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The Web and InterNetworking Group

PreDA: Predicate Routing for DTN Architectures over MANET

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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 intermediary 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* (ns-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

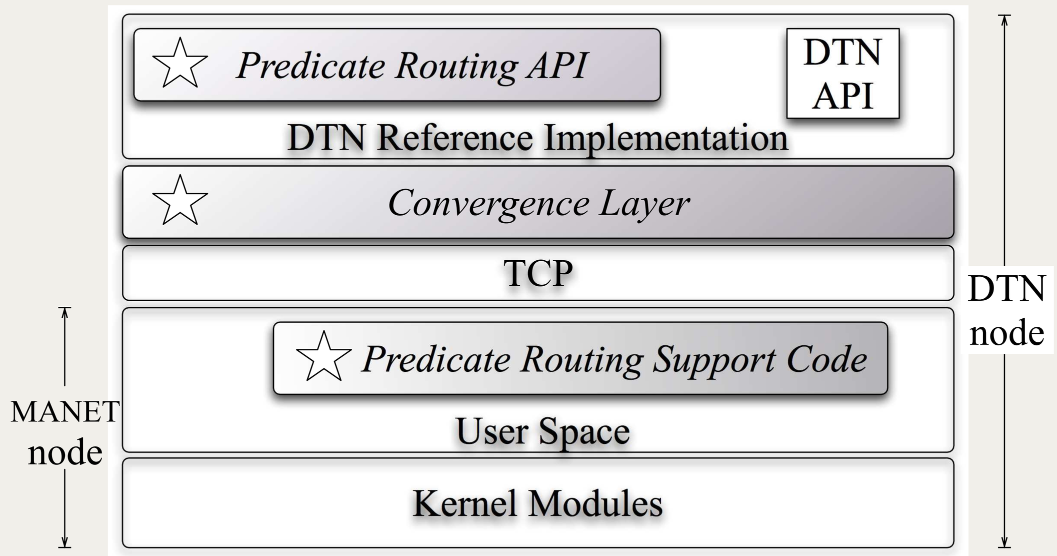

Figure 1: Architecture of a PreDA enabled DTN node running over a MANET substrate. In the stack our modified and added components are marked by "stars."

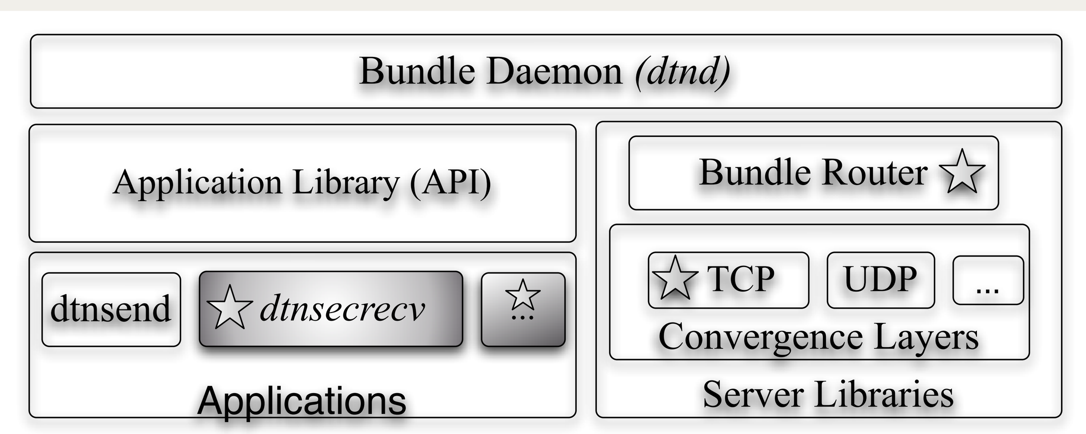

Figure 2: Architecture of the DTN reference implementation. The modules enabling PreDA are marked with a "star".

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 in hops to every other node in the network.

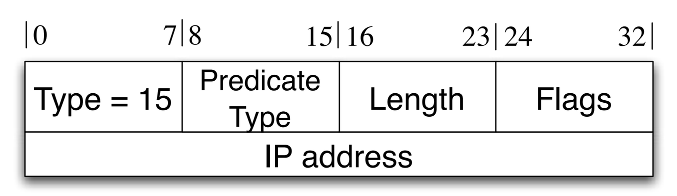

Figure 3: Proposed PreDA packet extension, to propagate with DTN discovery, piggybacked in HELLO messages.

Predicate	Action
src = $\neg W \wedge$ dest= D	drop

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

Predicate	Action
src = $\neg I \wedge$ dest= D	to I
src = $I \wedge$ dest= D	to D

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

Predicate Routing in Action on Our UML Testbed

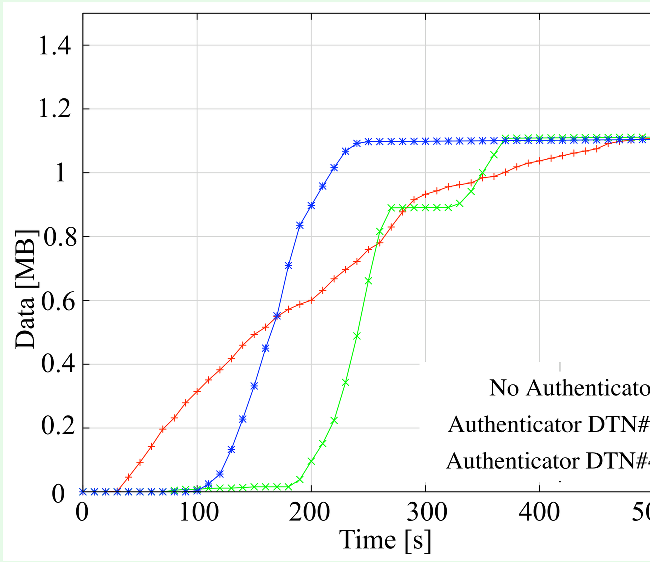

Figure 4: Data delivered at the destination vs. time for 2% packet loss probability.

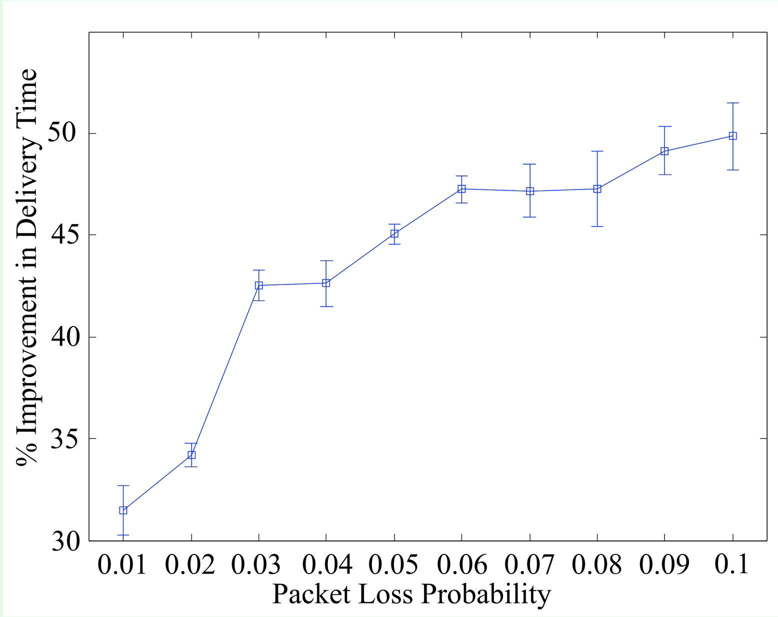

Figure 5: Percentage improvement in data delivery time vs. packet loss probability with 95% confidence interval when an authentication predicate is injected.

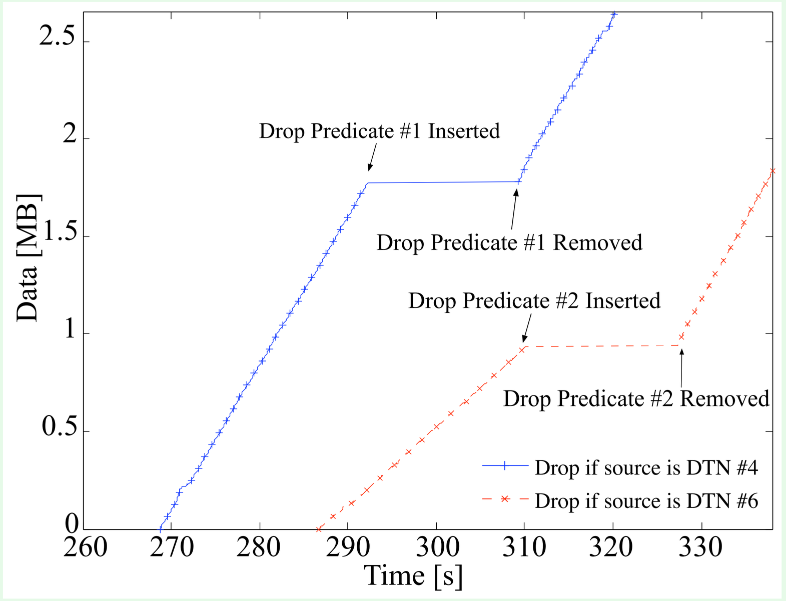

Figure 6: Throughput drops and resumes after the "dropping" predicates propagate and are removed.

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 (ns-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

[1] Timothy Roscoe, Steven Hand, Rebecca Isaacs, Richard Mortier, and Paul W. Jardetzky. Predicate Routing: Enabling Controlled Networking. *Computer Communication Review*, 33(1):65–70, 2003.

[2] Eiko Yoneki and Jon Crowcroft. Towards Data-Driven Declarative Networking in Delay Tolerant Networks. In *DEBS 08 International Conference on Distributed Event-Based Systems*. ACM, 2008.

[3] Gabriele Ferrari Aggradi, Flavio Esposito, and Ibrahim Matta. Supporting Predicate Routing in DTN over MANET. In *CHANTS '08: Proceedings of the third ACM Workshop on Challenged Networks at MOBICOM*, pages 125–128, San Francisco, California, USA, 2008. ACM.