An Overview of Disruption Tolerant Networking Technologies

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Outline

• Motivation for Disruption Tolerant Networking
• What it is, how it works
• Types of DTNs
• Current Research Areas
• Work from USC
Internet’s Success (TCP/IP protocol suite)

- Consensus based communication protocols
  - Routing (IP)
  - Reliable data transfer (TCP)

- Unwritten Assumptions
  - Source and Destination are continuously connected (forming bi-directional end-to-end paths)
  - Short roundtrip times (small delays)
  - Relatively symmetrical data rates
  - Low bit error rates
  - Maximum Transmission Unit of 1500 bytes (Ethernet World)

- Packet switching

  Extend it Everywhere!
Evolving Networks

Interplanetary Internet (IPN)

Highly Mobile Tactical Network

Habitat Monitoring - ZebraNet

Sensor Networks - Autonomous node control
Evolving networks do not follow the Internet’s underlying assumptions.
In fact they exhibit the exact opposite characteristics
• Intermittent Connectivity
• No contemporaneous path
• Variable and/or long delays
• Asymmetric data rates
• High bit errors

The Result
TCP/IP fails!!

New research has emerged…
Delay/Disruption Tolerant Networking
DTN Overview of Work

www.dtnrg.org
What is DTN?

DTN is a network of regional networks

- Networks that violate one or more of the underlying TCP/IP assumptions
- Really it’s just an overlay
- Accommodates long delays between regions and even within regions
- Underlying physical/link layers maybe very diverse
  - Radio Frequency (RF)
  - Ultra-wideband (UWB)
  - Sonar or ultrasonic
- Store and Forward Network (Message Switching)
DTN in a nutshell

DTN Source

Where are you headed?

Knoxville, Wheeling, then Fort Pitt.

DTN Bundle

Can you take this letter to my Brother at Fort Pitt?

Forwarding Agent

Dave Smith
@ Ft. Pitt

This is Bundling

Dave Smith
@ Ft. Pitt

DTN Destination

Knoxville, Wheeling, then Fort Pitt.
DTN in a nutshell

DTN Bundle
Forwarding Agent

Dave Smith
@ Ft. Pitt

DTN Destination
Overview of DTN Architecture

- Regions and DTN Gateways
- Name Tuples
  - Allow for late binding
  - Based on Uniform Resource Identifier (URI)
- Path Selection/ Routing decisions
- Bundling layer: aggregates messages
- Custody transfer
- Convergence Layers (TCP, UDP, LTP)
- Security
Types of DTN applications?

- Scheduled
- Probabilistic
- Opportunistic
Problem Space Design

CONNECTIVITY

Unpredictable

Probabilistic connectivity, dynamic traffic, short propagation delays

Deterministic connectivity, static traffic, long propagation delays

Static or Quasi-static

Dynamic

TRAFFIC

Short

Long

PROPAGATION DELAY

Sensors go to sleep in random fashion to conserve energy

Unpredictable connectivity, dynamic traffic, short propagation delays
Research challenges

• Architecture
  Naming, Bundles, Convergence layers

• Routing
  Family of protocols, broadcast

• Congestion/Flow control
  Family of algorithms

• Security

• Deployment

• Testbeds and Experiments
## DTN Research Status

<table>
<thead>
<tr>
<th>Category 1: Build-out of Current Capabilities</th>
<th>Category 2: Expansion of Core DTN Capabilities</th>
<th>Category 3: DTN Basic Research Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>b. Prioritized traffic</td>
<td>b. Development of DTN proxies for FTP, SMTP, Foreground and background web traffic (pull with low priority cache population)</td>
<td>b. Software to characterize routes</td>
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<tr>
<td>c. Imposition of schedule/contact limits (data rate, volume, etc.)</td>
<td>c. Instant Messaging Voicemail/push-to-talk radio</td>
<td>- Pure opportunistic</td>
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<tr>
<td>d. Custody transfer</td>
<td>c. Network News</td>
<td>- Histogram-based prediction</td>
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<tr>
<td>e. Reactive fragmentation</td>
<td>c. SNMP</td>
<td>- Bayes-net conditional prediction</td>
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<td>f. Process persistence and reanimation &amp; integration with scheduling and power management capabilities</td>
<td>c. New convergence layers and adapters</td>
<td>c. Routing protocols to express the full range of routing alternatives</td>
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<tr>
<td></td>
<td>- SMTP</td>
<td>- Always-on</td>
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<tr>
<td></td>
<td>- Digital Fountain</td>
<td>- On-request</td>
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<td></td>
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<td>- Scheduled</td>
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<td>- Opportunistic</td>
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<td>d. Routing algorithms for optimal allocation of outbound traffic to a mixed set of contacts</td>
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<td>e. Integration of externally-developed routing and congestion management capabilities</td>
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Current Research

• Routing for sensor type networks
  - Spray-n-wait
  - Seek-n-focus
• Experimental testbed development
  - Emulab augmented with mobility models
• Congestion control
  - Three different algorithms
Routing in DTN’s

• Two ends of the spectrum
  - Flooding (minimum delay)
  - 1-Hop: (minimum transmissions)
• Based on utility functions
  - Time last seen
  - Storage capacity
  - Mobile capability
  - Power to live
• USC
  - Two different algorithms
Routing in DTN’s

• Seek-n-focus
  - Seek - Low utility, random
  - Focus - follow utility function

• Spray-n-wait
  - Spray L messages(copies)
  - Wait
Scenario A: Effect of Traffic Load

(500x500, M = 100 nodes, K = 10)

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<tr>
<th></th>
<th>Delay</th>
<th>Transmissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low traffic</td>
<td>same as epidemic</td>
<td>&gt;10x epidemic</td>
</tr>
<tr>
<td></td>
<td>1.4-2.2x other schemes</td>
<td>3-4x constrained</td>
</tr>
<tr>
<td>High traffic</td>
<td>1.8-3.3x</td>
<td>same as above</td>
</tr>
</tbody>
</table>
Experimental Testbeds

What an Emulab like system provides:

• Dynamic link conditions for delay, bandwidth, and even link availability

• Ability to run Bundling Protocol on top of a topology and over different topologies

• Ability to evaluate routing protocols across the variety of networks discussed earlier

• A common facility for other researchers to conduct experiments
  Avoids everyone having their own “version/vision” of what constitutes a DTN
Conclusion

• Motivation for Disruption Tolerant Networking
• How they work
• Types of DTNs
• Current Research Areas
• Work from USC

www.dtnrg.org

Special thanks to Will Ivancic
NASA Glenn Research Center for the western themed DTN example slides
Thank You!

Questions?