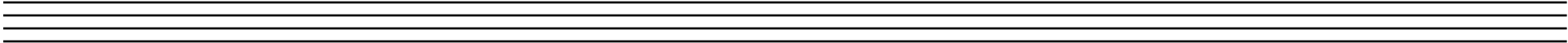


An Overview of Disruption Tolerant Networking Technologies

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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 Background

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!

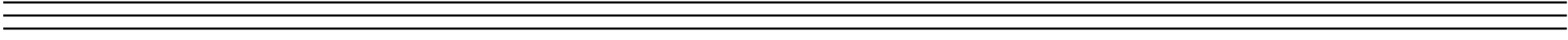
Evolving Networks

Interplanetary Internet(IPN)

Highly Mobile Tactical Network

Habitat Monitoring - ZebraNet

Sensor Networks - Autonomous node control



Properties of Evolving Nets

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)

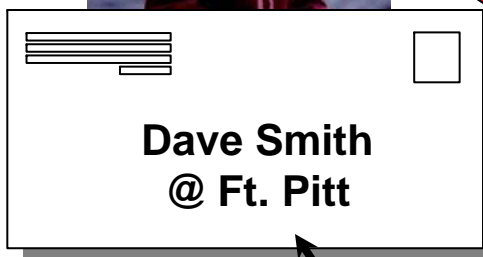
DTN in a nutshell

DTN Source



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

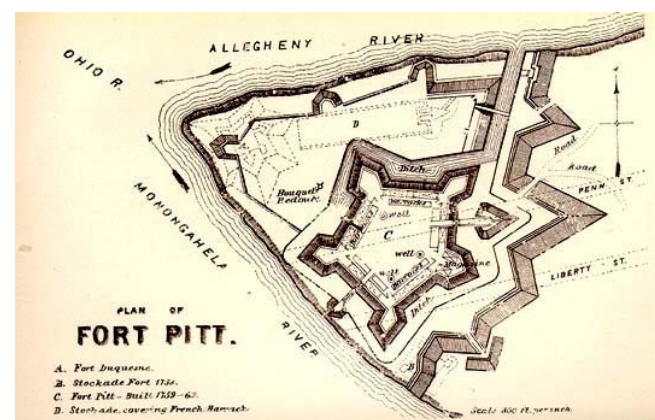
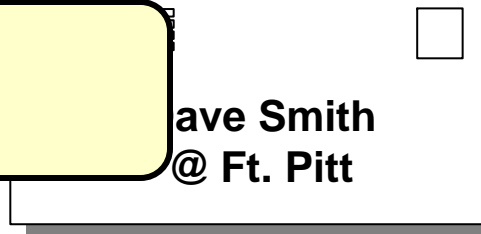
DTN Bundle
Forwarding Agent



Knoxville,
Whaling, then
Fort Pitt.

DTN Destination

This is
Bundling



DTN in a nutshell

DTN Bundle
Forwarding Agent



DTN Bundle
Forwarding Agent

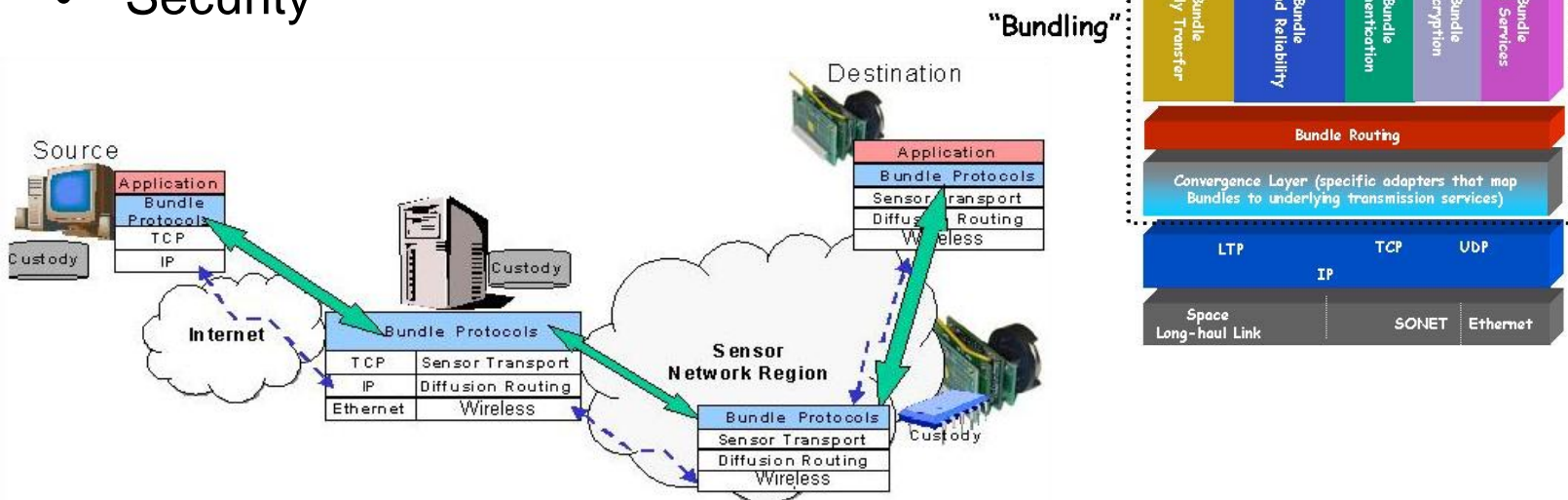


DTN Destination



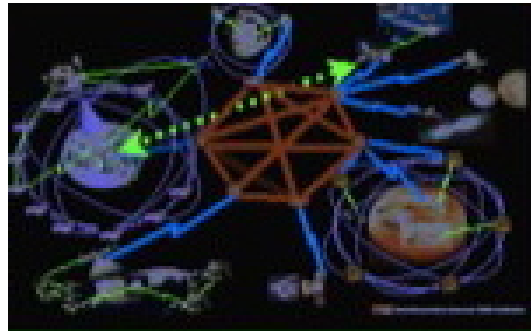
Overview of DTN Architecture

- 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

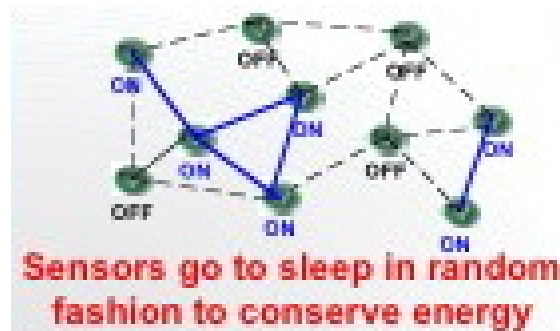


Types of DTN applications?

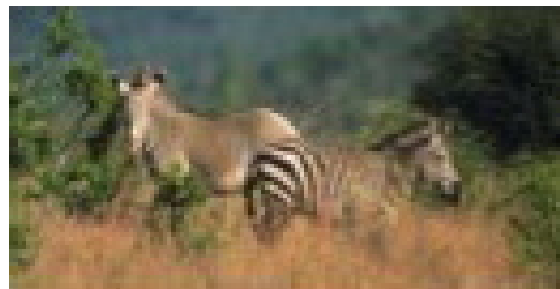
- Scheduled



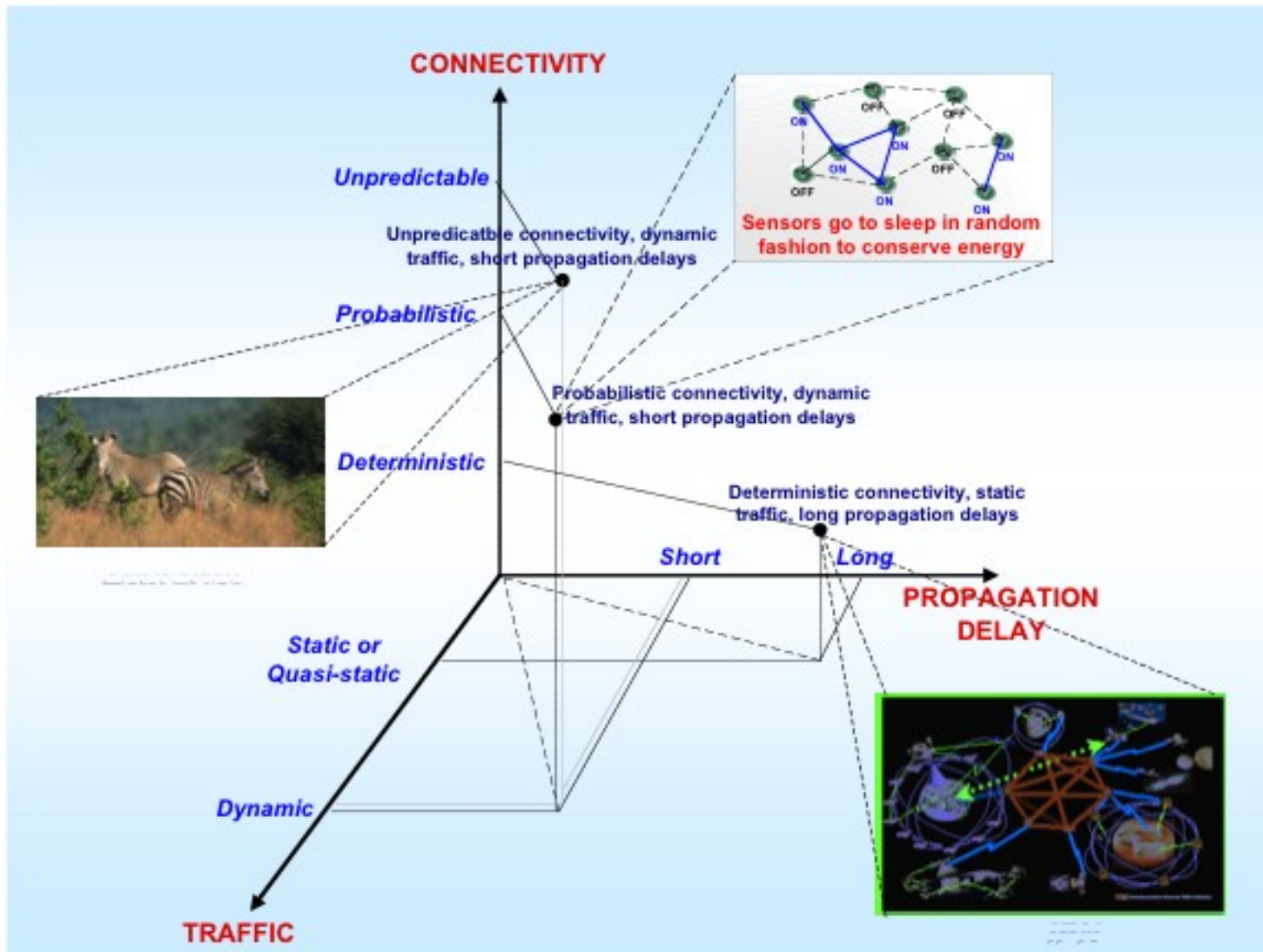
- Probabilistic



- Opportunistic

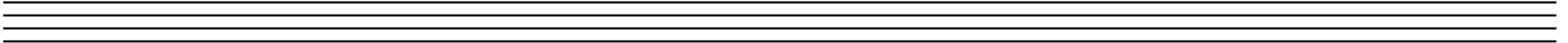


Problem Space Design



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

| CATEGORY 1: BUILD-OUT OF CURRENT CAPABILITIES | CATEGORY 2: EXPANSION OF CORE DTN CAPABILITIES | CATEGORY 3: DTN BASIC RESEARCH AREAS |
|---|--|--|
| <ul style="list-style-type: none"> a. Security model b. Prioritized traffic c. Imposition of schedule/contact limits (data rate, volume, etc.) d. Custody transfer e. Reactive fragmentation f. Process persistence and reanimation & integration with scheduling and power management capabilities | <ul style="list-style-type: none"> a. Network management statistics gathering and control mechanics b. Development of DTN proxies for <ul style="list-style-type: none"> - FTP, - SMTP, - Foreground and background web traffic (pull with low priority cache population) - Instant Messaging - Voicemail/push-to-talk radio - Network News - SNMP c. New convergence layers and adapters <ul style="list-style-type: none"> - SMTP - Digital Fountain | <ul style="list-style-type: none"> a. Congestion avoidance and remediation. b. Software to characterize routes <ul style="list-style-type: none"> - Pure opportunistic - Histogram-based prediction - Bayes-net conditional prediction c. Routing protocols to express the full range of routing alternatives <ul style="list-style-type: none"> - Always-on - On-request - Scheduled - Predicted - Opportunistic d. Routing algorithms for optimal allocation of outbound traffic to a mixed set of contacts e. Integration of externally-developed routing and congestion management capabilities |

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

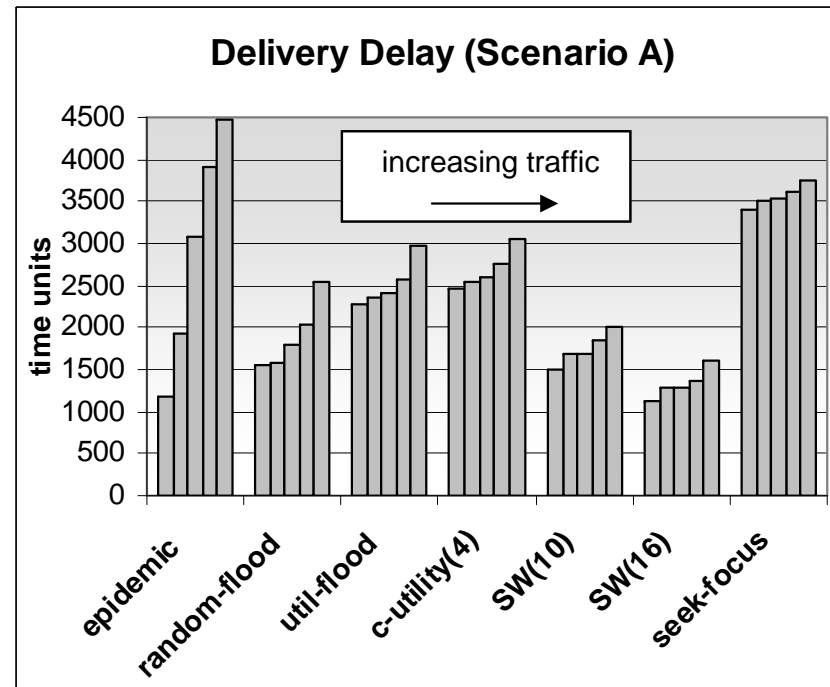
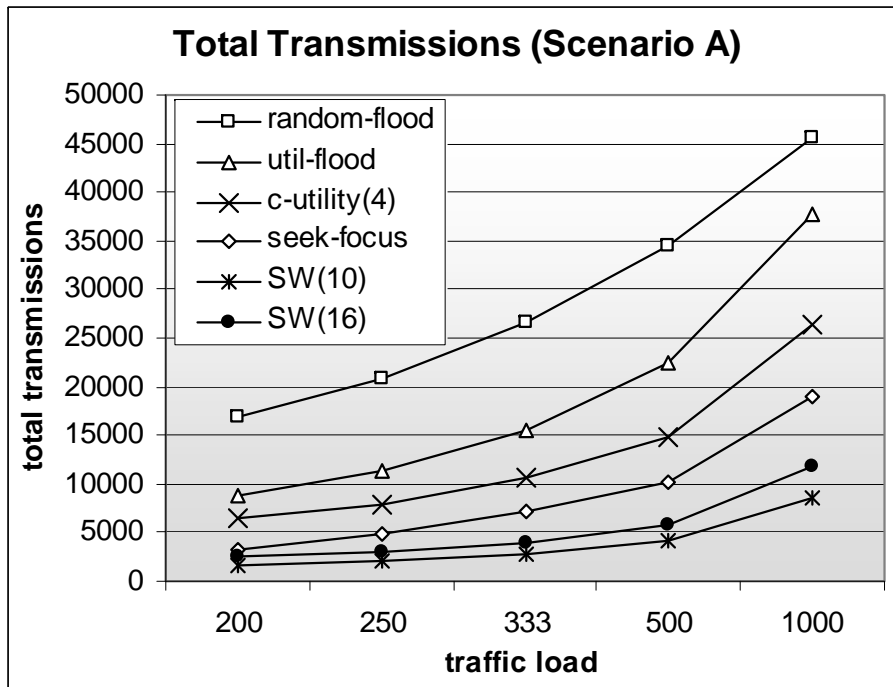
- Two ends of the spectrum
 - Flooding (minimum delay)
 - 1-Hop: (minimum transmissions)
- Based on utility functions
 - Time last seen
 - Storage capacity
 - Mobile capability
 - Power to live
- USC
 - Two different algorithms

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)



| | <u>Delay</u> | <u>Transmissions</u> |
|---------------------|---|--|
| <u>Low traffic</u> | same as epidemic <u>1.4-2.2x</u> other schemes | <u>>10x</u> epidemic <u>3-4x</u> constrained |
| <u>High traffic</u> | <u>1.8-3.3x</u> | same as above |

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?