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Development and performance evaluation of cognitive radio based mobile wireless sensor network using NS-3

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Abstract- Wireless Sensor Network is now days used to perform the various types of monitoring activities. Basically wireless sensor network is self-organizing ad-hoc network which consist of numbers of nodes. For the communication of collected data, WSN uses unlicensed spectrum band i.e. Industrial, Scientific and Medical band. Radio frequency spectrum is a limited natural resource with a high economic value. It is finite but non-consumable natural resource. It will be wasted if not used efficiently. The limitation of the radio frequency Spectrum utilization is mainly due to the unavailability of efficient technology and equipment for different types of radio frequency spectrum applications. The increasing demand for Wireless Sensor Network, wireless communication introduces efficient spectrum utilization challenge. To tackle this challenge, cognitive radio based mobile wireless sensor network is proposed in this paper. Cognitive radio aided mobile sensor network is developed using NS-3 and its performance is evaluated for average delay in packet transmission, average jitter, packet loss and throughput.

Keywords- Cognitive Radio, NS-3, PU, SU, Spectrum, WSN.

I. INTRODUCTION

Cognitive Radio is a radio system which automatically detects and analyze radio spectrum environment to recognize temporarily vacant spectrum. Once the vacant spectrum is detected the radio starts its communication in this frequency band without creating harmful interference to the primary users. Cognitive radio is flexible which can change its communications parameters as per channel situation. Figure 1 shows the cognitive radio environment in which the radio frequency of primary user is used when the spectrum is vacant. Spectrum sensing plays a main role in CR because it is important to avoid interference with PU and guarantee a good quality of service of the PU [1].

Cognitive radio can improve spectrum utilization and communication quality with opportunistic spectrum access. Dynamic spectrum access provides multiple channel access which helps to solve the problems caused by the crowded deployment and bursty communication nature of networks. To access the white spaces of TV band IEEE 802.22 is the first worldwide cognitive radio based standard. The IEEE 802.22 standard is the first effort for achieving a Cognitive Radio international standard. It defines CR techniques that are explicitly targeted to enable unlicensed devices to exploit TV white spaces in the VHF and UHF bands (54-862 MHz) in a non-interfering basis [6].

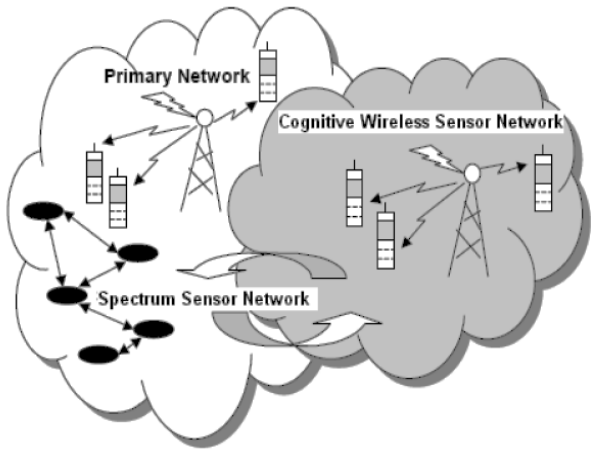

Figure 1 Cognitive radio Environment

II. DEVELOPMENT OF COGNITIVE RADIO BASED MOBILE WIRELESS SENSOR NETWORK.

Cognitive radio based mobile wireless sensor network utilizes cognitive capability to support the coexistence of licensed and unlicensed wireless users in the same area. The general scenario of the Cognitive Radio based mobile wireless sensor network is depicted in Figure 2. The mobile wireless sensor network monitors the spectrum usage, and is thus alert of the spectrum holes which are currently available and can potentially be used by the secondary network. The secondary users are able to communicate without causing unsafe interferences to the licensed network, which is the primary network.

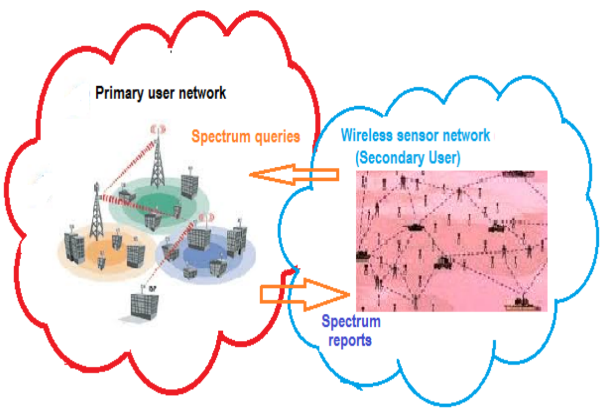

Figure 2 Primary user network & secondary user Mobile sensor network

III. ALGORITHM FOR DEVELOPMENT OF COGNITIVE RADIO BASED MOBILE SENSOR NETWORK USING NS-3

i. Include header file ns3/core-module, network-module, Mobility-module, config-store, wifi-module, aodv-module, internet-module, application-module, packet-sink, pu-model, netanim-module, starts-module, flow- monitor, flow-monitor- helper, ipv4-flow-classifier.
ii. Add upper MAC and disable rate control.
iii. Set Wi-Fi MAC to ad-hoc mode.
iv. Create 'n' numbers of random secondary user nodes Su.
v. Read Primary user file.
vi. Install the CR features into the nodes and return the list of devices.
vii. Save the control interface in the device control array.
viii. Assign IP address to the control devices.
ix. Create the bulk send application & install it on node.
x. Set the quantity of data to send in bytes.
xi. Create animation file to be run in netanim.
xii. Setup the flow monitor object.
xiii. Print the result to the standard output.

IV. PERFORMANCE EVALUATION FOR CR BASED MOBILE SENSOR NETWORK

Real-timeness and reliability are two important issues to maintain QoS in Cognitive radio based mobile wireless sensor network. Achieving a low end-to-end delay is an important parameter, which decides QoS for real-time application in Cognitive radio based mobile wireless sensor networks. Packet drop probability is another metric which must be minimized for reliable applications in wireless sensor networks. As the demand for real-time applications increases in cognitive radio based sensor networks, studying on the impacts of CR-related parameters on the delay, packet drop probability, throughput and jitter are important performance metrics to analyze performance of CR based Mobile sensor network.

- **Performance metrics**

$$\text{Throughput} = \frac{N}{T_{last} - T_{first}}$$

Where N is total number of bits received by transport layer of destination nodes, T_{last} is receive time of last packet in network by a destination node and T_{first} is send time of first packet in network.

$$\text{Average delay} = \frac{\sum_{i=1}^{Np}(t_i^r - t_i^s)}{Np}$$

Where Np is total number of received packets by destination nodes, t_i^r is receive time of i^{th} packet by transport layer of the destination node and t_i^s is send time of i^{th} packet by source node.

$$\text{Packet loss} = \frac{N_{drop}}{N_{drop} + N_{recv}}$$

Where N_{drop} is total number of dropped packets and N_{recv} is total number of successfully received packets by destination nodes.

Jitter = | D (i) – D (i-1) |

Where D is forwarding delay and i is the order in which frames are received.

Jitter is important metric for measuring cognitive radio based mobile sensor network performance, which measures latency variations caused by congestion, route changes, queuing. The jitter metric applies to packet sequence between two observation points. This parameter measures network performance consistency. When a network does not introduce any variability, the jitter is zero.

V. RESULT

Cognitive radio empowered mobile sensor network in NS-3, is developed by following algorithm as given in III. The simulation run time is fixed and the performance metrics such as Average delay, Average jitter, Packet loss and Throughput are evaluated based on the impact of number of primary user in a channel and number of secondary users in a channel, i.e. Pu < Su, Pu > Su and Pu=Su.

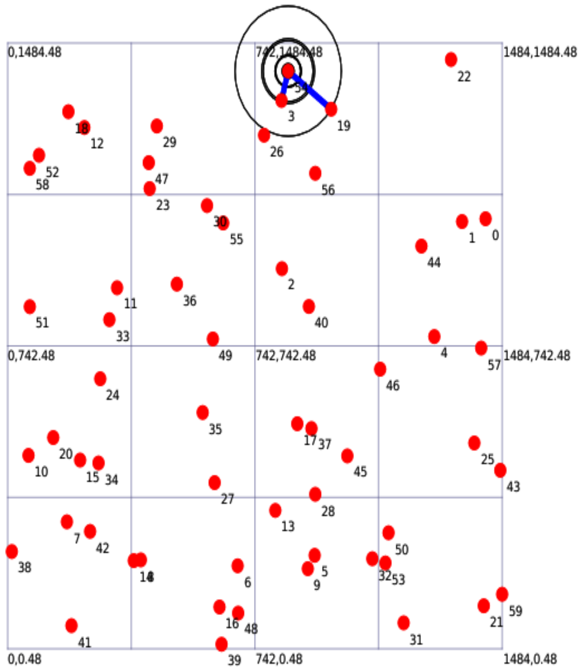

Figure 3 Simulation output for Pu=20 and Su=40

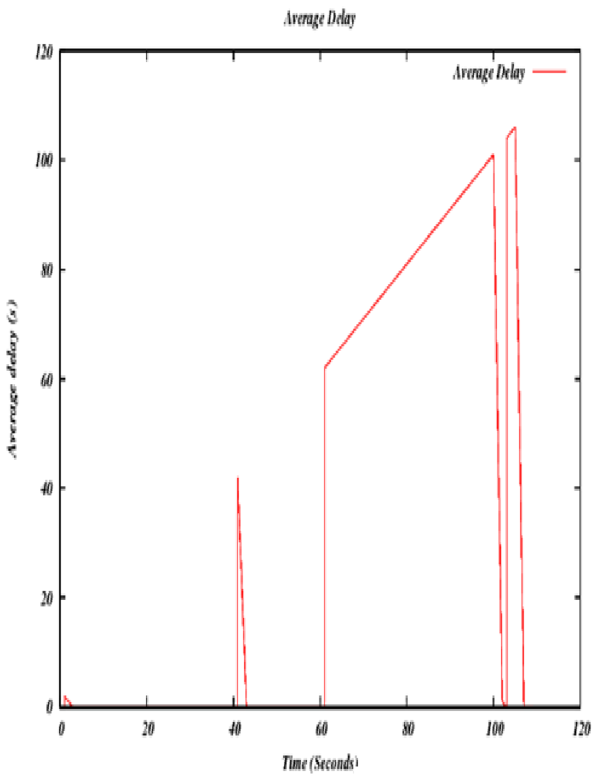

Figure 4 Graph showing Average Delay for Pu=20 & Su=40

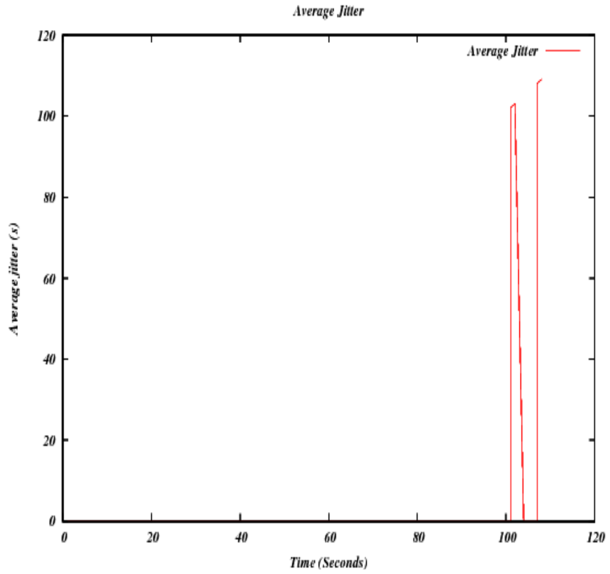

Figure 5 Graph showing Average Jitter for Pu=20 & Su=40

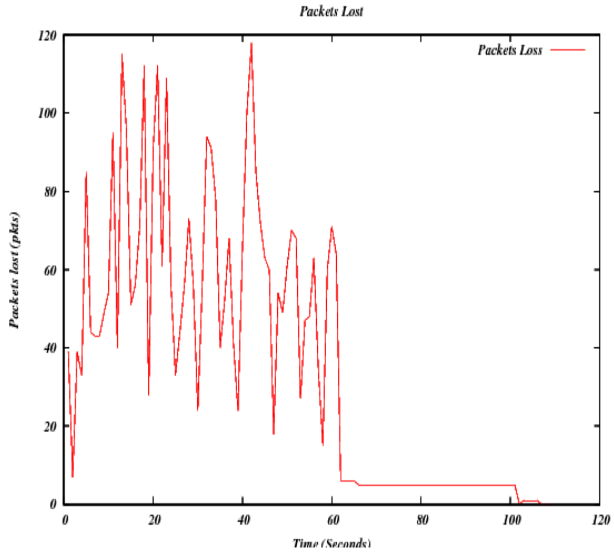

Figure 6 Graph showing Packet Loss for Pu=20 & Su=40

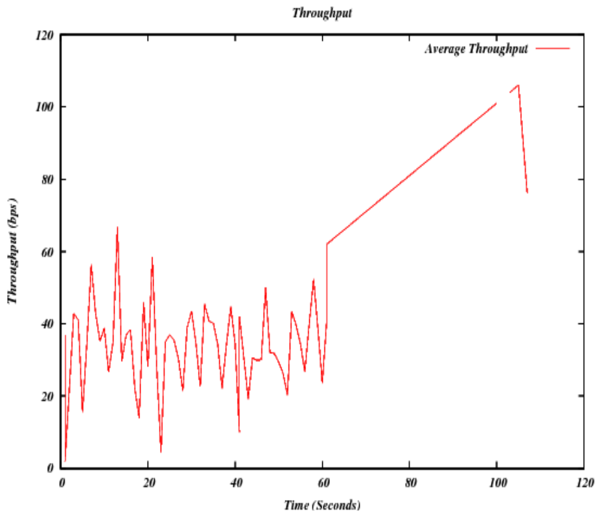

Figure 7 Graph showing Average Throughput for Pu=20 & Su=40

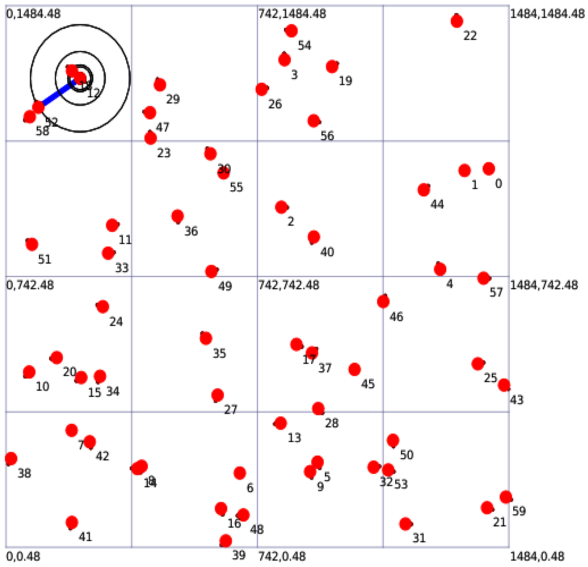

Figure 8 Simulation output for Pu=40 and Su=20

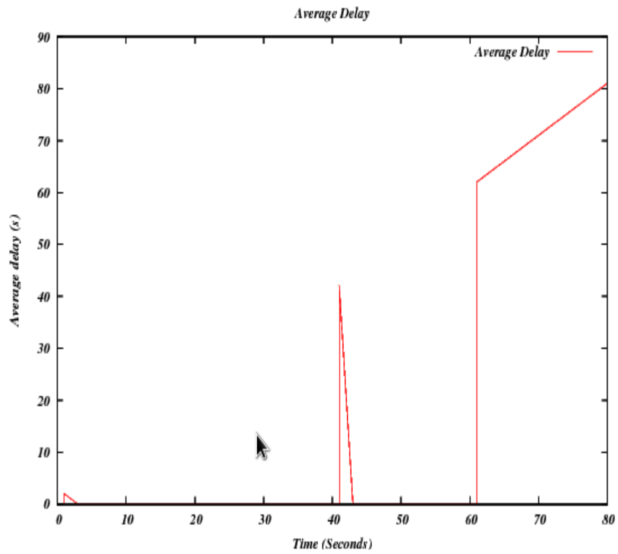

Figure 9 Graph showing Average Delay for Pu=40 & Su=20

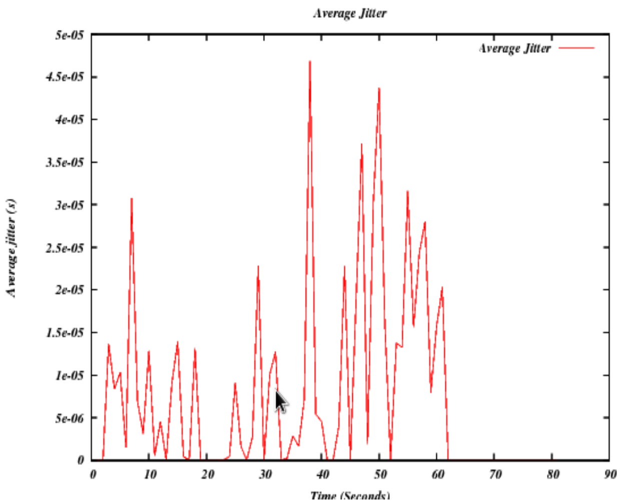

Figure 10 Graph showing Average Jitter for Pu=40 &

Su=20

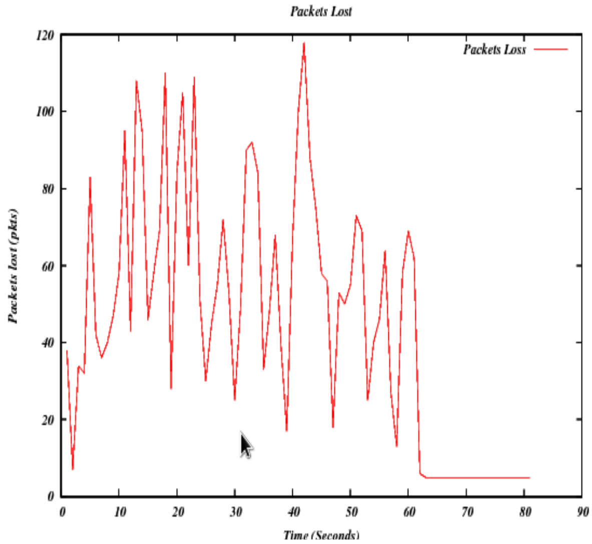

Figure 11 Graph showing Packet Loss for Pu=40 & Su=20

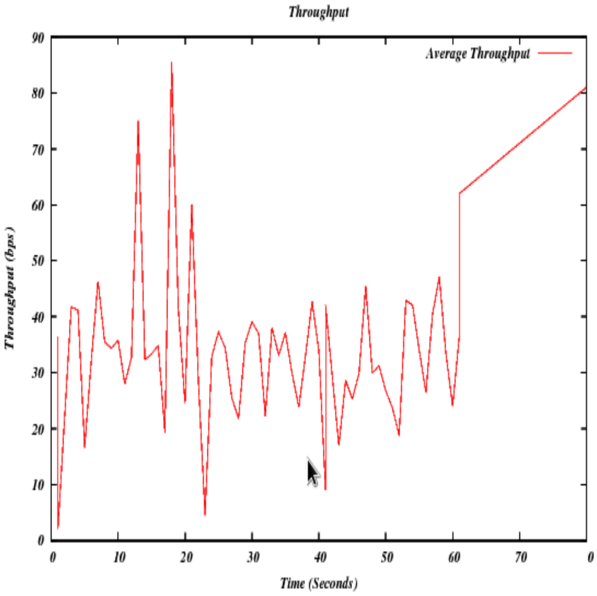

Figure 12 Graph showing Average Throughput for Pu=40 & Su=20

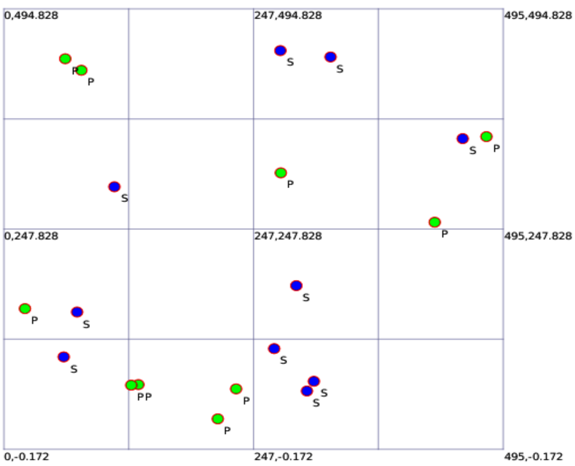

Figure 13 Simulation output for Pu = 10 and Su =10

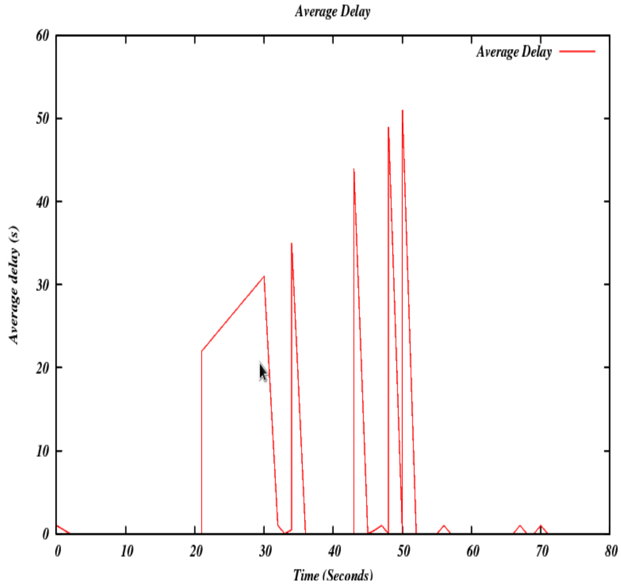

Figure 14 Graph showing Average Delay for Pu=10 & Su=10

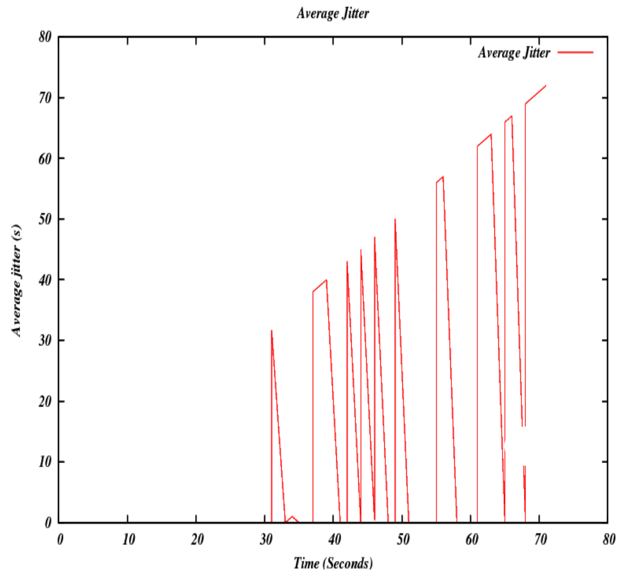

Figure 15 Graph showing Average Jitter for Pu=10 & Su=10

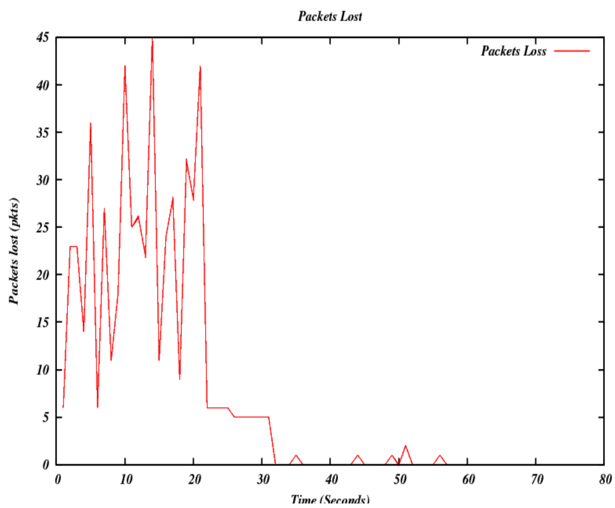

Figure 16 Graph showing Packet loss for Pu=10 & Su=10

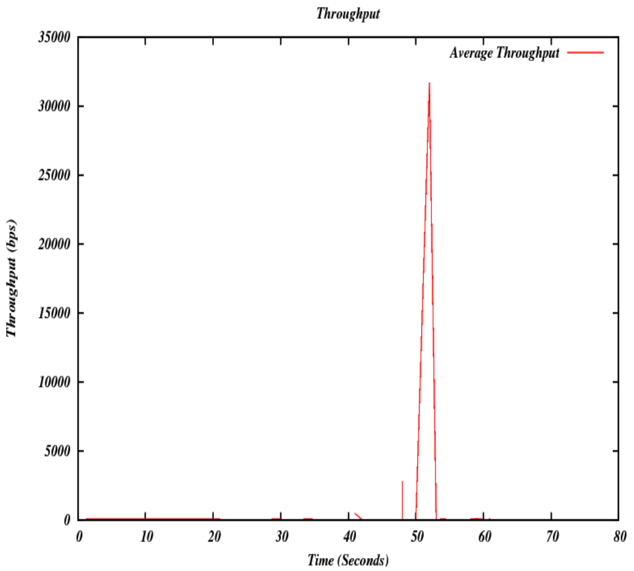

Figure 17 Graph showing Average throughput for Pu=10 & Su=10

- **Pu=20 and Su=40 (Pu<Su)**

Figure 3 shows Simulation output for Pu=20 and Su=40. Figure 4 shows simulation output for Average delay, up to first 40 sec average delay is very less, it is increasing from 40 sec to 100 sec and again it is less after 100 sec. Average jitter is shown in figure 5 , which is very less up to 100 sec and it is fluctuating in between 100 sec to 120 sec. Packet loss is shown in figure 6 , which is fluctuating in between 0 sec to 60 sec. , there after it is very less and constant in nature. Throughput is shown in figure 7, which is fluctuating in between 0 to 60 sec and there after increasing.

- **Pu=40 and Su=20(Pu>Su)**

Figure 8 shows Simulation output for Pu=40 and Su=20. Figure 9 shows simulation output for Average delay, up to first 40 sec average delay is zero, it is increasing after 60 sec and is constant thereafter. Average jitter is shown in figure 10, which is fluctuating in between 0 sec to 60 sec and there after it is zero. Packet loss is shown in figure 11, which is fluctuating in between 0 sec to 60 sec there after it is very less and constant in nature. Throughput is shown in figure 12, which is fluctuating in between 0 sec there after it is increasing.

- **Pu=10 and Su=10(Pu=Su)**

Figure 13 shows Simulation output for Pu=20 and Su=40. Figure 14 shows simulation output for Average delay, up to first 20 sec average delay is very less, it is fluctuating from 20 sec to 50 sec and there after it is very less. Average jitter is shown in figure 15, which is very less up to 30 sec and it is fluctuating in between 30 sec to 70 sec. Packet loss is shown in figure 16, which is fluctuating in between 0 sec to 30 sec, there after it is very less. Throughput is shown in figure 17, which is high in between 50 sec to 53 sec.

VI. CONCLUSION

In this paper, we developed the cognitive radio based mobile sensor network using NS-3. The performance of developed mobile sensor network is verified for average delay in packet transmission, average jitter, packet loss and throughput by varying number of primary user nodes and number of secondary user nodes. The results shows that incorporating the cognitive capability in sensor node for sensor networks can potentially improve the efficiency of spectrum utilization.

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