Disruption Tolerant Networks in UnetStack

Design Document

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Everything in this DD is Work In Progress!

Code snippets are just for illustration and are a mix of Java/Groovy with pseudocode

Overview

Disruption Tolerant Networks (DTNs) are used in a number of applications where conventional communication schemes are inadequate due to erratic network conditions, lack of network infrastructure, or long propagation delays in the communication medium.

In this project, we are attempting to use an adaptation of DTN protocols to improve message delivery in underwater networks using the UnetStack software platform. We are developing the protocol to target certain scenarios in which DTNs can have appreciable improvements in the network performance.

Use Cases

- Robotic SWANs are used for collecting marine data through the use of on-board water probes. These SWANs have multiple network interfaces through which data can be transmitted. However, due to inclement weather conditions, it is also possible that no data gets transmitted at all. DTNs can save the day in this case by relaying critical information through nearby nodes which may have better network access. Thanks to the Store-Carry-And-Forward (SCAF) mechanism of DTNs, a SWAN can also wait until network conditions improve to send data.
- Underwater networks can consist of static sensors and an AUV for relaying the data from the sensor. Due to battery limitations, these sensors have constraints on the number of times they can transmit information to an AUV. A protocol which enables the sensor to only send data when it has detected an AUV relay is nearby can help in saving power. From the AUV, the DTN can have the capability to automatically upload the data stored in the AUV's persistent storage to a removable storage device.
- DTNs could be used to help in disseminating information in swarms such as the STARFISH network.

Initial Goals

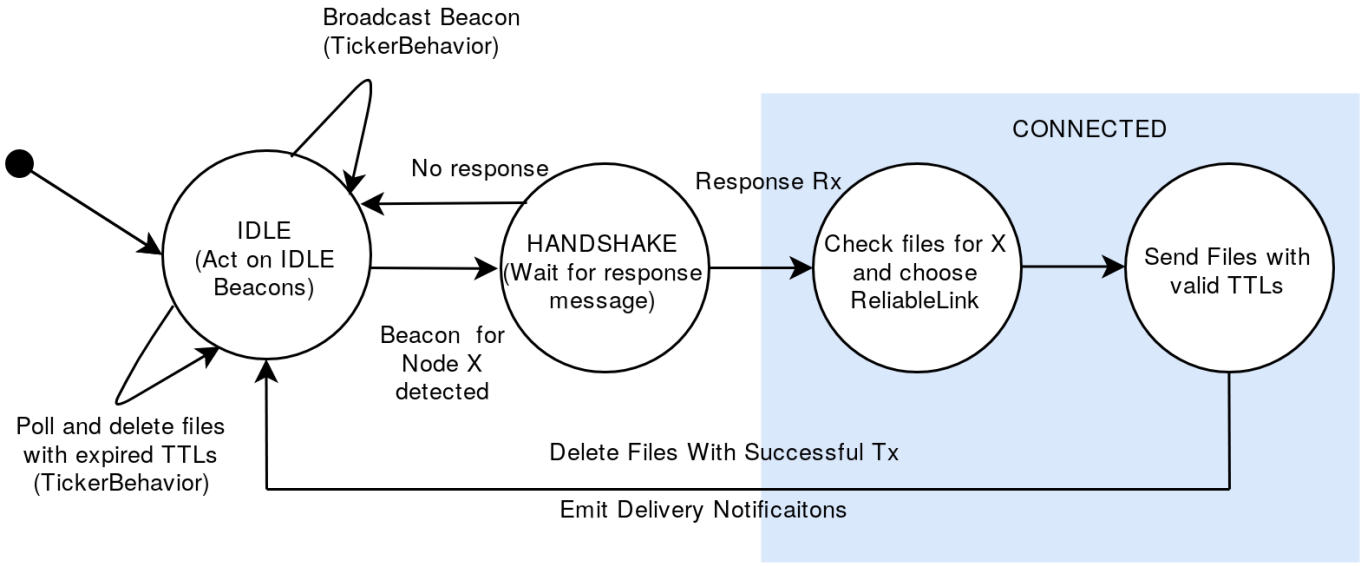
We are relaxing some of the requirements for DTNs for the first iteration of this project. Some of the current goals for the initial design include the implementation of:

- A **Beacon**, to allow nodes to advertise their existence and find other nodes.
- A **Storage** mechanism to allow for SCAF. This should also delete files which have been successfully acknowledged or those which have expired TTLs.
- A **PDU** (which will be wrapped in the DatagramReq) for storing DTN metadata such as TTL.
- A **DTNA** (DTN Agent) which can handle Datagram requests from other agents and send essential notifications about the relay of PDUs.

Goals which will not be covered by the first iteration but which may be covered in the future are:

- Dedicated ACK schemes. Though this is very important in DTNs, we are only focussing on single hop routing and we only need to make sure our message has reached the next hop node. This will be covered by using ReliableLinks for single hops.
- The DTNA should be able to talk over multiple ReliableLinks and should have the capability of choosing the best Link for a certain application.
- Multihop routing of PDUs.
- Dynamic routing protocols.
- Fragmentation and reassembly of large PDUs.
- Multiple copies of PDUs.
- Optimally ordering/prioritizing PDUs for relays between nodes.

Flowchart



Classes

DtnBeacon

The Beacon is a part of the DTNA. Its task is to periodically send a message to advertise the existence of a node to all neighbors by sending an empty DatagramReq with the Recipient set to the DTNA.

Beacons are not explicitly required to advertise the existence of links. The DTNA will snoop for packets sent on all Reliable links connected to it. If we detect a transmission during the beacon interval, then there is no need to send a Beacon on that Link.

DtnPdu

The PDU will hold the data to be transmitted along with the DTN metadata. We need to maintain the TTL and ID along with the data.

Here, the TTL represents the number of seconds left before the PDU expires. Once the PDU has expired, we delete it from persistent storage.

The ID is a nonce for uniquely identifying each PDU for tracking purposes. It is generated on the node which creates the PDU.

```
class DtnPDU extends PDU {
    int pduLength; // FIXME: does this get added to the size of the PDU?

    final int DATA_PDU = 0x01;
    final int SUCCESS_PDU = 0x02;
    final int FAILURE_PDU = 0x03;

    DtnPDU(int length) {
        pduLength = length;
    }

    void format() {
        length(pduLength);
        uint8("type");
        uint32("id");
        uint32("ttl");
        char("data", pduLength-8);
        padding(0xff); // do we really need padding?
    }
};
```

DtnStorage

The DtnStorage class will handle the SCAF mechanism. It will track PDUs, manage storage on the node and will delete expired PDUs.

Each PDU contains a TTL which specifies the time until its expiry. DtnStorage can implement this by having an Sqlite3 database with three columns: PDU ID (Primary Key), Next Hop, and the Expiry Time based on the node's own clock. This database will be stored on the persistent storage.

Alternatively, we can use a HashMap, keyed by the Next Hop node. The value of the key, will have a set of tuples of the PDU ID and Expiry Time.

The PDUs themselves will be serialized to JSON for storage on the node using the Gson library. The filename of this JSON will be the PDU ID. This will make it easier to manage the files with relation to the database entries. All the serialized PDUs will be kept in a separate directory on each node.

When the DTNA finds a new node, it will query the database/data structure for the PDUs destined for the node. Once this is done, the TTLs are checked for expiry. If the PDU is still alive, the PDU's TTL will be reduced by (currentTime - arrivalTime). The agent will then send the PDU over one of the ReliableLinks. It will continue to listen for notifications for the delivery status of the PDUs. If the agent is notified of a successful transmission, the entry is deleted from the database/data structure and the corresponding JSON file is deleted along with it. If the agent receives a notification about delivery failure, it will try retransmitting the PDU periodically while 1) the other node is still "visible" 2) the PDU is Still Alive.

On a periodic basis (with a TickerBehavior), DtnStorage will scan the available files for their TTLs and will delete any files which have expired. The frequency of cleaning old files can probably be adjusted based on the amount of buffer space left on the node. The TTL will come from the application layer.

```
// This will also be an inner class of DTNA!
// should this be allowed to make the DatagramReqs or should that be
offloaded to the DTNA?
class DtnMsg {
    int nextHop;
    long expiryTime;
};

class DtnStorage {

    HashMap<long, DtnMsg> db;
    HashMap<String, long> datagramMap;

    TickerBehavior tb;
    DtnStorage(DTNA agent, int duration) {
        // this may not even be required since we check ttls before sending
anyway
        tb = add new TickerBehavior(agent, duration, {
            deleteExpiredMsgs();
        }
    }

    Set<DtnMsg> getNextHopMsgs(int nextHop) {
        Set<DtnMsg> msgs;
        for (def msg : db) {
            if (currentTime > msg.expiryTime) {
                deleteMsg(msg.id);
                continue;
            }
            if (msg.nextHop == nextHop) {
                msgs.add(msg);
            }
        }
        return msgs;
    }

    void savePdu(DtnPDU pdu) {
        String s = serializePDU(pdu);
        save(s);
        addDbEntry(pdu.get(id), pdu.get(nextHop),
pdu.get(ttl)+currentTime);
    }

    void deleteMsg(int pduId) {
        removeDbEntry(id);
        delete(id);
    }

    void addDbEntry(long id, int nextHop, long expiryTime);
    void removeDbEntry(long id);
    DtnMsg[] deleteExpiredMsgs();
    void deleteMsg(int pduId);
    int bufferFreeCapacity();
```

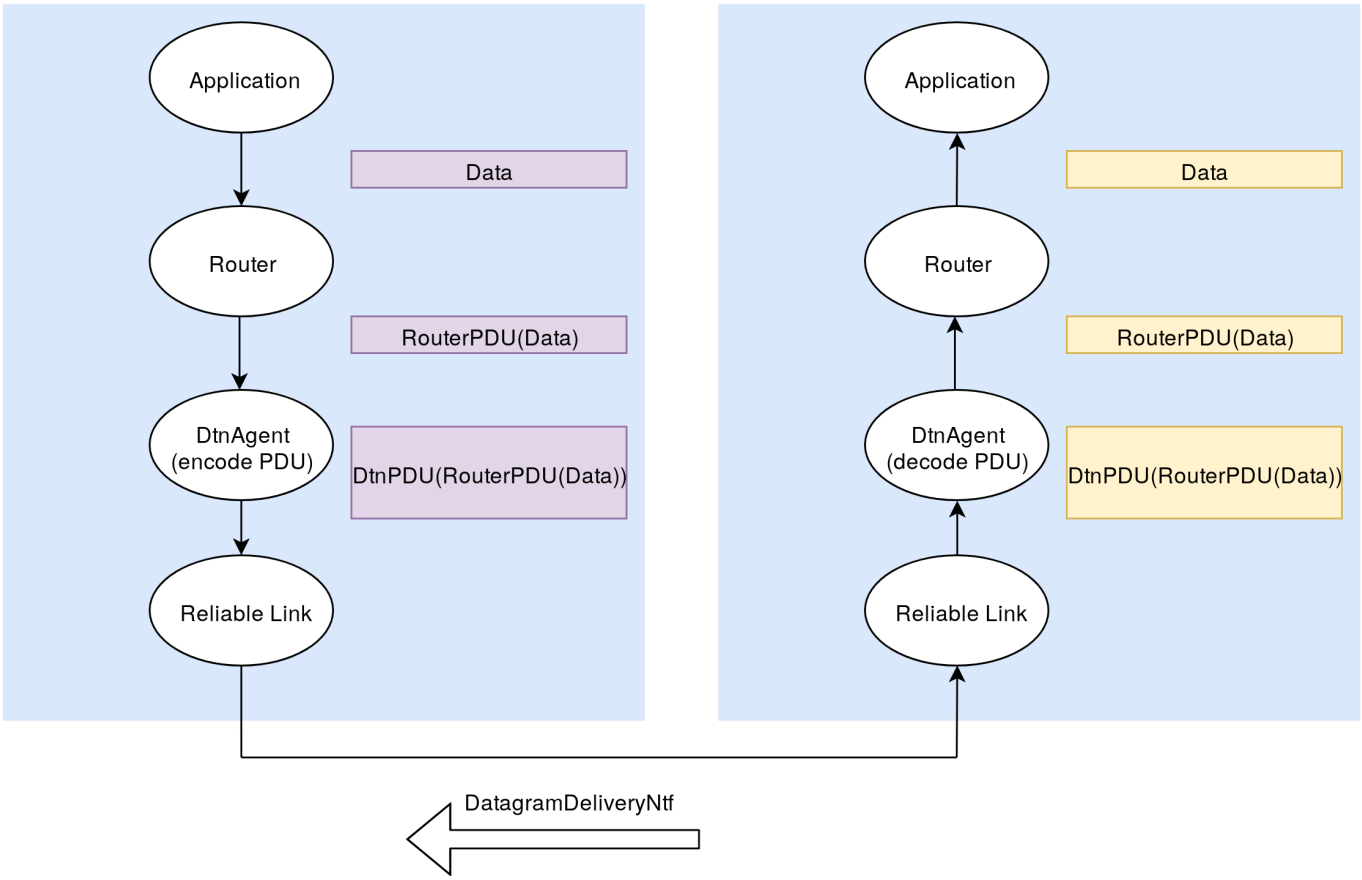
```
    String serializePDU(DtnPDU pdu);
    DtnPDU deserializePDU(String s);
    DtnPDU getPdu(int id);
    DtnMsg[] getNextHopMsgs(int nextHop); // i.e. just the PduIDs
};
```

DTNA

The DTNA is a UnetAgent which contains instances of the above classes. The DTNA will handle the sending of messages, sending and receiving of notifications, and logic for selecting the ReliableLink to be used.

The DTNA will support the Link service. This implicitly means it will have to support the Datagram service as well. However, it will not support the Reliability capability as there is no guarantee that we will receive the notification of a successful delivery. The Agent can only provide delivery notifications on a best effort basis to Datagrams which have Reliability set to null. Datagrams which require Reliability will be refused.

This DTNA will receive Datagrams from the Router. This means the DTNA will not be responsible for routing messages for the time being. It will also receive messages from Reliable links which need to be passed up to the router. The below block diagram illustrates this:



(Yellow == DatagramNtf, Purple == DatagramReq)

For now, we trust the Link to take care of notifications and the resending of payloads. The DTNA will subscribe to these topics to mark PDUs ready for deletion. At the moment, we will only choose to send messages on the first ReliableLink we can find.

NOTE: We only advertise success, not failure! This is because a failed message at one instant may succeed later. But if the TTL of a message expires, we must advertise this.

Future work: If a Datagram cannot be sent on a given link, the Agent will try sending it on the other links until 1) the message is transferred successfully 2) the Beacon message from the receiving node is no longer received 3) all the other options for ReliableLinks have been exhausted. In case 3) it might be beneficial to resend the message at exponentially increasing intervals, or as future work, transfer custody of the message to another node.

!Needs changes!

```
class DTNA extends UnetAgent {

    // These can inner classes / part of the same pkg
    DtnStorage storage;

    AgentID reliableLink;
    AgentID router;
    AgentID notify;

    HashMap<String, long> datagramMap;

    TickerBehavior beacon;
    TickerBehavior sweepStorage;
    int addr;
    final int BEACON_DURATION = 100000; // should this be a param?
    final int STORAGE_DURATION = 100000;

    void setup() {
        register Services.LINK
        register Services.DATAGRAM
    }

    void startup() {
        storage = new DtnStorage(this, STORAGE_DURATION);

        // I'm not really sure if this is required
        phy = agentForService Services.PHYSICAL
        subscribe(phy)
        subscribe(topic(phy, Physical.SNOOP))
        router = agentForService Services.ROUTING

        notify = topic()

        def nodeInfo = agentForService Services.NODE_INFO
        addr = get(nodeInfo, NodeInfoParam.address)

        add new OneShotBehavior({
            getReliableLink();
        })

        beacon = add new TickerBehavior(BEACON_DURATION, {
```

```
            reliableLink << new DatagramReq(channel: Physical.CONTROL, to:
Address.BROADCAST)
        })

        sweepStorage =  add new TickerBehavior(STORAGE_DURATION, {
            def deletedPduIDs = storage.deleteExpiredMsgs();
            // now we need to send failed ntfs for all the deleted msgs
            for (pduId : deletedPduIDs) {
                DtnPDU pdu = new pdu(link.MTU());
                // no data needed for this
                // nor does it need to be added to the tracking map
                def bytes = pdu.encode(type: FAILURE_PDU, id: pduId);
                link << new DatagramReq(data: bytes, to: nextHop);
            }
        })

        // FIXME: How to get the last message sent on a link?
        onSendingMessage:
            beacon.reset();
    }

    void getReliableLink() {
        reliableLinks.clear();
        def links = agentsForService(Services.LINK);
        for (def link : links) {
            CapabilityReq req = new CapabilityReq(link,
DatagramCapability.RELIABILITY);
            Message rsp = request(req, 500); // this could take a while if
we have a lot of links
            if (rsp.getPerformative() == Performative.CONFIRM) {
                subscribe(link);
                reliableLink = link;
                break;
            }
        }
    }

    Message processRequest(Message msg) {
        switch (msg) {
        // FIXME: Need to distinguish DatagramReqs based on the origin
        case DatagramReq:
            if (msg.getReliability() || msg.getTTL() == NaN ||
storage.bufferFull()) {
                return new Message(msg, Performative.REFUSE);
            } else {
                def bytes = msg.getData();
                storage.storeMsg(bytes);
                return new Message(msg, Performative.AGREE);
            }
            return null;
        }
    }

    int getMTU() {
```

```
        return reliableLink.getMTU-8;
    }

    void processMessage(Message msg) {
        switch (msg) {
            // do we need a protocol number
        case RxFrameNtf:
            if (msg.to != addr) {
                // now we know this node is alive!
                // start sending messages residing in the SCAF to it
                def msgs = getMsgsForNextHop(addr);
                for (def msg : msgs) {
                    def bytes = deserializeJSON(msg.id);
                    // TRY REQUEST INSTEAD HERE!!!
                    send new DatagramReq(to: msg.to, data: bytes);
                }
            }
            break;
        case DatagramNtf:
            DtnPDU pdu(reliableLink.getMTU());
            def pduData = pdu.decode(msg.data);
            switch(pduData.type) {
            case DATA_PDU:
                //store data pdus
                // in multihop I'm not too sure what will happen here:
                // but for now we can just send it to router and see what
happens
                // now send the DDN:

                def req = new DatagramReq(data: data)
                router.send(req); // FIXME: ???
                break;
            case SUCCESS_PDU:
                //delete our own copy. Though for now we are dealing with
link level
                // so this may not be needed
                def successfulId = pduData.id;
                break;
            case FAILURE_PDU:
                // not sure what to do here. used when a message for my
node expires
                def failedId = pduData.id;
                break;
            }




            break;
        case DatagramDeliveryNtf:
            // how do we get the message to which it is mapped? ->
inReplyTo
            String s = msg.inReplyTo;
            def pduId = datagramMap.get(s);
```

```
                storage.deleteMsg(pduId);
                // FIXME: Important!
                // should we resend a DtnNtf using the PduID?
                break;
            case DatagramFailureNtf:
                // failing is ok, just as long as ttls aren't exceeded
                // we probably shouldn't need to do anything here
                break;
            }
        }
    };
```

Open Issues

- Does a receiving node need to store the PDU?
- Do all PDUs take all the available size
- what do we tell the other node when a TTL expires?
- Why do DDN's/DFN's have to: set to the sending node?
- Don't send beacon unless you get an AGREE from the layer
- Should DeliveryNtfs be broadcast on a topic?
- Generate a failure when we have TTL exceeded
- What do we do once we receive a DatagramNtf? Do we send it over to router or store it in SCAF? Will Router pass the message up to the App?
    - atm we are bundling it in a DatagramReq and sending it off to Router
- What is the difference between calling a fxn and using a 1-shot behavior?
- How can I print messages in the shell?
- why does unetstack rename all the old files?

Resolved

- how do I subscribe to DDN/DFNs?
    - they are getting sent to shell, but not to my agent for some reason
- DatagramFailedNtf/DatagramDeliveryNtf does not give me information about which DatagramReq it is in response to