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Wi-Fi Mesh Router Integrated with Disruption Tolerant Network Protocol Support

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June 2015

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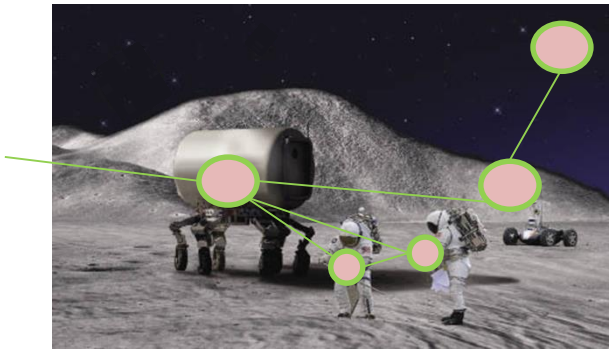
Index

Introduction.....2
Procedure 3-5
Final Result 6
Discussion/Implications.....7
Next Tasks 7
References.....8
Appendices..... 9-13

Introduction

Emerging mesh protocols enable IEEE 802.11 to provide proximity communication links in locations that do not have pre-deployed dedicated communication infrastructure.



Disruption Tolerant Networking (DTN) is used to provide end-to-end reliability when the retransmission path contains network nodes that are not constantly connected, and bandwidth is at a premium.

An integrated DTN Mesh would provide reliable communication coverage for mobile and power-conserving assets. Inexpensive wireless routers with OpenWRT firmware along with network-attached storage devices can be used to develop and demonstrate the functionality of integrating DTN nodes into a mesh.

Disruption Tolerant Network:

DTN is a networking architecture that is designed to provide communications in the most unstable and stressed environments, where the network would normally be subject to frequent and long-lasting disruptions and high-bit error rates that could severely degrade normal communications. In such environments, traditional IP protocols (such as TCP/UDP) do not work well if at all.

DTN is based on Bundle Protocol (RFC 5050). BP resides at the application layer of some number of constituent nodes, forming a store-and-forward overlay network. The basic idea behind DTN network is that endpoints aren't always continuously connected.

Disruption Tolerant Networks are frequently used in disaster relief missions, peace-keeping missions, and inter vehicular networks. Most recently NASA has tested DTN technology for spacecraft communications.

Mesh Network:

Mesh routers provide point-to-point and point-to-multipoint connectivity. Mesh routers automatically discover the best path between end-points. A mesh router creates a connection to one or more other wireless mesh routers to allow data to be passed between them. A mesh router link potentially provides greater redundancy because it assumes a certain degree of dynamic change in the environment.

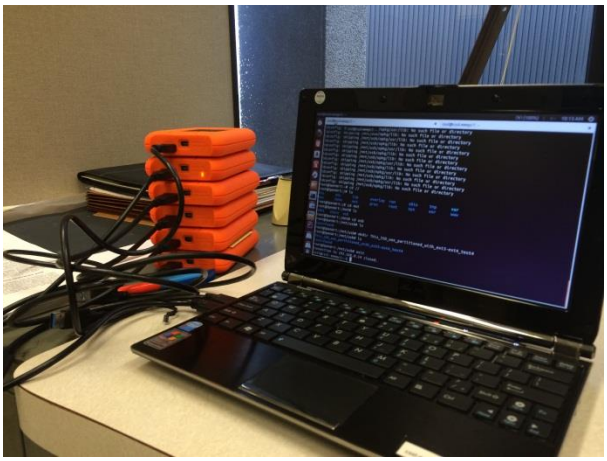
Our routers have been modified by replacing the original firmware and installing OpenWRT; basically, routers are running Linux, and this will allow us to program the routers for our own purpose. The routers have been programed to run IBR-DTN implementation of the bundle

protocol RFC5050. Ext3/ext4 partitions have been made to hard drives in order to store files and save packages and bundles from the router to the hard drive.

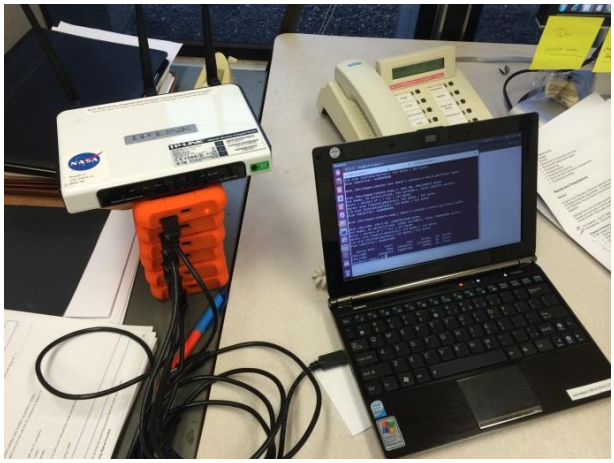
Procedure

This project consisted of four steps. Formatting external hard drives, downloading and installing required packages, programming the routers, and testing the network.

The hard drives have been partitioned with ext3/ext4 because that file system is compatible with OpenWRT. Our routers have USB ports, but since we modify the original firmware, additional procedures are necessary to be able to see the hard drive content while connected to the router. This can be done installing some packages that will be necessary to read the hard drive. Appendix A contains the guide that we wrote to make ext3/ext4 partitions and to install the required packages to read the hard drive from the router.



Partitioning the hard drives.



Preparing the router to read our hard drives.

Now our hard drives have solid states drives of one hundred twenty gigabytes attached to them. This allows us to install as many packages as we want.

We used IBR-BTN as a component for the programming of our routers. IBR-DTN is an open source implementation of the bundle protocol RFC5050 designed for embedded systems. IBR-DTN can be used as framework for DTN applications. IBR-DTN for Android is available from the Play Store. With that application cell phones can send messages back and forward conditioned to be connected to the same SSID. If they are connected to different SSID networks, the message will never get to the desired destination. Also if one phone is trying to send a message to a phone that is not connected to the network, the phone will hold the message until the other phone joins the network. It is necessary for the phone that is holding the message to stay connected to the network.

The purpose of this project was to program the routers in the way that phones can connect to different SSIDs network and make the routers find the location of the cell phones and forward the message from one router to other until finding the destination. Also, routers are programmed to store the message in case the destination is not connected to any of the routers.

Doing this now, it is not necessary for the phone (which was holding the message) to stay connected to the network, because now the routers are the ones holding the message bundles. The configuration script running in our TP-1043 routers is available in Appendix B.

```
cssl@cssl-eeepc1: ~                                                    2:11 PM
Get:7 http://download.opensuse.org/repositories/home:/j_morgenroth/xUbuntu_12.10/ ./ ibrdtn-tools 0.10.1 [130 kB]
Fetched 1,476 kB in 6s (219 kB/s)
Selecting previously unselected package dtndht1.
(Reading database ... 241315 files and directories currently installed.)
Unpacking dtndht1 (from .../dtndht1_0.2.3_i386.deb) ...
Selecting previously unselected package libnl-nf-3-200:i386.
Unpacking libnl-nf-3-200:i386 (from .../libnl-nf-3-200_3.2.7-4_i386.deb) ...
Selecting previously unselected package libnl-cli-3-200:i386.
Unpacking libnl-cli-3-200:i386 (from .../libnl-cli-3-200_3.2.7-4_i386.deb) ...
Selecting previously unselected package ibrcommon1.
Unpacking ibrcommon1 (from .../ibrcommon1_0.10.1_i386.deb) ...
Selecting previously unselected package ibrdtn1.
Unpacking ibrdtn1 (from .../ibrdtn1_0.10.1_i386.deb) ...
Selecting previously unselected package ibrdtnd.
Unpacking ibrdtnd (from .../ibrdtnd_0.10.1_i386.deb) ...
Selecting previously unselected package ibrdtn-tools.
Unpacking ibrdtn-tools (from .../ibrdtn-tools_0.10.1_i386.deb) ...
Processing triggers for ureadahead ...
ureadahead will be reprofiled on next reboot
Setting up oracle-java7-installer (7u25-0~webupd8~1) ...
Downloading Oracle Java 7...
--2013-10-22 14:09:39--  http://download.oracle.com/otn-pub/java/jdk/7u25-b15/jdk-7u25-linux-i586.tar.gz
Resolving download.oracle.com (download.oracle.com)... 184.51.206.104, 184.51.206.195
Connecting to download.oracle.com (download.oracle.com)|184.51.206.104|:80... connected.
HTTP request sent, awaiting response... 302 Moved Temporarily
Location: https://edelivery.oracle.com/otn-pub/java/jdk/7u25-b15/jdk-7u25-linux-i586.tar.gz [following]
--2013-10-22 14:09:40--  https://edelivery.oracle.com/otn-pub/java/jdk/7u25-b15/jdk-7u25-linux-i586.tar.gz
Resolving edelivery.oracle.com (edelivery.oracle.com)... 23.5.246.140
Connecting to edelivery.oracle.com (edelivery.oracle.com)|23.5.246.140|:443... connected.
HTTP request sent, awaiting response... 302 Moved Temporarily
Location: http://download.oracle.com/otn-pub/java/jdk/7u25-b15/jdk-7u25-linux-i586.tar.gz?AuthParam=1382469100_6b07185b86ff5aa5eadaf8f11
53c643e [following]
--2013-10-22 14:09:40--  http://download.oracle.com/otn-pub/java/jdk/7u25-b15/jdk-7u25-linux-i586.tar.gz?AuthParam=1382469100_6b07185b86
ff5aa5eadaf8f1153c643e
Connecting to download.oracle.com (download.oracle.com)|184.51.206.104|:80... connected.
HTTP request sent, awaiting response... 416 Requested Range Not Satisfiable

    The file is already fully retrieved; nothing to do.

Download done.
Removing outdated cached downloads...
sha256sum mismatch jdk-7u25-linux-i586.tar.gz
Oracle JDK 7 is NOT installed.
dpkg: error processing oracle-java7-installer (--configure):
 subprocess installed post-installation script returned error exit status 1
Setting up dtndht1 (0.2.3) ...
Setting up libnl-nf-3-200:i386 (3.2.7-4) ...
Setting up libnl-cli-3-200:i386 (3.2.7-4) ...
Setting up ibrcommon1 (0.10.1) ...
Setting up ibrdtn1 (0.10.1) ...
Setting up ibrdtnd (0.10.1) ...
Setting up ibrdtn-tools (0.10.1) ...
Processing triggers for libc-bin ...
ldconfig deferred processing now taking place
Processing triggers for ureadahead ...
```

Installing IBR-DTN in our routers.

```
cssl@cssl-eeepc1: ~                                   cssl@cssl-eeepc1: ~
#####################################
# static connections
#####################################

config 'static-connection'
        option uri                      dtn://node-five.dtn
        option address          192.168.0.11
        option port                     4556
        option protocol         tcp
        option immediately      yes

#config 'static-connection'
#       option uri                      dtn://node-ten
#       option address          10.0.0.10
#       option port                     4556
#       option protocol         udp
#       option immediately      no


#####################################
# convergence layer configuration   #
#####################################

#
# You can specify an multicast address to listen to for discovery announcements.
# If no address is specified the multicast equivalent of broadcast is used.
#
config 'daemon' 'discovery'
        option address          224.0.0.142
- ibrdtn 74/177 41%
```

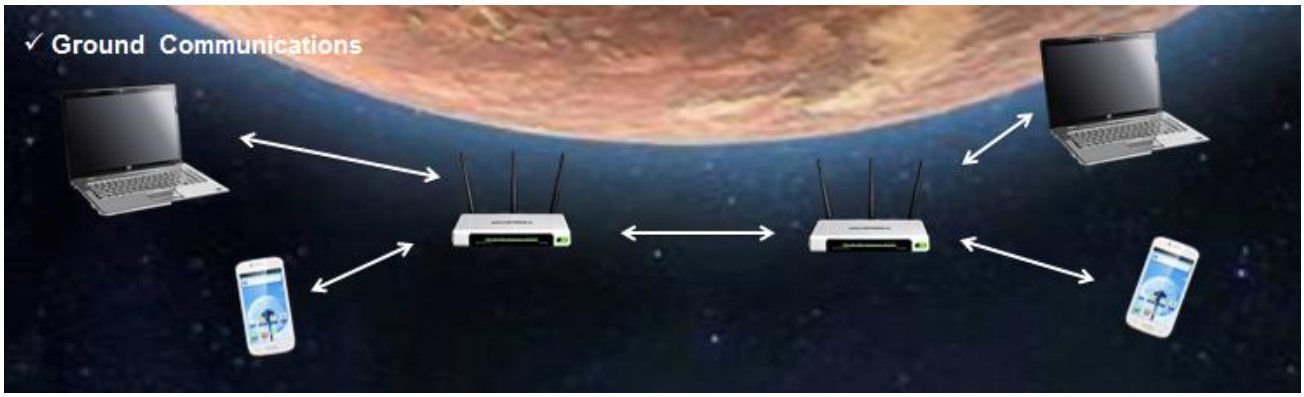
Making the configuration for the network.

```
#####################################
root@OpenWrt:/# /etc/init.d/ibrdtn start
running dtnd ... done
root@OpenWrt:/# /etc/init.d/ibrdtn stop
stopping dtnd ... done
root@OpenWrt:/# dtnd -c /tmp/ibrdtn.config
Thu Oct 31 16:24:03 2013 INFO Configuration: Configuration: /tmp/ibrdtn.config
Thu Oct 31 16:24:03 2013 INFO NativeDaemon: IBR-DTN daemon 0.10.1 (build 12a0490)
Thu Oct 31 16:24:03 2013 INFO Configuration: Configuration: /tmp/ibrdtn.config
Thu Oct 31 16:24:03 2013 INFO BundleCore: Local node name: dtn://OpenWrt
Thu Oct 31 16:24:03 2013 INFO BundleCore: Forwarding of bundles enabled.
Thu Oct 31 16:24:03 2013 INFO NativeDaemon: using simple bundle storage in /tmp/ibrdtn/bundles
Thu Oct 31 16:24:03 2013 INFO NativeDaemon: using BLOB path: /tmp/ibrdtn/blobs
Thu Oct 31 16:24:03 2013 INFO SimpleBundleStorage: 15 Bundles restored.
Thu Oct 31 16:24:03 2013 INFO NativeDaemon: API initialized using tcp socket: loopback:4550
Thu Oct 31 16:24:03 2013 INFO NativeDaemon: TCP ConvergenceLayer added on br-lan:4556
Thu Oct 31 16:24:03 2013 INFO NativeDaemon: TCP ConvergenceLayer added on mesh0:4556
Thu Oct 31 16:24:03 2013 INFO DiscoveryAgent: listen to [ff02::142]:4551
Thu Oct 31 16:24:03 2013 INFO DiscoveryAgent: listen to [224.0.0.142]:4551
Thu Oct 31 16:24:03 2013 INFO DiscoveryAgent: add interface br-lan
Thu Oct 31 16:24:03 2013 INFO DiscoveryAgent: add interface mesh0
Thu Oct 31 16:24:03 2013 ERROR IPNDAgent: join failed on br-lan; 99: setsockopt()
Thu Oct 31 16:24:03 2013 ERROR IPNDAgent: join failed on mesh0; 99: setsockopt()
Thu Oct 31 16:24:03 2013 INFO NativeDaemon: Using epidemic routing extensions
Thu Oct 31 16:24:03 2013 INFO EpidemicRoutingExtension: Initializing epidemic routing module
p
cssl@cssl-eeepc1: ~
root@OpenWrt:/# /etc/init.d/ibrdtn start
running dtnd ... done
root@OpenWrt:/# /etc/init.d/ibrdtn stop
stopping dtnd .... done
root@OpenWrt:/# dtnd -c /tmp/ibrdtn.config
Tue Oct 29 08:02:22 2013 INFO Configuration: Configuration: /tmp/ibrdtn.config
Tue Oct 29 08:02:22 2013 INFO NativeDaemon: IBR-DTN daemon 0.10.1 (build 12a0490)
Tue Oct 29 08:02:22 2013 INFO Configuration: Configuration: /tmp/ibrdtn.config
Tue Oct 29 08:02:22 2013 INFO BundleCore: Local node name: dtn://OpenWrt
Tue Oct 29 08:02:22 2013 INFO BundleCore: Forwarding of bundles enabled.
Tue Oct 29 08:02:22 2013 INFO NativeDaemon: using simple bundle storage in /mnt/usb/AndroidBundles/tmp/ibrdtn/bundles
Tue Oct 29 08:02:22 2013 INFO NativeDaemon: using BLOB path: /mnt/usb/AndroidBundles/tmp/ibrdtn/blobs
Tue Oct 29 08:02:25 2013 INFO SimpleBundleStorage: 87 Bundles restored.
Tue Oct 29 08:02:25 2013 INFO NativeDaemon: API initialized using tcp socket: loopback:4550
Tue Oct 29 08:02:25 2013 INFO NativeDaemon: TCP ConvergenceLayer added on mesh0:4556
Tue Oct 29 08:02:25 2013 INFO NativeDaemon: TCP ConvergenceLayer added on br-lan:4556
Tue Oct 29 08:02:25 2013 INFO DiscoveryAgent: listen to [ff02::142]:4551
Tue Oct 29 08:02:25 2013 INFO DiscoveryAgent: listen to [224.0.0.142]:4551
Tue Oct 29 08:02:25 2013 INFO DiscoveryAgent: add interface br-lan
Tue Oct 29 08:02:25 2013 INFO DiscoveryAgent: add interface mesh0
Tue Oct 29 08:02:25 2013 ERROR IPNDAgent: join failed on br-lan; 99: setsockopt()
Tue Oct 29 08:02:25 2013 ERROR IPNDAgent: join failed on mesh0; 99: setsockopt()
Tue Oct 29 08:02:25 2013 INFO NativeDaemon: Using epidemic routing extensions
Tue Oct 29 08:02:25 2013 INFO EpidemicRoutingExtension: Initializing epidemic routing module
```

Status of the Disruption Tolerant Network.

Final Result

Phones can send text and voice massage back and forward though the DTN. Phones can be connected to different SSID and they still have communication between them. This is because the router has been programmed for this purpose using a Wi-Fi mesh. This means that one cell phone can send a message to another cell phone and the router will forward the message to the other router in which the cell phone is connected. In case one of the phones were not available in the network at that time, the routers will store the message in its hard drive, and as soon as the client (cell phone) join the network, the router will deliver the message. After cell phone 1 sends the message**,** the router automatically stores the message, meaning that cell phone 1 can leave the network, and the router will be responsible for delivering the message to the respective destination.



Layout of the Disruption Tolerant Network.

Discussion/ Implications

Project goals have been accomplished, but additional configuration was necessary to make routers forward bundles to other routers and finally to the phones. At the beginning we believed that just programming the routers to run IBR-DTN packages was enough for the routers to detect other neighbors running the same packages. To our surprise, the routers were keeping the bundles instead of sending to their neighbors until the bundles found the final destination. To resolve this problem we set static routes with the ip-address of the neighbors available in the DTN network. Next step for this project is to increase bandwidth and since network's configuration needs to be done with Linux, we would like to create visualization with real-time graphics to make a user-friendly network.

Next Tasks

Integration of Linux open-source to provide a visualization tool for IEEE 802.11s (HWMP Hybrid Wireless Mesh Protocol) heterogeneous, mobile, ad-hoc mesh networking. One solution is to develop a "vis" server as has been done for BATMAN.

Objective is to demonstrate an open-source visualization solution for OpenWRT and other Linux platforms**.**

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Michael Doering, Sven Lahde, Johannes Morgenroth and Lars Wolf: *IBR-DTN: an efficient implementation for embedded systems*, in *Proceedings of the Third Workshop on Challenged Networks, CHANTS 2008, San Francisco, California, USA, September 15, 2008*, pages 117-120, September 2008 (DLMW08, BibTeX).

Appendix A. Guide to make ext3/ext4 partition

Identify the device boot (sda, sda1…5, sdb1). As sudo, you can get this information typing fdisk –l, and now you are able to see all the devices connected to the computer, you must identify correctly which one you want to modify with Ext3 partition. For our hard drives, the name of the device is sdb. If you have more than one storage device connected to the USB port of the computer, this name probably will change.

After identifying the device you desire to modify, run fdisk {path to your device provided by fdisk –l}. (Example: sudo fdisk /dev/sdb)

The following commands will be helpful to make a good partition:

d –delete a partition
l –list known partition types
n –add a new partition
p –print the partition table
q –quit without saving changes
t –change the partition table
u –change display/entry units
v –verify the partition table
w –write table to disk and exit

Verify (v) for any partition in the device. Partition Id should be 83-Linux, and if that partition Id is not listed in the table, proceed to delete all partition in the device using d command.

Fdisk works with sectors, change that to cylinders using “u” and this will make the process more kind and allow us to talk in terms of gigabytes.

Now to create a new partition type “n”, press “p” to create a primary partition and choose 1 as partition number.

Leave the first cylinder as the default value, but set the last cylinder as the one that you desire. Since the capacity of our hard drives are 120GB, a good value for the last cylinder will be 119GB (type “ +119G”).

Create another partition, and this one will be the swap area; leave all the values to be the default ones, and hit <ENTER> a couple of times.

Type “p” to see the partition table, confirm that the System Id is Linyx 83. If not, change this using “t”.

Write “w” to exit.

Disconnect and connect the device from the computer. Now you need to create the file-system on the drive.

sudo mkfs –t ext4 /dev/sdb1
Now run a check on the drive, and enter it into your fstab so that the drive mounts each time you plug-in to the router.

sudo fsck –f –y /dev/sdb1

Preparing the router to read hard drives:
opkg update
opkg install kmod-usb2
insmod ehci-hcd

If you see messages like unresolved symbol usb_calc_bus_time, try loading usbcore and then try ehci-hcd again:
opkg update
insmod usbcore
insmod ehci-hcd

Appendix B. Script for configuration of Routers

```
#######################################
# IBR-DTN daemon                      #
#######################################
config 'daemon' 'main'
# The local eid of the dtn node. Default is the hostname.
option uri            dtn://android102.dtn
   # timezone offset in hours
#    option timezone        +1
    # logfile for standard output
    option logfile        /tmp/ibrdtn.log
    option errfile        /tmp/ibrdtn.err

 # debug level
#    option debug        20

 # block size limit
#    option blocksize        512M
#    option foreign_blocksize    128M
# If something bad happened, the safe mode will be activated.
# These are the restrictions for safe mode only.
#
config 'daemon' 'safemode'
    option forwarding    no
    option storage        64M
    option maxblock        16M
#    option wait_mount    /dev/sda1
#######################################
# storage configuration               #
#######################################
config 'daemon' 'storage'
    # possible engines are: simple, sqlite
    option engine        simple
```

```
    option blobs        mnt/usb/AndroidBundles/tmp/ibrdtn/blobs
    option bundles    mnt/usb/AndroidBundles /tmp/ibrdtn/bundles
#    option container    /tmp/ibrdtn/container.img
#    option path            /tmp/ibrdtn/container
#    option limit        1G
######################################
# routing configuration            #
######################################
#
# In the "default" the daemon only delivers bundles to neighbors and static
# available nodes. The alternative module "epidemic" spread all bundles to
# all available neighbors.
#
config 'daemon' 'main'
    # values: none | default | epidemic | flooding | prophet
    option    routing        epidemic
    option    forwarding    yes
#
# static routing rules
# - a rule is a regex pattern
# - format is <target-scheme> <routing-node>
#
#config 'static-route'
#    list pattern        ^dtn://[[:alpha:]].moon.dtn/[[:alpha:]]
    option destination    dtn://android-5acfdb8f.dtn
######################################
# static connections
######################################
config 'static-connection'
    option uri            dtn://node-five.dtn
    option address        192.168.0.11
    option port            4556
    option protocol        tcp
    option immediately    yes

#config 'static-connection'
#    option uri            dtn://node-ten
#    option address        10.0.0.10
#    option port            4556
#    option protocol        udp
#    option immediately    no


######################################
# convergence layer configuration   #
######################################
#
# You can specify an multicast address to listen to for discovery announcements.
# If no address is specified the multicast equivalent of broadcast is used.
#
config 'daemon' 'discovery'
   option address        224.0.0.142
```

```
   option timeout        5
   option crosslayer    yes
config 'daemon' 'tcptuning'
#    option 'idle_timeout'    120
#    option 'nodelay'        yes
#    option 'chunksize'        4096
config 'network'
    option type            tcp
    option interface    br-lan
    option port            4556
#config 'network'
#    option type            tcp
#    option interface    wlan0
#    option port            4556
#######################################
# bundle security protocol          #
#######################################
#
# the level specifies the security constains
#
# 0 = no constrains (default)
# 1 = accept only BAB authenticated bundles
# 2 = accept only encrypted bundles
# 3 = accept only BAB authenticated and encrypted bundles
#
#config 'daemon' 'security'
#    option level        0
#    option bab_key        /path/to/default-bab-key.mac
#    option key_path        /path/to/security-keys
#config 'daemon' 'tls'
#    option certificate    /path/to/tls-cert.crt
#    option key            /path/to/tls-key.key
#    option trustedpath    /path/to/tls-ca
#    option required        no
#    option noencryption no
#######################################
# time synchronization              #
#######################################
#config 'daemon' 'timesync'
#    option reference        yes
#    option synchronize        yes
#    option discovery_announcement    yes
#    option sigma            1.001
#    option psi            0.9
#    option sync_level        0.1
#######################################
# DHT                               #
#######################################
config 'daemon' 'dht'
    option 'enabled'    'no'
#    option 'id'        '<enter your unique id here>'
    option 'bootstrap'    'yes'
```

```
#    option 'nodesfile'    '/tmp/dht_nodes.dat'
    option 'port'         '9999'
    option 'enable_ipv6'    'no'
#    option 'enable_ipv4'    'no'
#    option 'bind_ipv4'    '127.0.0.1'
#    option 'bind_ipv6'    '::1'
    option 'ignore_neighbour_informations'        'yes'
    option 'allow_neighbours_to_announce_me'    'yes'
    option 'allow_neighbour_announcement'        'yes'
```

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13. ABSTRACT *(Maximum 200 words)*
Emerging mesh protocols enable IEEE 802.11 to provide proximity communication links in locations that do not have pre-deployed dedicated communication infrastructure. Disruption Tolerant Networking (DTN) is used to provide end-to-end reliability when the retransmission path contains network nodes that are not constantly connected, and bandwidth is at a premium. An integrated DTN Mesh would provide reliable communication coverage for mobile and power-conserving assets. Inexpensive wireless routers with OpenWRT firmware along with network-attached storage devices can be used to develop and demonstrate the functionality of integrating DTN nodes into a mesh. This project consisted of four steps. Formatting external hard drives, downloading and installing required packages, programming the routers, and testing the network.

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