Delay Tolerant Networks: Challenges and Applications

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The Advanced Internet Technology in the Interests of Society Laboratory
Presentation Outline

• Future networks & their characteristics
• Delay tolerant networks
• Our research focus in DTN
• Open research areas in DTN
• Available resources
Basic Applications and Networks

- The Internet: the largest network
  - Interconnecting communication devices across the globe using TCP/IP protocol suite
  - Designed based on a number assumptions.....
Guaranteed end-to-end connectivity
Short and fixed delays
Symmetric data rates
Low error rates
Existing Infrastructure
Emerging Networks and Apps

- Connecting heterogeneous networks operating on different transmission media
  - Different protocols and characteristics
- Communication is not limited to the Internet
  - Violating many of basic assumptions in the Internet....
Guaranteed end-to-end connectivity
Short and fixed delays
Symmetric data rates
Low error rates
Existing infrastructure
Future Networks

- Node constraints
  - Highly integrated, low-power, low-cost devices
- Network dynamics
  - Host mobility, network mobility, dynamic membership,
- No guaranteed end-to-end connectivity
  - Link and node failures $\rightarrow$ network with intermittent connectivity
- Long & variable propagation delays
  - Asymmetric data rates
- Heterogenous networks seamlessly connected
  - Decentralized
Delay Tolerant Networks
D* Tolerant Networks

- Disruption
- Delay
- Disconnection

When TCP Breaks: Turn to Delay- and Disruption-Tolerant Networking

Delay-Tolerant Networking Architecture,” RFC 4838, April 2007. V. Cerf et al.,
Network Examples of DTN

- Vehicular Networks
  - DakNet
  - Message ferry
  - Village network
- Mule Networks
  - Zebranet
    - The goal is tracking of zebras in wildlife
  - Sámi Network Connectivity
  - Carrier Pigeons
    - RFC 1149, RFC 2549 - Implemented by Bergen Linux users group
Network Examples of DTN

- Inter Planetary Networks
  - Deep space networks
- Sensor Networks
  - Acoustic underwater networks
- Ad hoc Networks (MANET)
  - Military tactical networks

DTN Architectural Objectives

- Asynchronously interconnecting different networks
  - Network of regional networks
- Each networks can have
  - Arbitrary underlying technologies
  - Different administrative controls
  - No accessible infrastructure
Bundle Concept

- Use of bundles instead of packets
- Bundle store & forward-routing
- Custody transfer by intermediate nodes

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DTN Origin

- Interplanetary Internet (IPI)
  - Development since late 1990s
  - Expanding internetworking to interplanetary scale

Pre-standardization efforts: DTN Research Group (DTN RG) in the IRTF

www.computer.org/.../dsontline/2006/08/w4spot.xml
Network Constraints

- Application
  - → Monitoring, communications, etc.,
- Node types and interactions
  - → Mobile nodes, stationary nodes
- Mobility patterns
  - → Deterministic, stochastic, predictable, etc.
- Network topology
  - → Known or not
- Scheduling Assumptions
  - → Knowledge oracle type
- Energy level constraint
  - → Similar to sensor network
- Physical constraints
  - → Bandwidth, range, speed, etc.

(N=Node, MR=Mobile Node)
Our Research Focus
Challenges

• Architecture
  - Naming and addressing

• Routing protocols
  - Traditional end-to-end path may not exist
  - End-to-end routing will not work
  - Routes maybe time dependent

• Multi-layer connectivity
  - Interconnecting DTNs

• Node design
  - Storage capacity, range, physical link
A) Vehicular DTN - Village Networks

- Expanding connectivity
  - Lack of infrastructure
  - Lack of funding
- Villages and remote areas
- Network architecture
  - Stationary nodes
  - Mobile routers
  - Relay nodes - placed at intersections
A) Vehicular DTN - Village Networks

Objective
Network cost optimization by minimizing the number of relay nodes

Problem
- Relay node placement to reduce network cost
- Developing various routing algorithms

Solution
Formulating the node placement as a cost optimization problem (ILP Problem) & developing heuristic algorithms
B) Vehicular DTN - Multi-Layer Interactions

- **Motivation**
  - Protecting against catastrophic (regional) failures
- **Cross-layer interaction**
  - Integrating VDTN and other network layers
  - In-bad and out-of-band signaling
  - Using different media for data and control signals
B) Vehicular DTN - Multi-Layer Interactions

- Innovative applications
  - Distance learning
  - eHealth
C) Anycasting in VDTN

- Inter and intra-domain traffics
- Intra-domain traffic can go through ISPA or ISPB
- Objective
  - Optimizing the network to reduce cost (ILP formulation)
  - Designing heuristics
Supports & Collaborations

• Funding Supports
  - The Euro-NF Network of Excellence of Seven Framework Programme of EU
  - Networks and Multimedia Group of the Institute of Telecommunications - Covilhã Lab, Portugal

• Collaborating Institutions
  - Central Connecticut State University
  - Institute of Telecommunications, Networks and Multimedia Group, Portugal
  - University of Texas at Dallas
  - Scuola Superiore Sant’Anna, Pisa, Italy
Open Research Areas ......
Naming and Addressing

- Unique end-point identifiers \{region id, host id\}
  - Defining regions
- Supporting unicasting, multicasting, anycasting
  - Shared addresses for multiple nodes
- The end user may be mobile and move between regions
  - Address mapping or resolution needed
  - Routing takes place based upon complete URI: sender “just sends”
Routing in DTN

- Routing depends on basic network assumptions
  - Mobility, mobility patterns, node capacity, scheduling knowledge, etc.
- Routes are time dependent
  - Requires long term storage
  - Long term storage can lead to buffer contention
- Routing objectives
  - Minimize the delay
  - Maximize the throughput
- Topology dynamics
  - Is the topology known (e.g., road, mobility patterns, etc.)
- Optimal routing solutions
  - Knowledge vs complexity

- Contacts Summary
  - Average link availability
  - Average bandwidth
- Contacts
  - Exact times of contact
  - Exact route
- Buffering
  - Available storage
  - Local vs Global
- Traffic Demand Oracle
Open Research Areas
Exact Vs. Partial Scheduling

- Show through simulation the relative performance between routing based on exact and partial scheduling information
  - Implementing the time-based shortest path: modified Dijkstra's Algorithm
- The general performance of the two routing algorithms can be expected to be as follow

Input: $G=(V,E), s, T, w(e,t)$
T: Start time
$w (e,t)$: edge cost function
Output: $L[u]$
The earliest time message reaches node $u$

Properties:
- Loop free paths
- Low complexity

Algorithm:
- $Q = V$
- $L[s] = 0, L[v] = ∞ \forall v \in \{V - s\}$
- while $Q \neq \emptyset$ do
  - Let $u \in Q, s.t L[u] = \min_{x \in Q} L[x]$
  - $Q = Q - \{u\}$
  - forall $e \in E, s.t. e = (u,v)$ do
    - if $L[v] > L[u] + w(e, L[u] + T)$ then
      - $L[v] = L[u] + w(e, L[u] + T)$
    - end
  - end

Performance of Contact Time Oracle Routing
Performance of average contact period oracle

More..... click here
Open Research Areas
Multicasting efficiency in VDTN

- Multicasting is the simultaneous transmission of data from a source to a group of destinations
  - Warning system
  - Distance learning
- Maintaining reliable transmission in a timely manner is very critical
- Objective
  - Reducing resource demand of the application (storage, link utilization, etc.)
  - Minimizing the delivery time
- A common approach in route selection is link-sharing in the tree structure
  - Developing the time-variant Steiner multicast tree (TV-SMT) used for routing data in the network
Open Research Areas
Multi-layer Survivability

- Networks with mechanical backbone or limited energy levels can be highly susceptible to failures
  - Mechanical failures in buses, road blocks, traffic jams, etc.

- VDTN networks can also be considered as an alternative approach offer protection against catastrophic failures
LEGO Mindstorms Platform

• Motivation
  - Examining performance
    • Different protocols,
    • Examine blocking and constraints

• Possible extensions
  - Using GPS
  - Understanding random movements
  - Utilizing different link layer technology
  - Creating a colony network
  - Utilizing PDAs
  - Communication overheads

Lego Project: [http://www.sm.luth.se/csee/courses/smd/147/pages05/projects/DTN_PROPHET_LEGO_project.pdf](http://www.sm.luth.se/csee/courses/smd/147/pages05/projects/DTN_PROPHET_LEGO_project.pdf)
Available Resources....
References

- http://www.cs.wmich.edu/wns/project_opppnet.html - Opportunistic Networks - Leszek Lilien
References

References


References

Conferences

- WDTN Workshop Technical Program - [http://www.sigcomm.org/sigcomm2005/w4-wdtn.html](http://www.sigcomm.org/sigcomm2005/w4-wdtn.html) - papers all available


- Other wireless conferences - [http://www.prehofer.de/Research/Welcome.html](http://www.prehofer.de/Research/Welcome.html)

- IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks - [http://ieee-wowmom.cse.buffalo.edu/](http://ieee-wowmom.cse.buffalo.edu/)

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Seminars / Universities

• Prof. Jens-Peter Redlich - Interplanetary Internet - http://sar.informatik.hu-berlin.de/teaching/_previous-years/2006-s%20Interplanetary%20Internet%20Seminar/index.htm

• Dr.-Ing. Dirk Kutscher - DTN http://www.tzi.de/~dku/research.html
Online Resources

- The Consultative Committee for Space Data Systems (CCSDS) - (deep space communication)
  http://public.ccsds.org/default.aspx
- Magic Bike Project - http://www.magicbike.net/
- The Delay-Tolerant Networking Research Group (DTNRG) - http://www.dtnrg.org/wiki
- Mitre Projects
**SIMULATORS**


- **DTNSIM2**
  [https://styx.uwaterloo.ca/dtnsim2/](https://styx.uwaterloo.ca/dtnsim2/)

- **A very good list of simulators**
Internet to Rural Access

- Wizzy Project - South Africa -
  http://www.wizzy.org.za/link/category/5/
- TIER Project -
  http://tier.cs.berkeley.edu/wiki/Home - The aim of the TIER project is to address the challenges in bringing the Information Technology revolution to the masses of the developing regions of the world
- United Villages http://www.unitedvillages.com/

An online list: http://del.icio.us/faridfarahmand/rural