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Multicast over the Delay Tolerant Network Prophet Protocol

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Summary

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- DTN Architecture
- DTN Routing Protocols
- Multicast over DTN-Prophet Protocol
- Simulation Results
- Conclusions

Introduction

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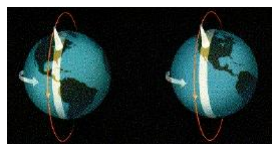
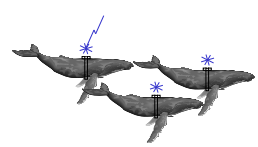
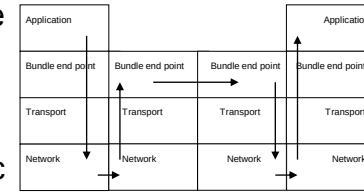
- Delay/Disruption Tolerant Networks (DTNs) are networks that may experience frequent and long duration partitions.
- Examples: military communications in the battlefield, deep space communications, some forms of ad-hoc sensor/actuator networks, rescue actions in catastrophe hit areas, wild life monitoring and Internet connectivity in places where performance may suffer.

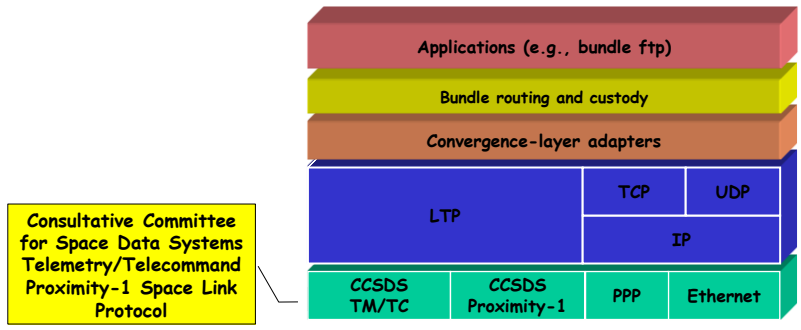

Bundle Layer

- Link disruptions are not properly handled by the Internet protocols, due to high delays and high packet loss.
- The DTN Research Group, which was chartered as part of the Internet Research Task Force (IRTF), has proposed an architecture (RFC 4838) and a communication protocol for DTNs (RFC 5050).
- "Bundle Layer" added on top of the transport layer for the end-to-end exchange of messages (called bundles) taking advantage of scheduled, predicted, opportunistic or permanent connectivity.



Licklider Transmission Protocol aka *Long-haul Transmission Protocol*

- LTP is a retransmission protocol for delay-tolerant reliable communication between two points.
- RFC 5325-5327.



DTN characteristics

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- Random and predictable node mobility
- Intermittent/Scheduled/Opportunistic Links
- Large or variable delays
- High Error Rates / Low Usable Capacity
- Limited node uptime (e.g. to save power)
- Link bandwidth/loss/delay asymmetry
- Heterogeneous Network Architectures
- End-to-end path may not exist

Delay-Tolerant Networking Architecture

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- Goals
  - Support interoperability across ‘radically heterogeneous’ networks
  - Tolerate delay and disruption
    - Acceptable performance in high loss/delay/error/disconnected environments
    - Decent performance for low loss/delay/errors

Message Abstraction

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- Network protocol data unit: bundles
  - "postal-like" message delivery
  - origination and useful life time -assumes synchronized clocks
  - source, destination, and respond-to EIDs (Endpoint Identifiers)
  - *Options*: return receipt, "traceroute"-like function, alternative reply-to field, custody transfer
  - fragmentation capability
  - overlay atop TCP/IP or other (link) layers: layer 'agnostic'
- Applications send/receive messages
  - "Application data units" (**ADUs**) of possibly-large size
  - Adaptation to underlying protocols via 'convergence layer'

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DTN Routing Protocols

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- Epidemic Routing floods the network with the messages.
  - Although it provides a good solution for DTNs as regards the delivery ratio and latency, it is very wasteful of resources.
- PROPHET (Probabilistic ROuting Protocol using History of Encounters and Transitivity) protocol: uses the history of encounters between nodes and transitivity to estimate the probability of nodes meeting and exploits the mobility of some nodes to bring messages closer to their destination.
  - has lower demands on buffer space and bandwidth, with equal or better performance in cases where those resources are limited and without loss of generality for scenarios where it is applicable.

Multicast over DTN-Prophet Protocol

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- PROPHET is a routing protocol for unicast communication in DTNs.
- We propose the Multicast over DTN-Prophet Protocol (MoDTN-PP) as an extension to the Prophet Protocol for non-custodial multicast.
  - Non-custodial means that the protocol will do its **best effort** to deliver messages.
- We use indications of the location and direction of the moving nodes to help forming a pseudo multicast tree.
- We show that if there are a minimum number of contacts between nodes, multicast works efficiently, minimizing the number of message replications done in the network.

The DTN Prophet Protocol Probabilistic Model

- P(x,y) is the delivery or contact probability from node x to node y, which is used as a routing criteria.
- 3 equations with 3 initialization constants (P_{init} , γ, β):

  $P_{(a,b)} = P_{(a,b)old} + (1- P_{(a,b)old}) \times P_{init}$; $0 \leq P_{init} \leq 1$.
  - updates the probability whenever two nodes meet: it will increase P(x,y) every time they meet.

  $P_{(a,b)} = P_{(a,b)old} \times \gamma^{k}$; $0 \leq \gamma < 1$.
  - reduces the probability as time passes (*k* time units).

  $P_{(a,c)} = P_{(a,c)old} + (1- P_{(a,c)old}) \times P_{(a,b)} \times P_{(b,c)} \times \beta$; $0 \leq \beta \leq 1$.
  - expresses transitivity, as messages can go from “a” to “c” directly or via “b”.

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Multicast over DTN-Prophet Protocol: Mobility Information

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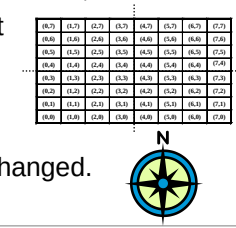
- During contacts, the following additional information is exchanged:
  - Nodes own geographical position and the geographical position of the nodes they contacted;
  - Nodes moving direction and the moving direction of the nodes they contacted.
- Mobility information is only approximate:
  - May be inferred from wireless access points, other nodes, or GPS.
  - Direction is coded in 2 bits identifying the quadrant the node is heading to.
  - Current node position is coded with 3 bits for each of the x and y coordinates.
  - Just 1 byte is added to the routing information exchanged.



Multicast over DTN-Prophet Protocol: Pseudo Multicast Tree

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- The pseudo multicast tree is dynamic
  - Consists of the source, a set of destinations and intermediate nodes (mules).
- When a node wishes to join the multicast group, an heuristic is used to select the best neighbour to contact the group:

Weight	Condition of neighbour
30	is the source of the group
14	already serves as a mule
10	can contact the source with $P_{(x,y)}>=0.7$
6	can contact the source with $0<P_{(x,y)}<0.7$
4	is contacted with $P_{(x,y)}>0.7$
3	is near the source
2	moves towards the source, or the neighbour and source go in the same direction
1	can contact the targeted multicast group

  - The weights of conditions that are true are added. The neighbour that reaches the highest value is selected. The heuristic favours connections as direct as possible to the multicast source.

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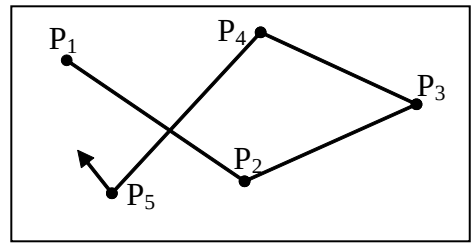
Simulation scenarios
Scenario 1

- Scenario 1 is based on the Random Waypoint Mobility Model: nodes randomly select a destination, go there, pause for a random time and repeat.



Simulation scenarios
Scenario 2

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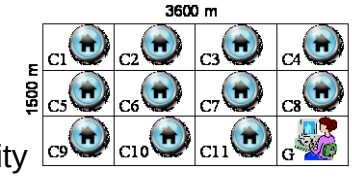
- Scenario 2 is based on the Community Model: nodes move randomly, but the scenario is divided in sub-areas, such as “Home” and “Gathering place” for the nodes.
- In scenario 2, nodes have high probability of moving back and forth between their “Home” sub-area and the “Gathering place” sub-area.
- 11 Community areas and 1 Gathering place area.
- Adequate to model human mobility



- The following destination selection probabilities are used:

From/To	Home	Gathering place	Elsewhere
Home	-	0.8	0.2
Elsewhere	0.9	-	0.1

Simulations

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- 1 multicast group with 8 destinations.
- Unicast traffic configured to be about twice the multicast traffic.
- ProphetSim simulator, based on OMNeT++ version 3.2p1 with the Mobility Framework version 1.0a6.
- MoDTN-PP parameters:

Parameter	Value
Pinit	0.75
β	0.25
γ	0.98

  - Preliminary simulations indicated that these values are acceptable choices.

Simulation Results: Bundle delivery ratio

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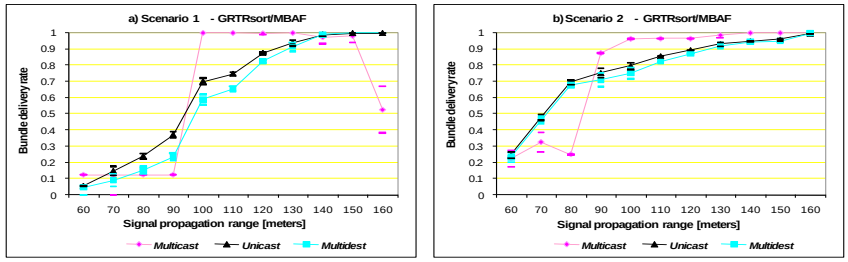

- For wireless ranges shorter than 100m, unicast and multicast have a bad performance.
  - This is because contacts are infrequent and their quality is not good: the multicast tree and multicast operations have no opportunity to work.

Simulation Results: Bundle delivery ratio

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- For ranges between 100 and 150m, multicast performs well.
- For ranges above 150m, for scenario 1, multicast performance declines. This is because unicast bundles are transmitted first and there is no replication limit, so multicast bundles starve.
  - a scheduling mechanism that properly shares the bandwidth between unicast and multicast should be implemented (further work)
- Multicast performs better in Scenario 2 because the nodes move frequently to the gathering place.

Simulation Results: Bundle delay average

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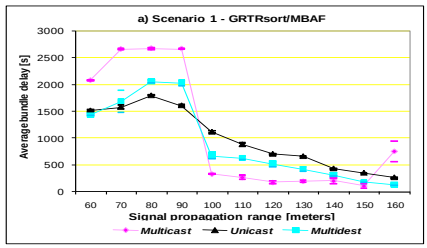

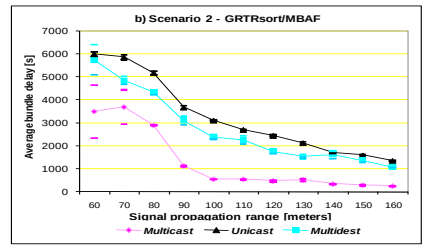

- The mobility information (only in the multicast case) permits the pseudo multicast tree to have more direct connections, optimizing the paths and reducing delay.

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Conclusions

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- DTN is a new networking paradigm.
- We extended the Prophet Protocol with a multicast mode, adding information with indications of node position and direction of movement to help forming pseudo-multicast trees. This proved to be a good routing criteria, contributing to the existence of a pseudo-multicast tree, which results in shorter message transfer delays.
- Multicast communications can be used if a minimum of contacts between nodes exists.
- Multicast can improve DTNs efficiency, saving resources as the number of message replications is minimized.

Reference

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José Santiago, Augusto Casaca, Paulo Rogério Pereira, Multicast in Delay Tolerant Networks using Probabilities and Mobility Information, *Ad Hoc & Sensor Wireless Networks, An International Journal, vol. 7,* number 1-2, pp. 51-68, 2009.