Cloud-Based Routing Resource Allocation in Cognitive Radio Networks

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***Abstract*—Wi-Fi Direct technology is enabled to support multiple services to be done via Wi-Fi connection. It provides the most efficient method to develop ad-hoc community among mobile devices for connecting quickly with one another without needing an access to the network. It allows communicating at common Wi-Fi rates for various applications including document exchange and online connection. This one-stop WiFi Direct application is able to connect a device to a single device at a time, i.e., only peer to peer communication is allowed within one hop. Hence, multi-device communication within multi-hop distance in a trusty Cognitive Radio (CR) network environment is in demand. This paper presents the development of an Android-based application with optimum cloud routing service to transfer files or chatting via Wi-Fi Direct technology in CR network. A system is developed using smartphones (with developed applications) and nodes with WI-FI connection. An indirect multi-hop routing approach is created if more devices transfer files simultaneously from hop to hop. After login and initializing, a device discovers the neighboring nodes first and then connects those (as necessary) to transfer a file or start chatting. The very moment a connection is established, a log file is generated in internal memory and save a backup copy in cloud containing necessary networking information of the client devices. The aim of these backup log files is for forensic investigation for intrusion detection/prevention and secured communications. Then the chatting or file transfer is carried out between the connected devices either in single or multi-hop routes. Results show that the system's efficiency is around 92%. It shows that multi-device, multi-hop Wi-Fi Direct services can be implemented using Android devices with Eclipse Java programming in CR networks.**

***Index Terms*— Cognitive Radio Network; Cloud-based Routing; Peer to Peer Multi-hop Communications; Resource Allocation; Wi-Fi Direct.**

I. INTRODUCTION

The benefits of Wi-Fi Direct is the capability to make link among products from various companies. The units should be agreeable with Wi-Fi Direct to determine a peer-to-peer hookup that exchanges information immediately between one another with a considerably minimum setup. The "pairing" of Wi-Fi Direct gadgets may be created for the need of a whole area interaction, a Wireless transmission for all of the units. Wi-Fi Direct might not just change the necessity for routers, but may, in addition, replace the necessity of wireless access point with programs which do not depend on reasonable energy [1-5].

Android OS is a Linux-based cellular phone OS created by Google. Android is exclusive working platform because it provides information and guidelines to use in hardware and smartphones [6-7]. It comes down set up on a number of smartphones and tablets, supplying customers' accessibility to Google Chrome, YouTube, Maps, Gmail, etc. just like a PC.

The analysis provides that cloud storage does have more strengths for subsequently different competing storage strategies. Data stored in cloud storage can be access from anywhere that features online accessibility. Together with the proper storage space program, one can actually enable other individuals to gain access to the information, flipping a private task into a collective work. This proves that the cloud storage is very convenient for the user as it is very flexible for use [1-7].

The reason cloud is chosen for this research is to store data and routing path automatically in the cloud. This can be easy for node tracking purpose. Every time a new path is taken, the routing path can be backed up to the cloud in the form of the log file. By backing up the routing path, may enable the use of log files for further analysis for security purpose. By accessing the log file, any third party node or hackers who try to tap information from the path can be traced.

One of the major promising features that the Cloud provides is Auto Backup. Data can be backed up in the background without bothering the user once this configuration is set up. Even though the device is turned off during the preset backup time, data can be backed up the moment the device is switched on when there is internet connection [6-10]. Besides, the cloud storage has a feature called the archive backup, which enables the cloud to update the storage with a new copy of data each time there is an update done to the data file while preserving a copy of the old file for each version with a time-stamp. Users are allowed to access their data stored in the cloud only when they provide the right login information and password. Besides that, data can be encrypted while storing and retrieving data from the cloud. This can prevent the intruder from tapping the data [8-9].

Cloud routing has many advantages though there are some issues regarding routing algorithm need to be resolved. One of those is cloud routing consume very high energy in ad hoc networks. The main reason ad-hoc network consume energy is due to the attempts to search and transfer packets to the next participating node in an acquired route. The distance between nodes also another important contributing reason for the total energy consumption. This drains the mobile device's stored energy quickly. So, the best routing protocol needs to be chosen. Besides, internet connectivity is essential to transfer files or documents to cloud for each node. Users using Wi-Fi direct technology have no track record of the neighboring devices connected to it. This could lead to security breaching issues. A suitable platform is required to provide a working environment to overcome the above problems.

This paper aims to develop a Cognitive Radio (CR) network test-bed including an Android application as a platform and a cloud-based routing to transfer files via Wi-Fi Direct Technology and save a copy of the route taken as a log file in the cloud.

II. THE OPTIMUM ROUTING PROTOCOL SELECTION

There are many routing protocols available for ad hoc CR networks including, Ad-hoc On-demand Distance Vector (AODV), Dynamic Source Routing (DSR), Destination-Sequenced Distance Vector (DSDV), Optimum Link State Routing (OLSR), and Bellman Ford [10-18].

The protocols have their pros and cons as shown in Table 1. The protocol needs to be chosen to ensure optimum routing path and less energy consumption. Hence, OLSR is best suited for this research involving ad-hoc CR network with mobile devices. Besides, OLSR is suitable to implement in most of the android based mobile devices for wireless services.

Table 1
Routing Protocol Comparison

Features/Protocols	REACTIVE PROTOCOLS		PROACTIVE PROTOCOLS	
	AODV	DSR	OLSR	DSDV
Stability		✓	✓	
Delay(high)	✓		✓	✓
High Mobility	✓	✓		x
Routing Load (less)			✓	✓
Efficient Route Maintainance	x		✓	
Performance	✓		✓	✓
Throughput	✓		x	
Loop Free	✓	✓	✓	✓
Scalability	x	x	x	x
Routing Metrics	Fastest & shortest path	Shortest path	Shortest path	Shortest path
Reliability	✓	✓	✓	✓

III. THE SYSTEM MODEL

We considered 10 stationary access points (APs) as primary users (PUs), who are fixed in their specific location and the SU can change their locations as per need. The PUs' has 13 specified 2.4 GHz dedicated channels for their own use, which are non-identical to avoid inter-channel interference. The Android-based smartphones and tablets are considered as SUs. APs are located at various distances from the SUs with multiple hops.

For experiments, we assumed noise floor between -45 dBm to -100 dBm, which includes clean sunny weather to harsh weather (heavy rain with thunderstorm). Figure 1 shows the overall system scenario, whereas Figure 2 shows the system workflow.

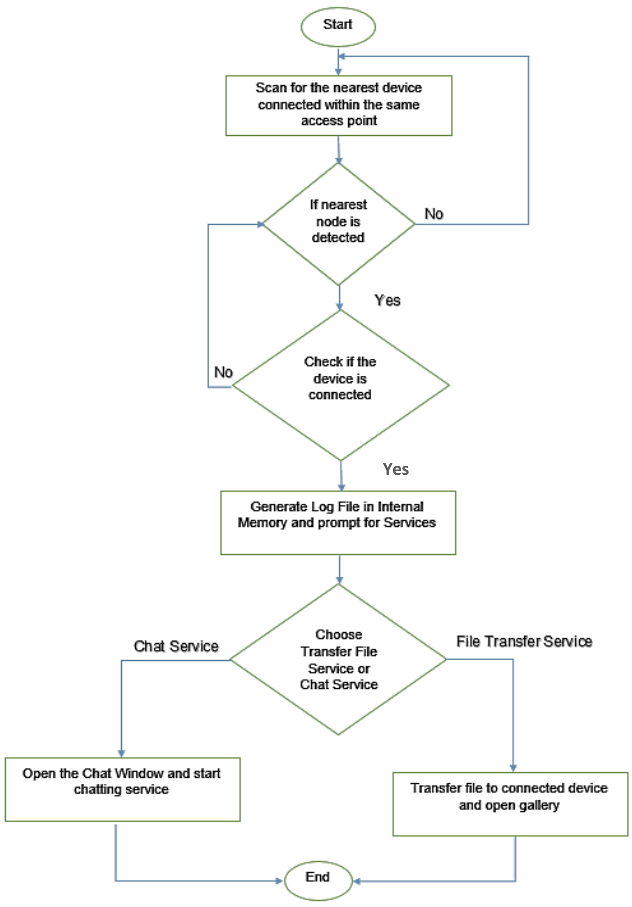

Figure 2: Overall system flow

IV. ANDROID SDK

To create a new application in Android Platform, Software Development Kit (SDK) is needed. The SDK consists of an extensive collection of advancement resources including a debugger, libraries, a tool emulator predicated on test guideline, QEMU, files, and lessons. The developed SDK application is simulated first in PC environment to find its efficiency before uploaded to smartphones and tablets. The programs comprise of computer systems running Linux software and Android java editor (Eclipse using the Android developing Tools (ADT)) [3]. The simulation flow is shown in Figure 3.

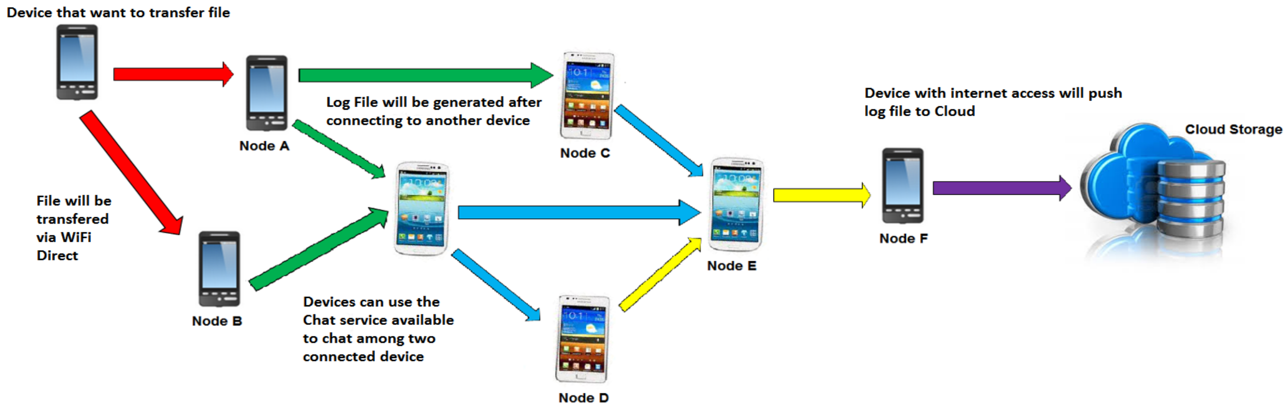

Figure 1: System Overview

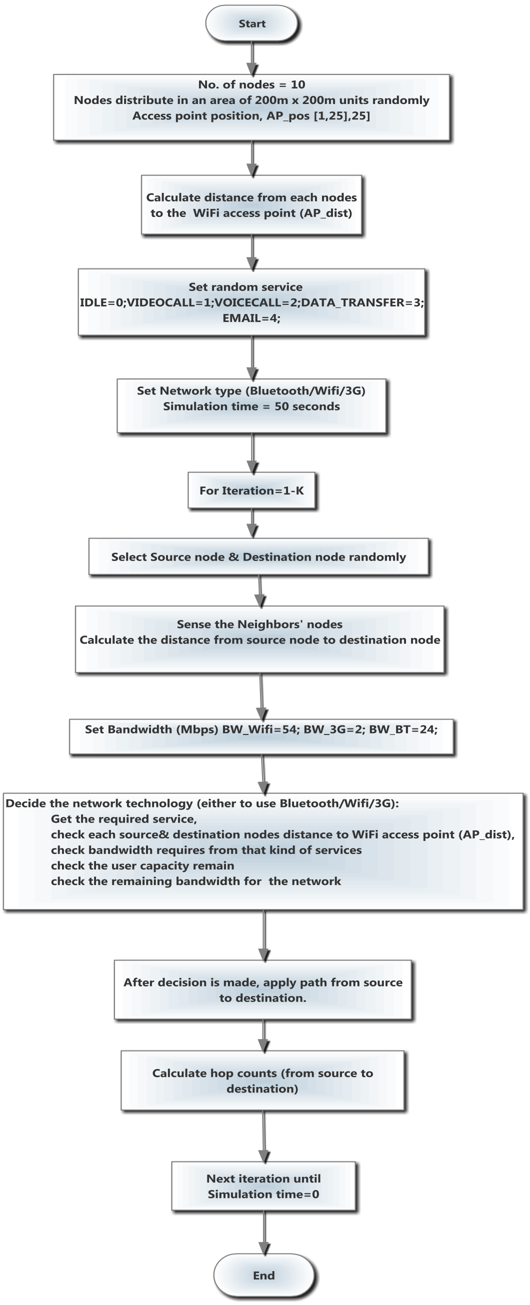

Figure 3: Application platform development flow using SDK

V. Experiments and Measurements

The experimental set-up scenario is shown in Figure 4. We used 10 WLAN access points (AP) as PU, and 8 smartphones & two tablets as SU set in an indoor (lab building) and outdoor (open playground) environment alternately. All the SU devices are equipped with developed application platform Graphical User Interface (GUI). The developed application package was installed on smartphones and tablets. The measurements (applications/services) include received signal strength (RSS), neighbour nodes detection, log file generation, multihop file transfer, chat service, and route to the cloud (cloud storage). They were measured in the CR network in terms of 10 'Trials' repeatedly for a particular experimental set-up. The experiments were repeated 10 times for each application at three different time duration (Clear/sunny morning, Cloudy noon, and Clear evening) on three different days and saved the detection rate accordingly. Finally, we calculated the average for all values and plotted to compare for the different attempt.

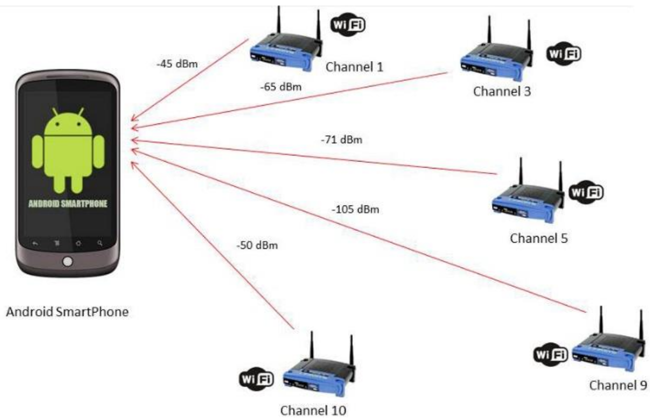

Figure 4: Experimental system model for cognitive radio detection and routing

VI. Results and Discussions

For channel detection and communication in CR network, the similar techniques as in [1-5, 16-18] are used in our test-bed as shown in Figure 4. Channel detection for SU's use is shown in Figure 5.

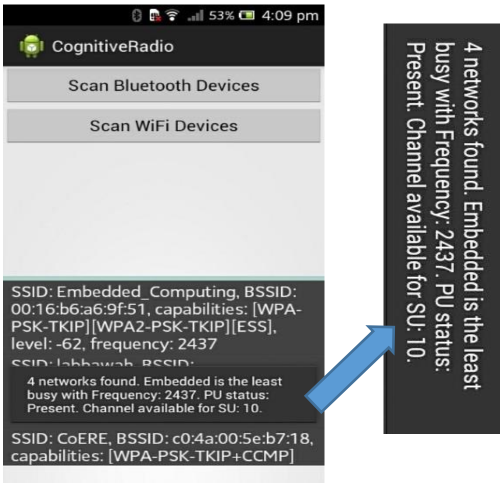

Figure 5: Main GUI of application

The application discovers nearby devices which are connected to the same WiFi access point to establish a peer-to-peer (p2p) CR network to communicate with them directly. It displays the user's Device name, its availability status and the nearby discovered devices as shown in Figure 6 with peering confirmation.

By clicking at a neighbor device with whom a user wishes to communicate, he/she can view all the necessary information about the neighboring device including MAC Address, Name, Primary Type, Secondary Type, WPS, Status, Group Owner Address, Interface Address, just by selecting it from the list. Then, able to communicate with it through Connect and Disconnect as shown in Figure 6.

Figure 6: GUI with discovered devices information

Clicking Connect button, the connection can be established and a log file will be generated along with a popped message that pops up notifying "Log File Generated" as in Figure 7. This log file is stored in internal memory of the device. Internal memory was chosen because it is safe to use.

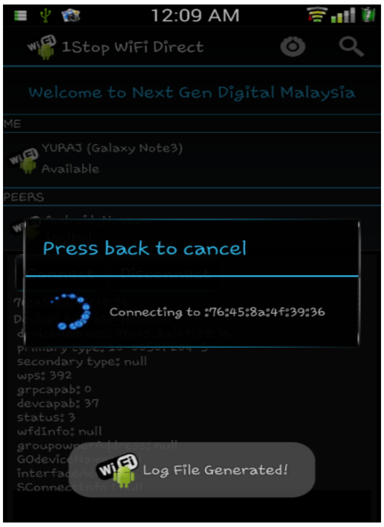

Figure 7: Log file is generation

The created log file named LogFile.txt is in text file format. For every new connection, log files are generated with relevant information of the connected devices. A record is created for all the connected devices with necessary information of the device such as Connected time and date, Device MAC Address, Device Name, Primary Type, Secondary Type, etc as in Figure 8. A channel detection log file (As per Figure 5) is shown in Figure 9.

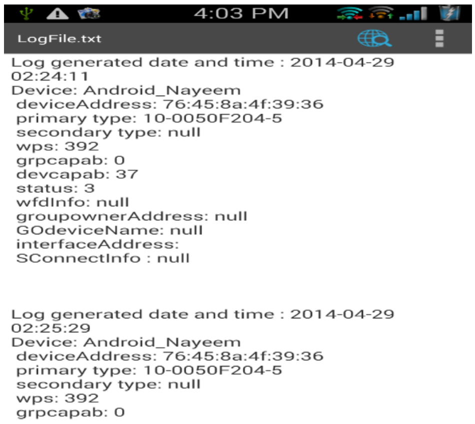

Figure 8: Connected devices details recorded in Log File

Figure 9: Channel detection record in Log File

This application supports node to node or multi-hop communication. A device with data to transfer, first, discovers its nearby neighbors and optimum routing information using OSLR routing protocol. Establishes a connection with the nearest node along the route, then sent the file to it. These steps are repeated with all the discovered nearby devices for each node to perform a multi-hop communication. The file transfer service in this application has been tested using image files only.

Four functions 'Disconnect', 'Transfer', 'Chat' and 'Dbox' pops-up to connected users as in Figure 10. Clicking on 'Transfer' button, the user is able to select and transmit files to a destination with a log-file stored in internal memory.

Figure 10: Transfer button will navigate to Gallery

Here, 'Chat' service supports one to one communication to send short messages to connected users. It works similar to 'Transfer' function.

The generated log files are routed and stored in the cloud for record and security measures. This service can also operate as a stand-alone application. It is called by the main application as a part of the function call.

When The Dbox button is clicked, the application navigates to Dropbox login interface for user authentication purpose. After authenticating, the log files are routed and uploaded to cloud storage automatically and transparently as in Figure 11.

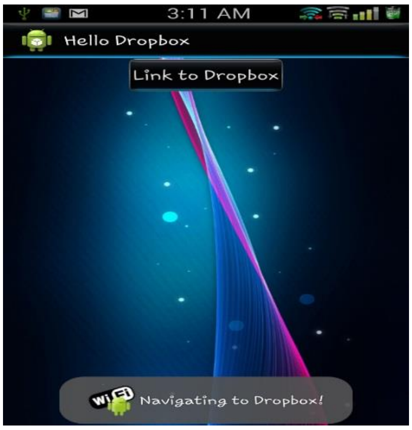

Figure 11: Dropbox Interface

Table 2 shows the percentage of successful system performances against a number of 10 trials conducted in one of the experimental set-ups at a specific time of a day (Cloudy noon). Here, 'Cloud Storage' means 'Cloud-based Routing' or route the log files to cloud storage using efficient OLSR routing protocol. System performance efficiency is determined by each successful launch of services in the system. In Table 1, trial number 6 shows 0% success (total failure) and forced close during the launch of the applications due to harsh weather. The average efficiency of this set-up (for all applications) with 10 trials is around 88.6%

Table 2
Experimental Application Efficiency in a Setup

Types of Service/ No fo trials (Success)	1	2	3	4	5	6	7	8	9	10
Discovery Service	✓	✓	✓	✓	✓	x	✓	✓	✓	✓
Device Information Display	✓	✓	✓	✓	✓	x	✓	✓	✓	✓
Log File Generation	✓	✓	✓	✓	✓	x	✓	✓	✓	✓
Connect Device	✓	✓	✓	✓	✓	x	✓	✓	✓	✓
Multihop File Transfer	✓	✓	✓	✓	✓	x	✓	✓	✓	✓
Chat Service	✓	x	x	x	x	x	x	x	✓	✓
Cloud Storage	✓	✓	✓	✓	✓	x	✓	✓	✓	✓
Percentage	100	86	86	86	86	0	86	86	100	100

Successful	✓
Failure	x

Each function/service (in Table 2) was tested for 10 times. Hence, there was a total number of 100 testing including 10 trials with 10 times repetition of each trial to verify the efficiency of the system. Most of the tests were successful (more than 50%) as shown in Figure 12, the average system efficiency per trial (The average of 10 repetitions for each trial). These average values for all services/applications varies from 85% to 100%. It also shows the average efficiency trend of this system, which varies from 89% to 95%. Thence, the overall (average of all trials with all applications) system efficiency is around 92% showing the workability of the practical CR network.

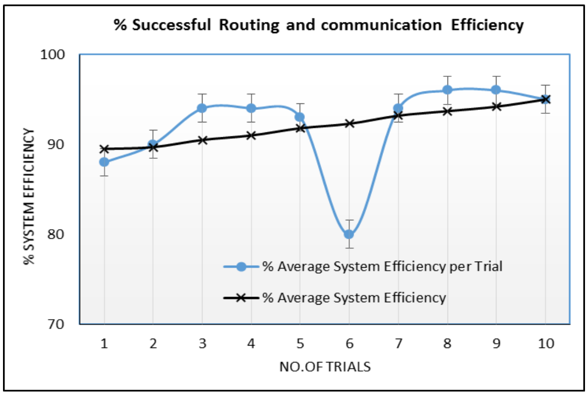

Figure 12: Average System Efficiency

VII. Conclusion

An ad-hoc based CR network test-bed was developed with successful implementation using Android smartphones. A simple Android application platform with GUI was created to run on these devices in the network.

The OLSR protocol with a tweaking appeared as the best routing protocol in terms of energy and bandwidth efficient for Wi-Fi Direct communication among Android devices in CR network. Log files that contain necessary networking information about connected devices were generated and saved in cloud successfully. This could be useful for identification in case of security breaches where a third-party device tries to tap data during the transfer process. This is convenient within the same community such as companies or universities where all the nodes (users) are connected to the same access point. Users are able to transfer important files or push a file to cloud where everyone can access the file and send quick messages simultaneously.

ACKNOWLEDGMENT

This work was supported by University Malaysia Pahang (www.ump.edu.my) with short Grant No. RDU170333, and University Malaysia Perlis (www.unimap.edu.my).

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