COGNITIVE RADIO FOR RESOURCE MANAGEMENT FOR CLUSTERED AD HOC NETWORKS IN POST-DISASTER COMMUNICATIONS

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ABSTRACT: Research activities have rapidly increased in disaster communications domain. A critical problem is the provision of communications facility to the disaster victims before rescue teams arrive; this allows victims to help each other. A novel resource management scheme for clustered ad hoc networks (CR-RM) in post-disaster communications is proposed in this paper to address the mentioned problem. Two disaster scenarios are presented, depending on the severity of disaster. A 3-tier conceptual mode for spectrum sharing is also proposed. At the end the performance of CR-RM scheme is evaluated for probability of successful transmission and spectrum efficiency.

Key words: Cognitive Radio, Resource Management, Clustered Ad hoc networks, post-disaster communications

INTRODUCTION

Disasters both natural and manmade can create widespread destruction; causing disconnection of communication links with outside world. There is rapid increase in research activities related to emergency communications (Wong, 1997; Tseng, 2006). Many solutions and networks have been proposed for this purpose, which targets different applications and uses various technologies (Meissner, 2002; Ochoa, 2006; Majid and Ahmed, 2007a, 2008).

A novel scheme using cognitive radio for resource management for clustered ad hoc networks in post-disaster communications has been presented in this paper. A 3-tier conceptual model for spectrum sharing is proposed for the said purpose. This scheme will help in better management of radio resource i.e., radio spectrum in an emergency situation and helps in providing effective communications among disaster victims.

MATERIALS AND METHODS

Clustered Ad Hoc Network for Emergency Communications: Clustered ad hoc network for emergency communications is established based on the assumption that after disaster strikes, there are some disaster victims which are having telecommunications equipment i.e., Mobile handSet (MS) with some remaining battery power. It is further assumed that these MSs are working in cellular mode in normal conditions and switch their mode to ad hoc on the identification of emergency (Majid and Ahmed , 2007b).

Once a mobile node is in emergency or ad hoc mode, it starts exploring nearby nodes to establish a network. Nodes group them in clusters. Mobile nodes forming the ad hoc network are grouped in four classes Unregistered Node (UN), Cluster Head (CH), Cluster Member (CM), and Cluster Gateways (CG), (Majid and Ahmed, 2009).

Each CH registers nodes within its k-hop communication area. The parameter k is considered as cluster radius and is used to control the number of CHs. i.e., Larger value of k corresponds to less number of CHs and vice versa.

Network scheme illustrating two disaster scenarios for post-disaster communications is shown in Fig.1. The purpose of clustered ad hoc network is to group the surviving nodes in such a way that the information regarding disaster victims can be communicated to Disaster Information Center (DIC).

Mechanism for establishment of clustered ad hoc network is out of scope of this paper.

Scenario I- Partially Destroyed Communications Infrastructure: It is considered that the communications infrastructure is partially destroyed in the affected area i.e., some of the base stations stops working or destroyed, as described in Fig.1 (scenario I). When a Base Station (BS) stops working, then MSs in its coverage range switches to ad hoc mode and form cluster ad hoc network. The CH is selected based on the reach-ability criteria i.e., any cluster member which can communicate to another MS within the coverage range of surviving BS is selected as CH. This CH then acts as a relay node for the rest of Cluster Members (CM) (Majid and Ahmed, 2009).

Scenario II- Communications Infrastructure totally wiped out: When the severity of disaster is very high, communications infrastructure may totally wipe out. MSs form clustered ad hoc network and communicate among them. CM enriched in battery power or energy is selected as CH. This network facilitates the people to start communicating among them and help each other prior to the arrival of parties involve in response activities or rescue teams. We propose the use of some external networks e.g., satellites and / or High Altitude Platforms (HAPs) to communicate the information from disaster affected are to DIC (Majid and Ahmed, 2009).

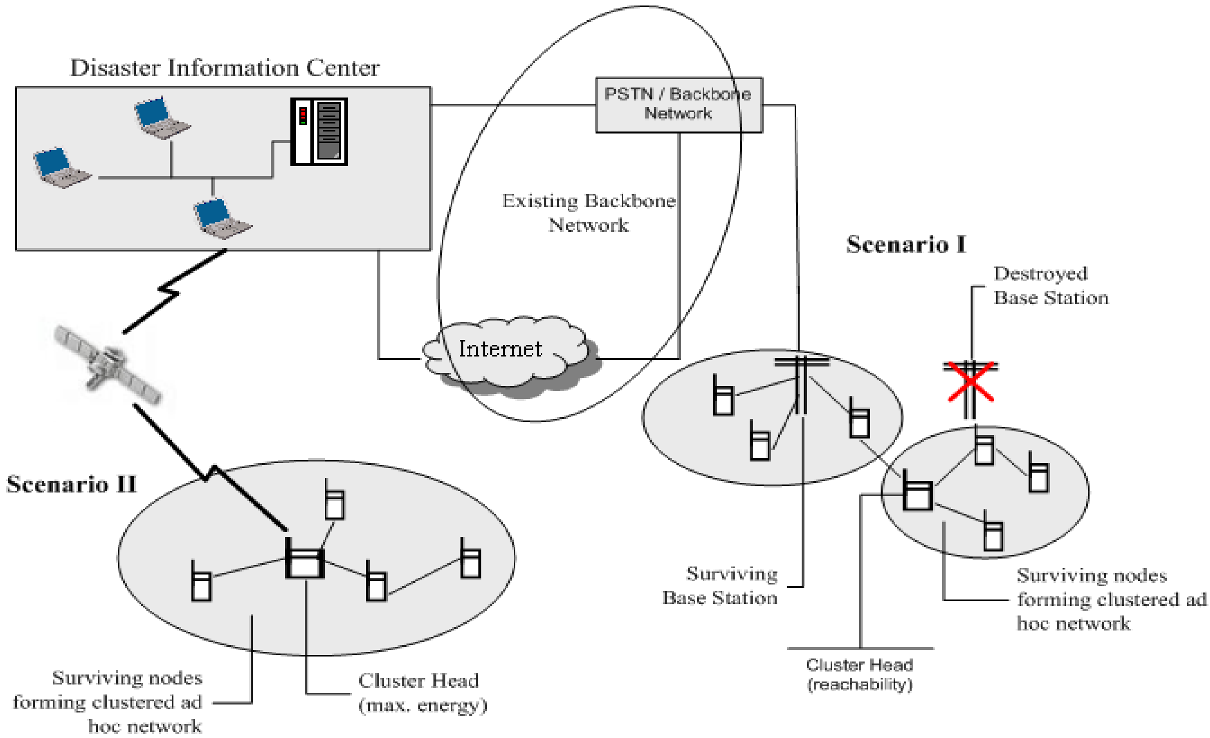

Fig.1: Clustered network scheme illustrating disaster scenarios

3-Teir Conceptual Model for Resource Management: Cognitive radio is an emerging technology used to solve the spectrum shortage problem by taking using opportunistic and dynamic access to spectrum (Haykin, 2005). Cognitive radio technology for post-disaster situations will help in reducing overall disaster cost both in terms of money and lives while enabling efficient utilization of precious radio spectrum resources.

A 3-Tier conceptual model for resource management using the cognitive radio approach is presented in Fig.2. Sending and receiving device first communicate to the resource manager (in our case CH) for allocation of radio resource namely, frequency channel for communication. CH decides whether to allow or not based on the sender and receiver side information (Zhou, 2004).

We assume that the MSs forming the clustered ad hoc network (referring Section II) are also cognitive radios. Each CM scans the spectrum either before sending RTS message or after receiving request for receiver side information i.e., when they need to provide information to resource manager. CH evaluates the current spectrum situation and takes its decision accordingly. The said process is described in Fig.3.

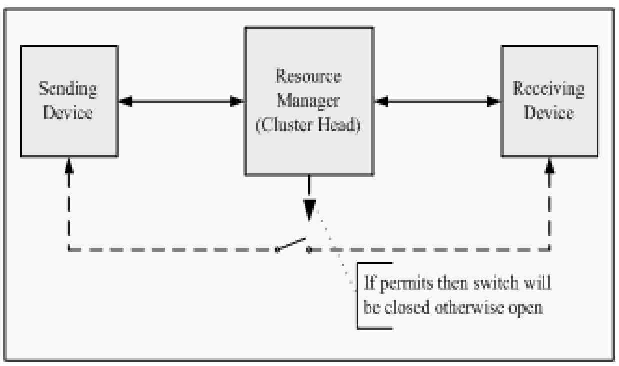

Fig.2: 3-Tier Conceptual Model for Resource Management

Source node provides Sx to CH while requesting for a spectrum resource to perform its desire communication. CH requests the destination node to provide it with the Rx. Sx and Rx indicates the spectrum holes which are identified by sending and receiving device respectively. CH being itself a cognitive radio also sense spectrum and then combine the overall information in a way to obtain the list of legitimate available frequency holes (Coile, 1997).

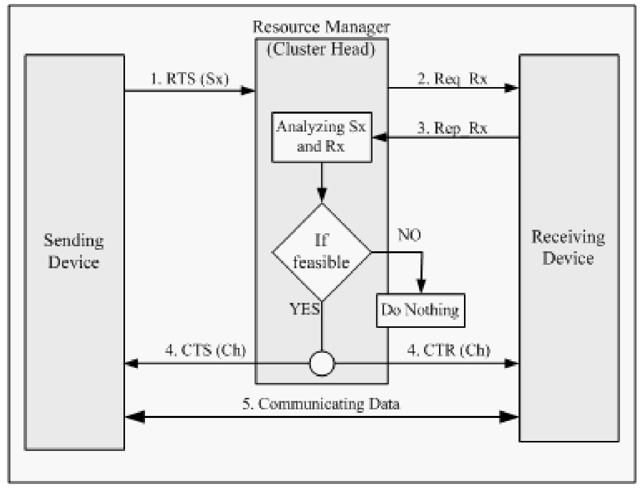

Fig.3: Process for resource allocation using Sx and Rx

Where,

Sx	: Sender side information
Rx	: Receiver side information
RTS	: Request to Send
CTS	: Clear to Send
CTR	: Clear to Receive
Req_Rx	: Requesting for Rx
Rep_Rx	: Replying or providing Rx
Ch	: Spectrum resource i.e., allocated frequency channel for communication

The main challenge is to combine the effect of spectrum scanning (i.e., indicating available spectrum holes) by the CH from all both sender and receiver and that of CH itself. We use simple mechanism to find the list of legitimate available frequency channel for sender and receiver communication. From that list then one of frequency channel that more prone to primary user interference is identified and assigned for communications.

We consider Sx, Rx as matrices with 1xn and 1xm dimensions respectively. Sx and Rx may not be identical but are correlated. CH first identifies the identical spectrum holes using the simple operation of AND gate as follows:

$$List = Append(Sx_i\, AND Rx_j)$$

where, 'i' is the number of columns in Sx and 'j' is the number of columns in Rx. The $List$ contains all the identical spectrum hole for Rx and Sx. These are the frequency channels which can be used for communicating data/message between sending and receiving devices.

Any frequency channel that exists in $List$ can be used for the said purpose However, we are targeting the emergency situations, and where the organizations involved in immediate response activities deployed their own networks (may be temporary base stations).

Therefore, we need to identify the spectrum resource that is less subject to interference and hence, provide a robust communications. CH executes the simple function to achieve the said goal.

$$Ch = Find\left(List, Cx\right) \quad (2)$$

Where, Ch is the selected channel and Cx is the list of spectrum holes identify by CH. Hence, a frequency channel that is available for both sender and receiver and is also sensed free by the resource manager (CH) is assigned for communication.

If either of equations eq. (1) or eq. (2) returns null, then CH just keeps quiet. Sending device on not receiving the CTS for pre-defined time, waits for the time defined via $backoff - timer$ and then re-send the CTS message to CH. The value of $backoff - timer$ is defining as:

$$backoff - timer = T_S + T_C + k \quad (3)$$

Where, T_S :time taken by receiving device to scan the spectrum and communicate this information to CH, T_C : is the time spent in combining the effect of Sx and Tx, and k is some random number.

RESULTS AND DISCUSSION

In order to evaluate the performance of the proposed resource management scheme, the results obtained through computer simulation has been shown. A system was taken which has a cellular network as primary user network. The channel is set to be AWGN. For simplicity, the scenario II was taken, in which a severe disaster strikes to the simulation area (e.g., tsunami), wiping out all the physical infrastructure of the cellular network. Hence, the surviving mobile nodes form clustered ad hoc network was activated. For analysis, two networks have been implemented; one is ad hoc cognitive radio network and other is CR-RM network.

Small size area was selected for simulation as described by (Majid and Ahmed, 2009). The node survived range is 1 to100. Randomly but pre-defined network density (ρ) strategy is adopted to determine for the overall simulation area 250 m is the range of Communication and channels is between 0 and 25.

The CR-RM performance is measured based on probability of successful transmission and network's spectral efficiency.

Probability of Successful Transmission: The successful transmission, as the communications of entire message using the same frequency channel. i.e., once an available frequency channel is assigned for a particular communication it remains available till that communications ends. As, one of the main challenges of cognitive radio networks is to minimize primary user interference ,therefore, traditionally, if a frequency channel is in use by some CR nodes and the same frequency channel is requested by primary user, the CR communications immediately stops and channel is set to free for primary user. This leads to the delay in CR communications, the unacknowledged packets need to be re-transmitted and both of this overhead cause wastage of node's energy (Papoulis, 1991).

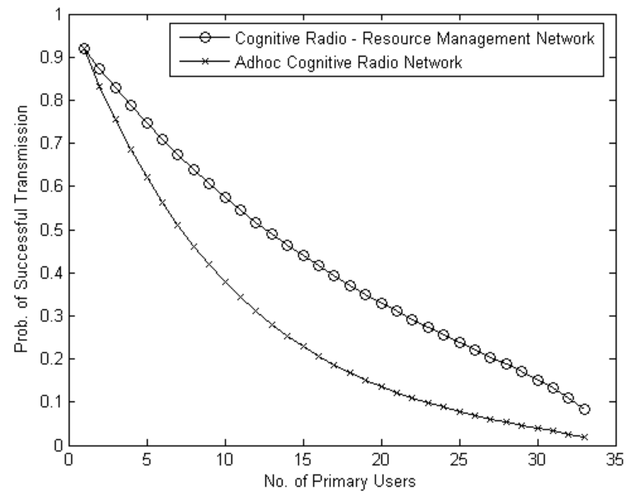

Fig. 4: Successful transmissions probability (Majid and Ahmed, 2009)

However, our proposed CR-RM is relatively less spectrum efficient due to the fact that it tries to maintain high probability of successful transmission.

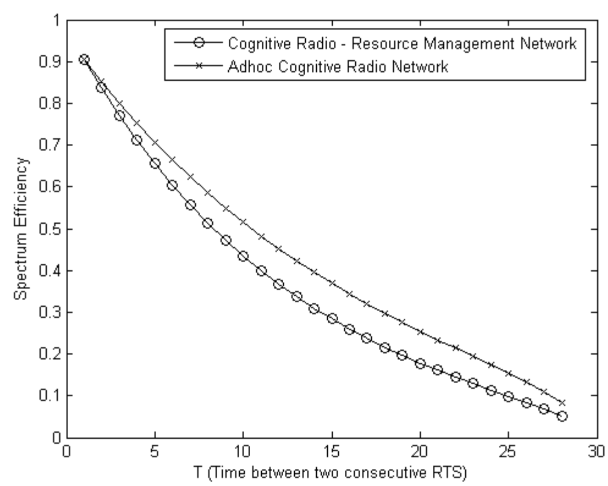

Fig.5: Spectrum efficiency Vs. T (Time between two consecutive RTS) (Majid and Ahmed, 2009)

CONCLUSION

A cognitive radio resource management scheme for clustered ad hoc network targeting the domain of emergency communications has been proposed in this paper. Emergency situations based on the severity of disaster are also widely categorized in two. In addition that, 3-tier conceptual resource management model is presented. Simulation results show that by minimizing time between two consecutive RTS better spectrum efficiency for CR-RM network can be obtained. The proposed CR-RM network provides high probability of successful transmission as compared to ad hoc cognitive radio network hence, providing robust communications in emergency situation (Saengudomlert, 2005).

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