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A TCP IN CR-MANET WITH DYNAMIC BANDWIDTH

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Abstract: In recent years, Cognitive Radio (CR) plays the vital role in solving the problem of spectrum scarcity which arise due to the impact of unlicensed users operating under the licensed user's bandwidth without affecting their performance. All through communication process, to make an efficient use of available resources, characteristics such as Bottleneck bandwidth, Interference and Round trip time need to be modified and adaptively update by TCP in its congestion window (CWND). Here we propose TCP CR-MANET to whelm the problem of efficient resource utilization by computing and administrating the licensed users Bottleneck bandwidth, Interference and Round trip time in the available buffer space of the relay nodes. TCP CR-MANET is implemented in NS2 simulator and experimentally analyzed throughput's outcome by tuning the above said characteristics.

Keywords: Cognitive Radio, Congestion control, Spectrum Sensing, Transport Protocol, and Mobile ad hoc network.

1. INTRODUCTION

Cognitive radio technologies have created the deep impact towards the growth of wireless communication, due to its ability in handling spectrum utilization effectively by redistributing the Unused spectrum in dynamically changing environments. The unlicensed bands, mostly that fall under 900MHz and 2.4GHz, are getting more and more congested [1]. The radio spectrum demand has been increased dramatically and still few more available spectrums can be allocated. However, according to Federal Communications Commission's (FCC) report [2], the same spectrum bands are underutilized due to existing amount of idle spectrum holes at spatial and temporal measurements. Cognitive Radio Technology has the potential to ameliorate the scarcity of wireless resources. In this paper, we cautious to pin-point that Cognitive Radio Mobile Ad Hoc Network (CR-MANET), internally neither consists of federal party to obtain the spectrum usage information from the neighborhood nor external third party provision (spectrum broker) that empowers the distribution of the offered spectrum resources.

In classical ad hoc networks, the mobility of relay nodes and the ambiguity residing with wireless channels are the two key factors that affect the reliable distribution data from source to destination [3]. CR-MANET can be deployed in various aspects of Intelligent Transport Systems (ITS) applications [4]. The main challenges of transport layer in a classical wireless ad hoc networks are [5] Congestion, Packet drops based on channel related problems, Packet losses on mobility. In case -1: The RTT value was increasing based on the increased queuing delay of relay nodes. When RTT value goes beyond the given limit, the relay nodes fail to forward packets, likely this event degrades the performance of TCP. In case 2. In the network, a packet drops due to channel related problems or channel induced, likely of fading and shadowing performance of channel. In case 3. Relatively Packet losses occurred in the network, when there was mobility related losses or Permanent losses [6]. The source node would mistakenly consider the above

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mentioned cases as congestion event. All these losses are taken as inducing factors that are applicable to CR-MANET. In CR-MANET, we rely an intermediate nodes, which periodically piggyback the spectrum information with Acknowledgement (ACK) and also update's Primary User's arrival on time, explicitly informing the source. Our protocol ensures prospectively channel switching event by adhering to the momentous updation in bandwidth of the interfered link. Thus we propose a TCP congestion window (CWND) which levers rapidly to the transformation in the environment. Hence the objective of TCP CR-MANET is to facilitate window based methodology of the classical TCP, and increased applicability.

2. MOTIVATION

Here we analyze the one of the problems of the preceding approaches of transport protocols like TCP NewReno in Cognitive Radio ad hoc network which drive us to have enhanced performance with the proposed system TCP CR-MANET. With respect to Cognitive radio ad hoc network, each node is furnished with a Radio frequency transceiver. The key deeds of the Cognitive Radio Networks are 1. Spectrum sensing, 2. Impact of primary user activity, 3. Spectrum change. Primary Users are to be established as Poisson arrivals, by having an "on" time $\left(\frac{1}{\alpha}\right)$ as and as well as an "off" time as $\left(\frac{1}{\beta}\right)$ respectively to all kinds of provided channels of the network.

2.1 Spectrum sensing

The Secondary User or Cognitive User and the intermediate nodes has to do a periodic check over the current channel according to pre-defined sensing time for identifying a presence of licensed users. When a sensing time t^s is zero, the sensing is disabled on that period, we observed that the congestion window keep increasing until it reaches the maximum capacity of the channel. TCP sender side obtains a multiplicative delay reach the maximum retransmission timeout (RTO), RTO event could be triggered which results the degradation of the end to end performance [8]. Sensing time plays the vital role in deriving the optimized performance [9] via 1) thorough recognition of primary user and 2) effective utilization of the channel, which are the two contradictory goals that need to be achieved by diagnosing a better blending factor. The transport layer acclimatizes the current rate of sensing state and decides optimal setting of sensing time [10].

2.2 Impact of Primary User Activity

A primary user's (PU) activity is periodically detected during spectrum sensing or data transforming. In case, on arrival of the primary user, if secondary user's (SU/CR user)operation affects the current channel, the system will be in search of various unoccupied channel in the spectrum. When the current channel's spectrum sensing is of periodic and well defined interval, two activities will be performed as Available Channel set Discovery at various spectrum bands, Harmonize with the subsequent hop neighbors to derive mutually adequate channels in the set.The transport protocol [11] to differentiate these states, based on the value of "on" and "off" stage (α and β) of Primary User activity, that comprises four different patterns as follows.

1. High Activity $\left(\frac{1}{\alpha}\leq 1,\ \frac{1}{\beta}>1\right)$,
2. Low – Activity $\left(\frac{1}{\alpha}>1,\ \frac{1}{\beta}\leq 1\right)$
3. Short term Activity $\left(\frac{1}{\alpha}>1,\ \frac{1}{\beta}>1\right)$
4. Long term Activity $\left(\frac{1}{\alpha}\leq 1,\ \frac{1}{\beta}\leq 1\right)$

The packet losses that would appear due to congestion and from the one occurring due to primary user's interference. The proposed event handler is triggered in some constraints, as shown in Table 1.

Table 1.
Event Occurrences

Information Type	*Low PU Activity*	*High PU Activity*
LowBandwidth Capacity	PU Interference, Congestion, ARTT.	PU Interference.
High Bandwidth Capacity	PU Interference.	PU Interference, ARTT

2.3. Spectrum change state

The effective utilization of the spectrum resources by Cognitive Radio Technology. Secondary users have opportunistically transmitting in the license bands on limited duration. Primary users is modeled as position arrival with "on" and "off" time respectively. TCP must be regulating accordingly the new available bandwidth [8][12]. TCP must be scaled the CWND to meet the channel condition.

3. TCP CR-MANET

The CR-MANET nodes employs a single radio transceiver, to regulate channels between licensed and unlicensed spectrum. The channels in different spectrum bands may have disparate channel bandwidths. Channels are operated under spectrum band and the data transfer is being carried over using OFDMA with CSMA/CA technique and processed by priority queue at Medium Access Control (MAC) layer. This MAC protocol [13] is based on the following assumptions: 1. A fixed MAC super-frame size for SU. An SU decides to access the channel based on SU scans. 2. The PU and SU to use N orthogonal (interference-free to each other) channels. An SU can access 1 to N channels simultaneously. 3. An SU is able to (and must) vacate the channels in use whenever interrupted by the PU. 4. Each channel contains at least one PU transmitter-receiver pair. 5. The MAC layer contains the information such that historical channel utilization of the PU and real-time channel availability. 6. The MAC layer can distinguish the PU's signal from noise.

3.1 Network Modeling

The chain topology network is simulated in CR-MANET. The Chain Topology wireless nodes are constructed and symbolized in the cognitive radio scenario, the transmission is initiated among the CR users when the PU starts transmitting the packets, if the channel used by CR user is the licensed channel of PU, it switches to another available channel, allocating the current channel to PU in order to maintain the performance of primary user.

3.2. Connection Establishment

The three-way handshake protocol are used to establish the connectivity of CR-MANET. The source sends a Synchronization (SYN) packet to the Sink. A relay nodes in the routing path appends the following information to the SYN packet: ID, Timestamp, and the tuple. On the receiver part,after getting the SYN packet, it sends a SYN-ACK message to the source.

3.3. Spectrum Sensing

CR-MANET uses ED (Energy Detection) as the sensing technology. Each SU performs sensing and data transmission processes in an asynchronous time-division manner. Therefore, the TCP sender regulates the timing and duration in a routing path based on sensing schedules [13]. The node requires different schedules for sensing, it may happen that a node receives messages from more than one TCP sender [14]. Sensing time t^s of each node is calculated using following equation (1)

$$t_i^s = \left[\frac{1}{W\gamma^2} [Q^{-1}(P_f) + (\gamma+1)Q^{-1}\left(\frac{(P_{off} P_f)}{P_{on}} \right) \right]^2 \tag{1}$$

with the parameters bandwidth (W), standard function (Q^{-1}), Probability of missed PU detection (P_f), SNR (□), Probability of PU on period (P_{on}), and Probability of PU off period (P_{off}). The PU interference occurs, when PU attempts to access a channel used by an SU. According to the characteristics of CR-MAC, an SU must not occupy the channel whenever the PU accesses it, in turn which may lead to have "PU-Interference Loss" event [15]. In a PU-interference loss event, the TCP client may face a time-out condition, if the MAC fails to recover the collided packets within deadline. Such an event probably leads to have a decreased TCP throughput. The PU's historical channel utilization, is recognized and maintained as "PU-Activity" information, by acquiring the knowledge about PU's activity, the SU senses (and decides to access) channels periodically in each MAC super-frame. Proximate arrival of PU may certainly push the channel to have PU-interference loss, subsequently the collided packets can be retransmitted in the beginning of the next super-frame rather than waiting for other retransmission mechanisms. Starvation is more serious when MAC super frame is longer which causes throughput decline. On the other hand, to aid process of retransmission the MAC super-frame is made short, to recover the collided packets .By forcing the collided packets to be retransmitted at the beginning of the MAC super-frame, the starvation cases can be relaxed. However, forcing the packets to retransmit causes duplicate packets. To maintain the congestion window, ACKs of re-transmitted packets are not taken into count and thus framed as duplicate ACKs.

3.4. Channel Switching

The channel switching is detected periodically in spectrum band, for PU arrival in the network and SU switching to the available bandwidth. The RTT-adjustment function [14] is triggered in the cases of bandwidth changes and propagation delay.

RTT = Propagation Delay + 1/ Bandwidth.

The RTT_{PATH} = $RTT_{VL} + RTT_{SL}$, Where RTT_{VL} and RTT_{SL} are the RTT of the CR link and the stable bandwidth link, respectively.

$$RTT_{VL} = t_{VL} + l_{VL}/bw_{VL},\ RTT_{SL} = t_{SL} + l_{SL}/bw_{SL} \tag{2}$$

Where t_{VL} propagation delay for RTT_{VL}, t_{SL} propagation delay for RTT_{SL}, l_{VL}, l_{SL} packet length of CR link, and packet length of stable link.

$$RTT_{PATH} = C + \frac{L}{BW_{VL}} \tag{3}$$

Where ($C = t_{VL} + t_{SL} + l_{SL}/bw_{SL}$), $L = l_{VL}$, We can use the least squares method to train C and L in Equation (3). Giving n entries of the corresponding RTT-bandwidth information pair where (BW_i, RTT_i) represents the i^{th} entry, C and L can be derived from:

$$L = \frac{\sum_{i=1}^{n} (BW_i - \overline{BW})\ (RTT_i - RTT)}{\sum_{i=1}^{n} (BW_i - \overline{BW})^2} \tag{4}$$

$$C = \overline{RTT} - LX\overline{BW} \tag{5}$$

Where,

$$\overline{\mathrm{BW}} = \frac{1}{n}\sum_{i=1}^{n} \mathrm{BW}_i \;,\; \overline{\mathrm{RTT}} = \frac{1}{n}\sum_{i=1}^{n} \mathrm{RTT}_i \;\; \mathrm{RTT(L, C, BW)} = \mathrm{C} + \mathrm{L/BW} \tag{6}$$

The nodes are switching their channels, to evaluate communication characteristics link bandwidth BW = W, link delay (L^T). The TCP sender aware these characteristics and RTT then compute easily the bottleneck bandwidth (W'_b). In channel switching, the sender must update CWND and RTT from equation (7) and (8). L'^T is the link delay before channel switching. A relay node change its channel, if primary user communication is detected and also measure ssthresh.

$$\mathrm{RTT}_{new} = \mathrm{RTT}_{old} + L^T - L'^T \tag{7}$$

$$\mathrm{CWND} = \alpha.\, W'_b \;\; \mathrm{RTT}_{new} \tag{8}$$

4. IMPLEMENTATION

When a relay node changes its channel, on account of PU communication detection, its bandwidth and link delay ($L'^T_{i;i+1}$) can also be changed. This change is drastic when the bottleneck bandwidth or RTT changes. Therefore, appropriately updates its congestion control parameters cwnd and ssthresh, using the feedback information received from the relay node is essential. The bottleneck node is located in two cases, the first case is that the bottleneck node is placed on a path from the TCP sender to bottleneck node, the buffer will be empty by the end of channel switching when the TCP sender stops sending packets during channel switching. The second case is that the bottleneck node is just the switching node and forward to the TCP sender. The TCP sender receives the feedback message after channel switching, then it calculates the RTT_{new} by using equation (9) and bottleneck bandwidth W'_b. Estimation of the CWND [17] and RTT process as shown in Fig1.b. The network consists of the Primary user and the CR users where the CR users actively participate in the packet transformation when the PU is idle and handoff the channel when the primary user enters the packet transferring mode.

$$\mathrm{RTT}_{new} = qL_{1,2}^{\;T} + .. + L_{i-1,i}^{\;T} + L'^{T}_{i,i+1} + \;\ldots. \tag{9}$$

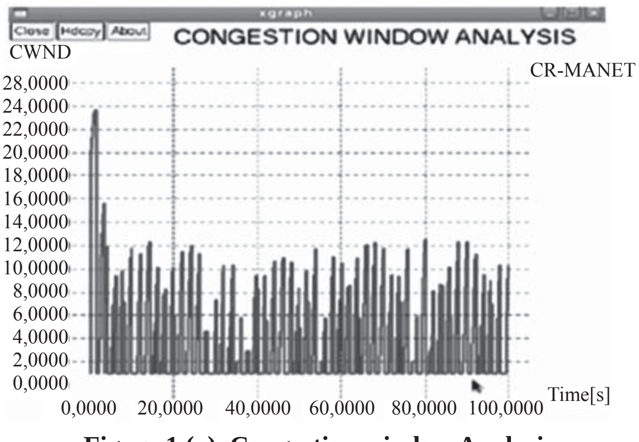

Figure 1 (a). Congestion window Analysis

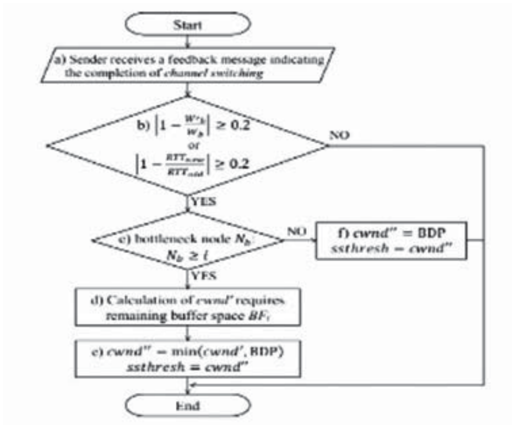

Figure 1 (b) Algorithm to update the cwnd

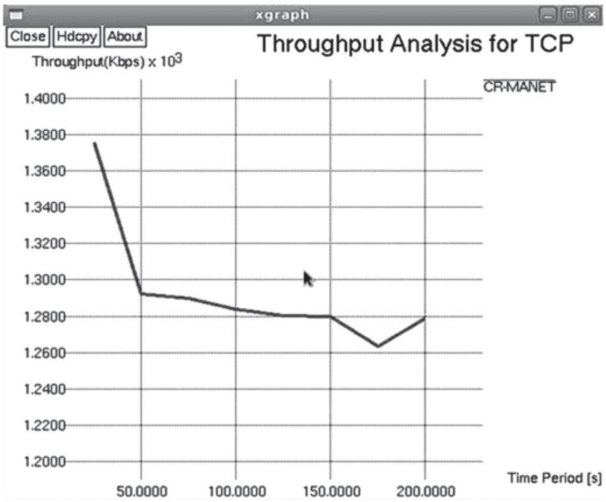

Figure 2 (a). Throughput Analysis for CR-MANET

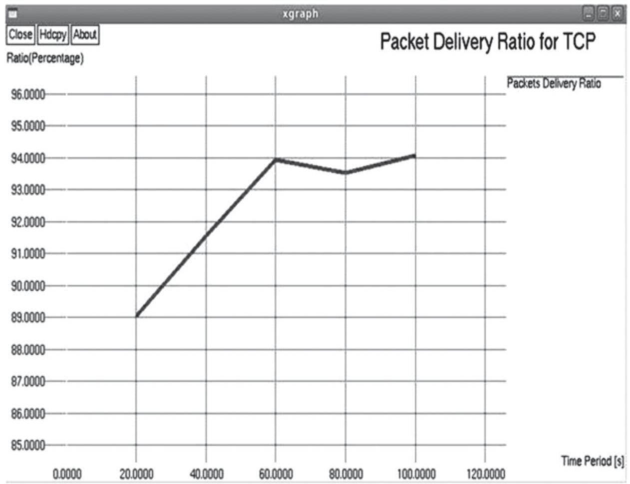

Figure 2(b). Packet Delivery Ratio

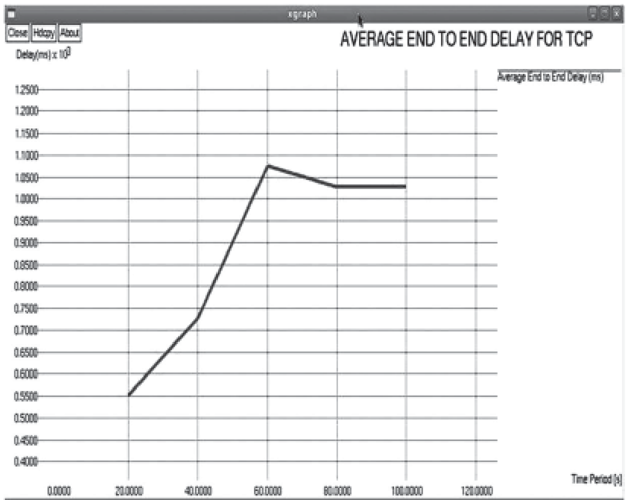

Figure 2(c). Average End to End Delay

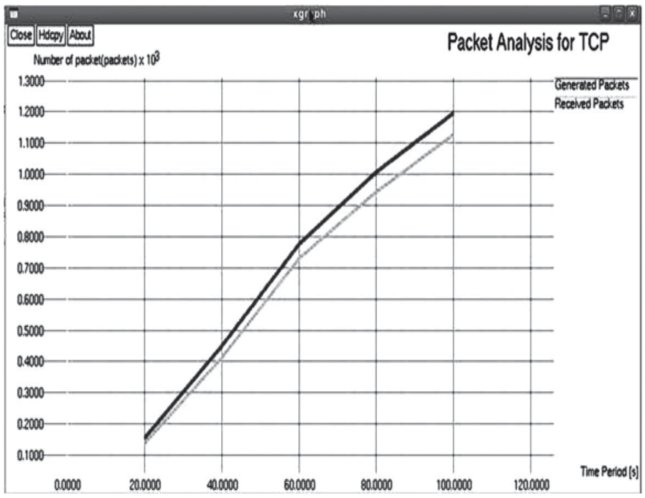

Figure 2(d). Generated Packet Analysis

Figure 2. (a) clearly states the throughput analysis of CR-Manet by tuning different parametrical setup with respect Bottleneck bandwidth, Congestion window and RTT. Figure 2. (b) States that Packet delivery ratio for Transport Control protocol. Figure 2. (c) and 2. (d) clearly shows Average end to end delay and Packet analysis for Transport control protocol for CR-Manet.

5. CONCLUSION

TCP CR-MANET experimentally proved to support optimal resource utilization by incorporating buffer space of relay node in computation and administration of Bottleneck bandwidth, Interference and Round trip time of the communication channel.TCP CR-MANET protocol implementation involves beside connection with the fundamental link and network layers, specifically during on events, such as channel switching, mobility and Interference.TCP sender should examine both the bottleneck node and buffer resource in the network and updates the CWND when either the bottleneck bandwidth and RTT parameters were modified in terms of channel switching.Accordingly experiment results show that TCP CR-MANET give way for efficient resource utilization while resolving spectrum scarcity of the communication networks.

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