SPINDLE-II Project Overview
Disruption-Tolerant Networking R&D at BBN

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BBN SPINDLE-II Project Team
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Outline

- BBN’s SPINDLE-II project
- A declarative knowledge-based approach to DTN
- Late binding of intentional names for endpoints
- Disruption-tolerant access to content
- Routing, network state dissemination, and policy support
BBN’s SPINDLE-II project

- **System Research and Development “thread”**
  - Led by Christopher Small.
  - Working with DTN RI (DTN2) developer community.
  - Completing missing features.
  - Adding to testing infrastructure, doing scalability testing.
  - Designing and implementing plug-in framework.
  - Documenting internal and external interfaces.

- **Technology Innovation “thread”**
  - Led by Prithwish Basu.
  - Balance of talk is about SPINDLE-II research.
SPINDLE-II
DTN RI architecture + plug-ins

- DTN RI core platform: open source
- Plug-ins: open source or proprietary
  - convergence layers, storage/KB, routing, naming
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A declarative knowledge-based DTN

• Knowledge bases offer flexible, extensible framework
  – Use inference to derive new facts from simpler facts.
  – Offer uniform query interface for explicit and derived facts.
  – Perform decision making and search of dynamic facts/rules.
  – Support rapid prototyping, deployment of new capabilities.

• Integrated declarative routing, naming, and policy
  – Approach extends naturally to content-based networking.
Specifying rich DTN information
Example: inference rules for link formation

- Rule to predicted link:

  \[\text{predictedLink} :: \text{spindleLink}.\]
  \[S : \text{predictedLink} [from\to X, to\to plane, upAt\to T1, downAt\to T2] :-\]
  \[\text{plane [trajectory\to Trj1], X [trajectory\to Trj2], walltime (Tnow), trajectory\_crossing (Tnow, Trj1, Trj2, [ T1, T2 ])}.
  \]

- KB contents can be shared, for informed routing decisions
  - forwarding, routing, and other decisions based on queries into the KB
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Late binding of intensional names

- **Intensional** naming is via attributes, not identity:
  - Canonical name: Christopher.Small@bbn.com
  - Intentional name: techLead@\{org=BBN,proj=SPINDLE-II,thread=dev\}.

- Disruption-tolerant network often needs late name resolution
  - Final destination not known at the originator.
  - Destination learned progressively within the network.

- Mapping of names from a rich namespace to routable endpoints
  - Extensible ontology to express multi-attributed intentional names.
  - Protocols to maintain name KBs and progressive resolution within network.

- Defer binding of next hop to convergence layer address and parameters
  - Capability for several communication modes (e.g., WiFi, GPRS, ...) may exist.
  - Parameters (address, protocol, data rate) may be negotiated on contact.
  - Can route with only coarse-grained information about future adjacencies.
Progressive resolution of attributes

Endpoint Names As Queries

snet:Sname

Sname : sensor [ cname \rightarrow X, value(Temp) \rightarrow T, isIn('DeathValley'), T>130.
may-bind varlist {?X,?T}
WHERE
snet :: sensor [ cname \Rightarrow string, value(Sentype) \Rightarrow int, isIn(Loc) \Rightarrow bool,
... ]
nexthop Cname = dtn:n2

rewrite LB header

snet:Sname

Sname : sensor [ cname \rightarrow X, value(Temp) \rightarrow T, long \rightarrow 116°49′33″W, lat \rightarrow 36°14′31″N ], T>130.
must-bind varlist {?X} may-bind varlist {?T}
WHERE
snet :: sensor [ cname \Rightarrow string, value(Sentype) \Rightarrow int, isIn(Loc) \Rightarrow bool,
... ]
nexthop Cname = dtn:n4

Death Valley Sensor Network

dtn:n1

name record
LB header
name ontology
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Disruption-tolerant access to content

- Boy Scout troop 47 is hiking through woods, led by Scout Master Chuck, who has maps of planned route on his PDA.

- Scout Master Chuck is lousy guide, and gets troop lost in the woods. He requests new maps from Google.

- Internet scenario:
  - Chuck is off the net, TCP connection request fails, no maps.
  - Scout troop stays lost until discovered days later by Ranger Rick.

- DTN scenario:
  - Request sent to local nodes (PDAs, iPods, etc.), and stay there.
  - Scout troop stays lost until discovered days later by Ranger Rick.
  - Request forwarded to Google after scouts are returned safely home.
Disruption-tolerant access to content

- What Scout Master Chuck didn’t know is that Junior Scout Billy has maps of the area in the browser cache of his Sony PlayStation Personal.

- With disruption tolerant access to content, Chuck’s request could have been satisfied by Billy’s PSP.

- Disruption-tolerant scenario
  - Chuck’s request for new maps is received by local PDAs, iPods, etc. Each checks to see if request can be satisfied by cached content.
  - Billy’s PSP determines it can satisfy the request, and replies with the cached map.
  - Chuck successfully leads troop out of the woods.
Challenges for content-based DTN

• Need distributed indexing, querying and retrieval.
  – Conventional distributed database models don’t work for DTN.
• Indexing will need to include reachable caches.
• Data may be encrypted; source must be authenticated.
• Users should be told of data freshness, time to retrieve, and have control over how cache misses are handled.

Note: we understand that this is a large problem space, and don’t expect to solve it completely.
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Adaptive routing and network state dissemination

Offered load: 40 bundles of 2800 bytes; Time: 1200s; Source-Destination path: 6-7 hops
In case of dissemination-based strategies, LS updates are sent every 30s

Hybrid performs better than pure strategies
Zero knowledge strategy consumes a lot of resources
Hybrid performs worse than zero knowledge strategy because of high update rate
Non-adaptive dissemination does not scale due to high update rate

Adaptive network state dissemination will help us track these curves
Adaptive routing and network state dissemination

- Adaptive hybrid routing strategies
  - Make use of routing information when available.
  - Explore locally when path is unknown or highly uncertain.
  - Dynamic choice of strategies based on policy.

- Adaptive state dissemination service shared by routing strategies
  - Exchange subset of topology information with neighbors.
    - Algorithm is not quite link state or distance vector.
    - Uses succinct space-time representation of topology.
  - Control rate, scope, and content of updates.
  - Tradeoff control overhead versus opportunistic data transfer.
  - Service can be used to distribute policy/naming/content metadata.
Policy-based resource utilization

• Declare and control resource use in DTN nodes
  – Link formation/use based on costs and delivery requirements.
  – Storage management.
  – Choice of security services.

• Use a declarative language to express and process policies
  – Node primitives controlled by policy are explicitly declared.
  – Deductive database rules check for policy consistency and conformance of usage to policy.
  – Constraint solver searches for communication opportunities that are authorized by policy

• Protocol for policy dissemination and consistent use in a DTN.
Summary

• Engineering of DTN Reference Implementation (DTN2)
  – Feature development
  – Testing
  – Documentation
  – Plug-in interfaces and plug-ins.

• Research
  – Intentional naming and late binding
  – Content-based networking
  – Routing and adaptive dissemination
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