PreDA: Predicate Routing for DTN Architectures over MANET

Flavio Esposito
flavio@cs.bu.edu

Ibrahim Matta
matta@cs.bu.edu

Abstract

We consider a Delay Tolerant Network (DTN) whose users (nodes) are connected by an underlying Mobile Ad hoc Network (MANET) substrate. Users can declaratively express high-level policy constraints on how “content” should be routed. For example, content can be directed through an intermediate DTN node for the purposes of preprocessing, authentication, etc., or content from a malicious MANET node can be dropped. To support such content routing at the DTN level, we implement Predicate Routing [1] where high-level constraints of DTN nodes are mapped into low-level routing predicates within the MANET nodes. Our testbed uses a Linux system architecture with User Mode Linux to emulate every DTN node with a DTN Reference Implementation code. In our initial architecture prototype, we use the On Demand Distance Vector (AODV) routing protocol at the MANET level. We use the network simulator ns-2 (re-emulation version) to simulate the wireless connectivity of both DTN and MANET nodes. Preliminary results show the efficient and correct operation of propagating routing predicates. For the application of content re-routing through an intermediary, as a side effect, results demonstrate the performance benefit of content re-routing that dynamically (on-demand) breaks the underlying end-to-end TCP connections into shorter-length TCP connections.

Overall PreDA Architecture

![Architecture Diagram]

Figure 1: Architecture of a PreDA enabled DTN node running over a MANET substrate. In the stack our modified and added components are marked by “stars.”

Declarative approaches have been widely discussed as clean-slate alternative to routing or transport protocols [1, 2]. Our work is the first to enable declarative routing into a DTN architecture overlayed over a MANET substrate.

Predicate Routing Design and Examples

A depicted PreDA packet together with the DTN neighbor discovery extension packet are attached with the HELLO message. Predicate info are disseminated together with DTN EID of newly discovered nodes, their MANET address, and their distance to every other node in the network.

![Predicate Routing Design]

Figure 3: Proposed PreDA packet extension, to propagate with DTN discovery, piggybacked in HELLO messages.

<table>
<thead>
<tr>
<th>Type</th>
<th>8</th>
<th>16</th>
<th>24</th>
<th>32</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predict</td>
<td>5</td>
<td>7</td>
<td>Length</td>
<td>Flags</td>
</tr>
</tbody>
</table>

Example 1: Drop traffic not originated by a White List W of nodes and directed to a node D.

Example 2: Direct all D traffic to an intermediate DTN node I for content authentication.

Predicate Routing in Action on Our UML Testbed

![Graphs]

Figure 4: Data delivered at the destination vs. time for 2% packet loss probability.

Figure 5: Percentage improvement in data delivery time vs. packet loss probability with 95% confidence interval when an authentication predicate is injected.

Figure 6: Throughput results showing the efficient and correct operation of propagating routing predicates. We demonstrate two applications. The first application re-directs content to an intermediary node for pre-processing (Example 2, Figure 4 and 5). We also demonstrate the correct operation of a second application where a malicious node is isolated by dropping all its packets (Example 1, Figure 6).

Summary of Contributions

- We provide a reliable DTN neighbor discovery mechanism that leverages AODV’s HELLO messages to propagate DTN node names. The convergence layer of the DTN stack then maintains the mappings from DTN node names to IP (MANET) node addresses (Figure 1 and 2).
- In addition to DTN node names, AODV’s HELLO messages are also used to propagate low-level MANET routing predicates (Figure 3). These latter predicates are mapped by the convergence layer from given DTN-level requirements on routing content.
- As a proof of concept, we implemented our architecture on our UML based testbed [3] that simulates a network of emulated DTN-MANET nodes as well as MANET-only nodes. The wireless connectivity and mobility of nodes are simulated using the ns simulator (re-emulation version). The emulation uses UML (User Mode Linux) to run real DTN (reference implementation) and MANET (AODV routing) code.
- We present throughput results showing the efficient and correct operation of propagating routing predicates. We demonstrate two applications. The first application re-directs content to an intermediary node for pre-processing (Example 2, Figure 4 and 5). We also demonstrate the correct operation of a second application where a malicious node is isolated by dropping all its packets (Example 1, Figure 6).

References