rate mentioned in figure2.



```
Data Sent            : 22393
Data Recv            : 16909
Router Drop          : 0
Drop Ratio           : 0.00755102040816326
Throughput           : 1.35272
Delay                : 0.000295700514518895
Overhead                     : 0
```

**Fig2: Numerical results of data process**

The below figure 3 represents the network trace file representation. This file helps in maintaining the route level, shows the various time intervals in the network and the variables used. The individual nodes energy is indicated by the trace file. The user can vary these values by using the transmission protocol. If the secondary users waiting time increases then there will be the increment in the delay. If the ordinary user wants to communicate with the main user, then the ordinary user buffers some packets and starts its route discovery process. In certain situations, the primary user consists availability of only one spectrum, and finding this spectrum is a bit difficult for the broadcasted (Route Request)RREQ and takes a lot of time for determining it.

```
M 0.00000 0 (27.63, 439.06, 0.00), (119.19, 201.91), 0.27
M 0.00000 1 (161.81, 164.59, 0.00), (307.58, 24.45), 0.29
M 0.00000 2 (407.08, 165.39, 0.00), (220.63, 52.48), 0.94
M 0.00000 3 (366.00, 225.54, 0.00), (207.75, 466.34), 0.17
M 0.00000 4 (217.06, 237.24, 0.00), (333.86, 307.97), 0.81
M 0.00000 5 (418.66, 5.50, 0.00), (77.35, 254.81), 0.67
M 0.00000 6 (429.24, 406.49, 0.00), (123.06, 349.42), 0.47
M 0.00000 7 (221.81, 330.59, 0.00), (165.79, 411.06), 0.20
M 0.00000 8 (271.90, 442.58, 0.00), (471.30, 361.29), 0.16
M 0.00000 9 (290.83, 382.06, 0.00), (430.07, 245.08), 0.88
s 0.001889577 _0_ MAC  --- 0 UNKN 0 [0 df2d97c6 3b40ad0c 0]
r 0.002889577 _0_ MAC  --- 0 tcp 0 [0 0 0 0] ------- [0:0 0:0 0 0] [0 0] 0 0
s 0.002964577 _0_ MAC  --- 0 tcp 0 [0 0 8 0] ------- [0:0 0:0 0 0] [0 0] 0 0
s 0.015654661 _2_ MAC  --- 0 CM2 0 [0 2988a213 79405e02 0]
s 0.088472671 _3_ MAC  --- 0 CM3 0 [0 680db4a5 76408e11 0]
s 0.234901752 _8_ MAC  --- 0 CM8 0 [0 c4746afc 70400dfd 0]
s 0.313111772 _6_ MAC  --- 0 CM6 0 [0 1aabaab8 7a4058d0 0]
s 0.442623382 _4_ MAC  --- 0 CM4 0 [0 35057ec 6b40c1aa 0]
s 0.555930716 _1_ MAC  --- 0 CM1 0 [0 d40ea7b8 64403e95 0]
s 0.639865143 _9_ MAC  --- 0 CM9 0 [0 5c8d984d 7240abc5 0]
s 0.800205454 _5_ MAC  --- 0 CM5 0 [0 47e72285 7a405ec8 0]
s 0.817076051 _7_ MAC  --- 0 CM7 0 [0 9c8b07e2 6b40ce7f 0]
s 2.556838879 _1_ AGT  --- 0 tcp 40 [0 0 0 0] ------- [1:0 2:0 32 0] [0 0] 0 0
r 2.556838879 _1_ RTR  --- 0 tcp 40 [0 0 0 0] ------- [1:0 2:0 32 0] [0 0] 0 0
s 2.558676196 _1_ RTR  --- 1 DSR 32 [0 0 0 0] ------- [1:255 2:255 32 0] 1 [1 1] [0 1 0 0->0] [0
0 0 0->0]
s 2.559651196 _1_ MAC  --- 1 DSR 32 [0 1000000 ffff0008 0] ------- [1:255 2:255 32 0] 1 [1 1] [0
1 0 0->0] [0 0 0 0->0]
r 2.559779507 _4_ MAC  --- 1 DSR 32 [0 1000000 ffff0008 0] ------- [1:255 2:255 32 0] 1 [1 1] [0
```

**Fig3: Trace file of the network process**

The performance of the end to end delay is observed in this network mentioned in figure 4. The NRSS mechanism gives an efficient result. The NRSS mechanism consists of the better algorithm. The algorithm consists of optimal clients, hand-off choice utility; pick up the rate of the channel and its security. This algorithm gives the information about the channel state, correspondence helping and optional client choice. Half of the network is traveled by the RREQ for finding the spectrum availability of the network. By this, the buffer packets are delayed for a long time before going into the receiver. The situation of the probability gets increased when there is an increment in the count of the primary users and its network scale. The average delay gets affected by this. The algorithm applied to this is an energy efficient and better resulting algorithm. So this gives a better solution for cooperative relay selection problem. This algorithm is a better encompassing methodology for getting an expanded output. It reduces the transmission-time of the PU. The user will get better calculations with the existing development by using the method new relay selection scheme (NRSS). The delay will be minimum in the NRSS when compared with the existing methods.

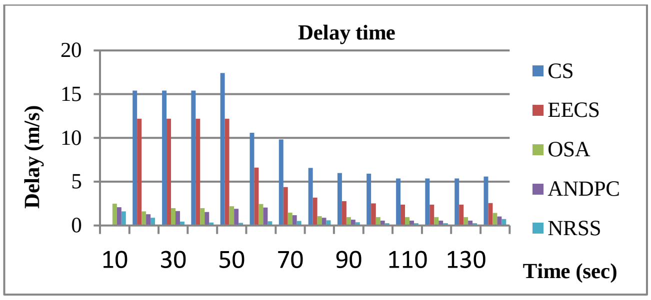



**Fig4: Delay time in the network**

**Energy consumption:**

The demonstration of the energy consumption is observed here represented in figure5. The NRSS is capable of having a less energy consumption when compared to the present running methods.

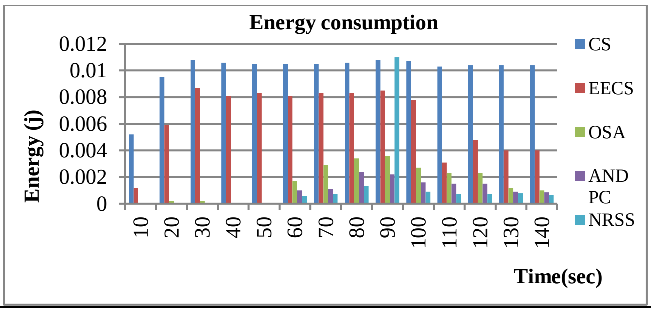



**Fig5: Energy consumption in network routing**

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The figure 6 demonstrates the performance of network throughput. By this, the user can increase the arrival rate of the packet, the increment in the spectral efficiency of auxiliary clients. This increment in the spectral efficiency of auxiliary clients and the arrival rate of the packet will connect to more primary clients. It gives a better solution to the cooperative relay selection problem. It gives a better calculation.

**Throughput of network**

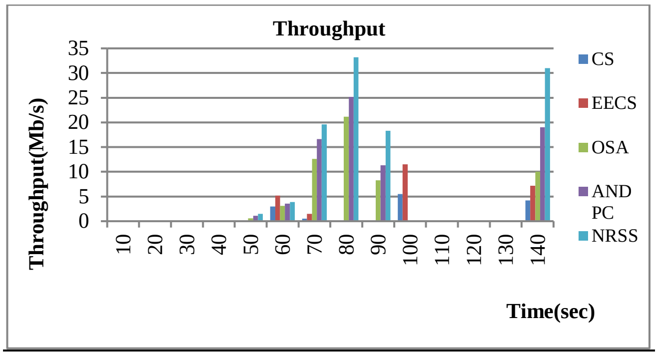


**Fig6: Throughput of network**

## 5. Conclusion

Three fuzzy parameters are used in the algorithms namely Signal to noise ratio (SNR), Cooperative gain and Channel gain. Implementation of new relay selection scheme (NRSS) it is based on fuzzy logic for dual hop cooperative communication. The performance of the cooperative network can be increased by our proposed technique.

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