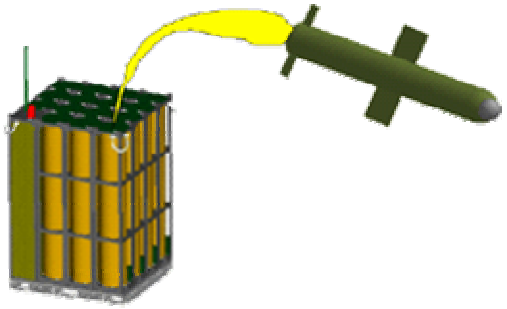


Disruption Tolerant Networking (DTN)

DARPA

Advanced Technology Office

BAA 04-13
Industry Day
21 January 2004

Purpose

- Describe Disruption Tolerant Networking Program
  - New Technologies Needed to Meet DoD Needs
- Provide Program New Start Plan
- Request Approval for BAA Release on DTN Technologies and Development

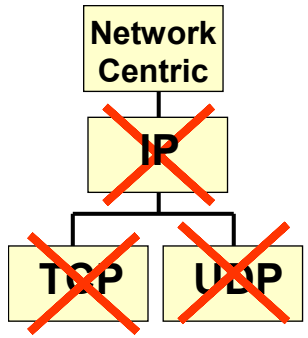
The Military Problem

- **Real Tactical Networks Will Not Behave as Office Networks Do!**
  - Wireless Connectivity Disrupted by Terrain, Weather, Jamming, Access Scheduling, …
  - FCS and SUO Both Evidenced Episodic Connectivity
- **Internet Technology Based on Relatively Static Network Topology**
  - Must Distribute Highly Dynamic Accessibility of MANET, Multi-Routed (Fiber, SATCOM, Terrestrial RF, …) Networks

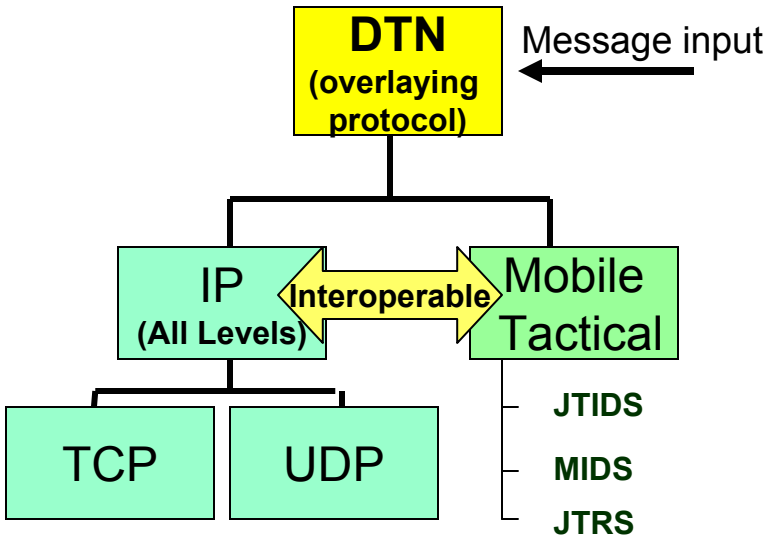
Toughening the Radio is Not the Answer!
Must Toughen Up the Network Itself!

Today's Design Choices

Today's Design Choices Are Not Sufficient to Deal With Military Needs



- All IP Networks Require:
  - Continuous End to End Path During Transfer
  - Knowledge of Specific Destination Node Address
  - Routing Information Distributed to Every Router
- TCP Fails* with Even Short Disconnects and Performs Poorly in Presence of Delay Jitter
- UDP Provides no Reliability Services and Can not "Hold and Forward"
- No Internet Protocol can Function End to End with Tactical Protocols



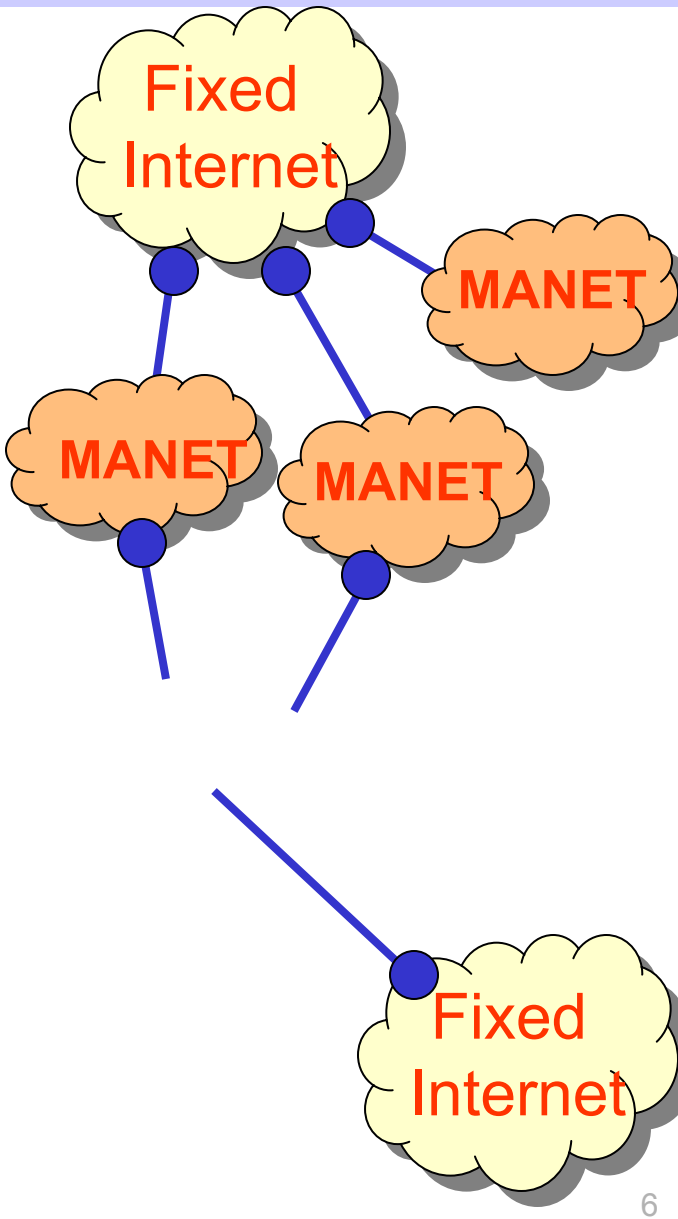
* *Stated with Permission of Vint Cerf*

How is Intermittent Connectivity Accommodated Currently?

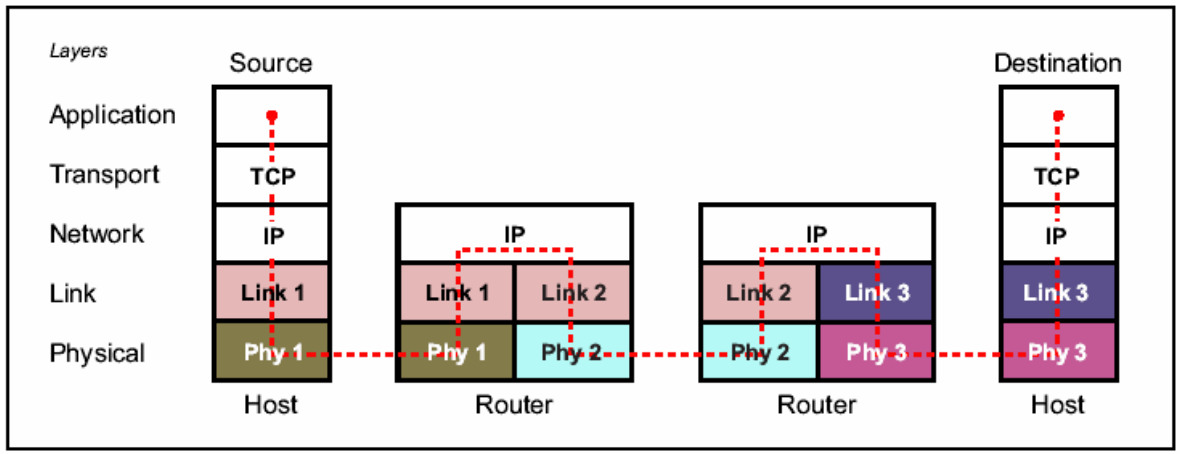
- Most cases: *It's Not.*
  - UDP used to avoid TCP timeouts
  - Custom reliability mechanisms with dubious benefits
  - Persistent Retransmission – Power Inefficient
  - If Only Single Intermittent Link– Pretend its an Email!
- Accommodation, if present, ad hoc and brittle:
  - Vendor/program Unique solutions
  - Applications lurk, waiting for connection opportunities (e.g. spyware) – excessive power in wireless environment
  - Existing services such as Mail (SMTP) and News (NNTP)
- No notion *ever* of scheduled connectivity and routing
  - Even fewer notions of predicted connectivity

Routing in Highly Dynamic Networks?

- Most MANET Research Focused on Routing within the MANET "IntraNet"
  - Assumed MANET Network Connectivity to Rest of Internet Static
- Integration of Tiered, Mobile Ad Hoc Networks with Large Scale Routing Networks Not Demonstrated or Understood
  - Complex Problem -- When MANETs Change Subnet Structure /Points of Access to Network
    - Move from SATCOM to Terrestrial Point of Presence
- Informing All Routers and Name Servers of Each Change in Topology Not Scalable Approach With Dynamic or Episodic Connectivity

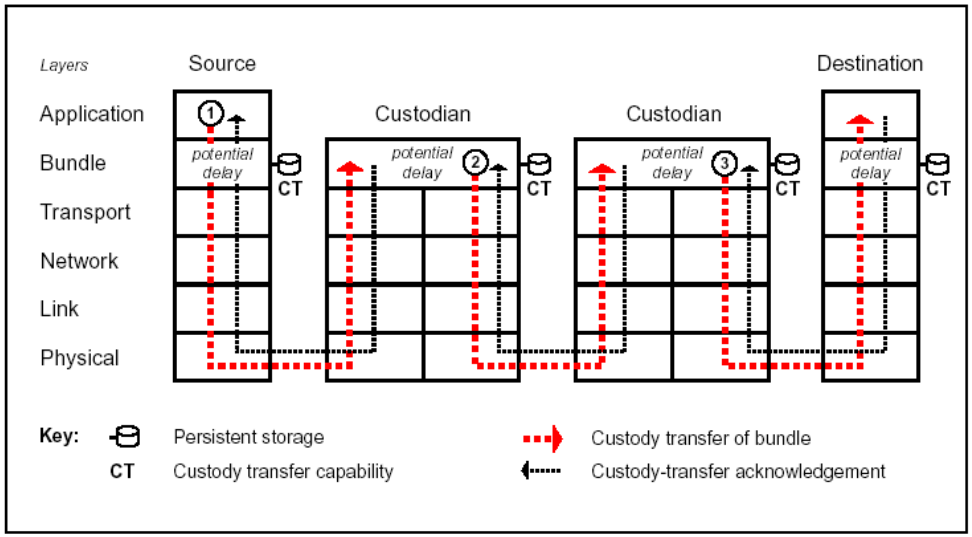


IP Routing vs. DTN Delivery



IP (UDP or TCP) Can Only Work if there is an IP Continuity Between Nodes for Duration of Transfer

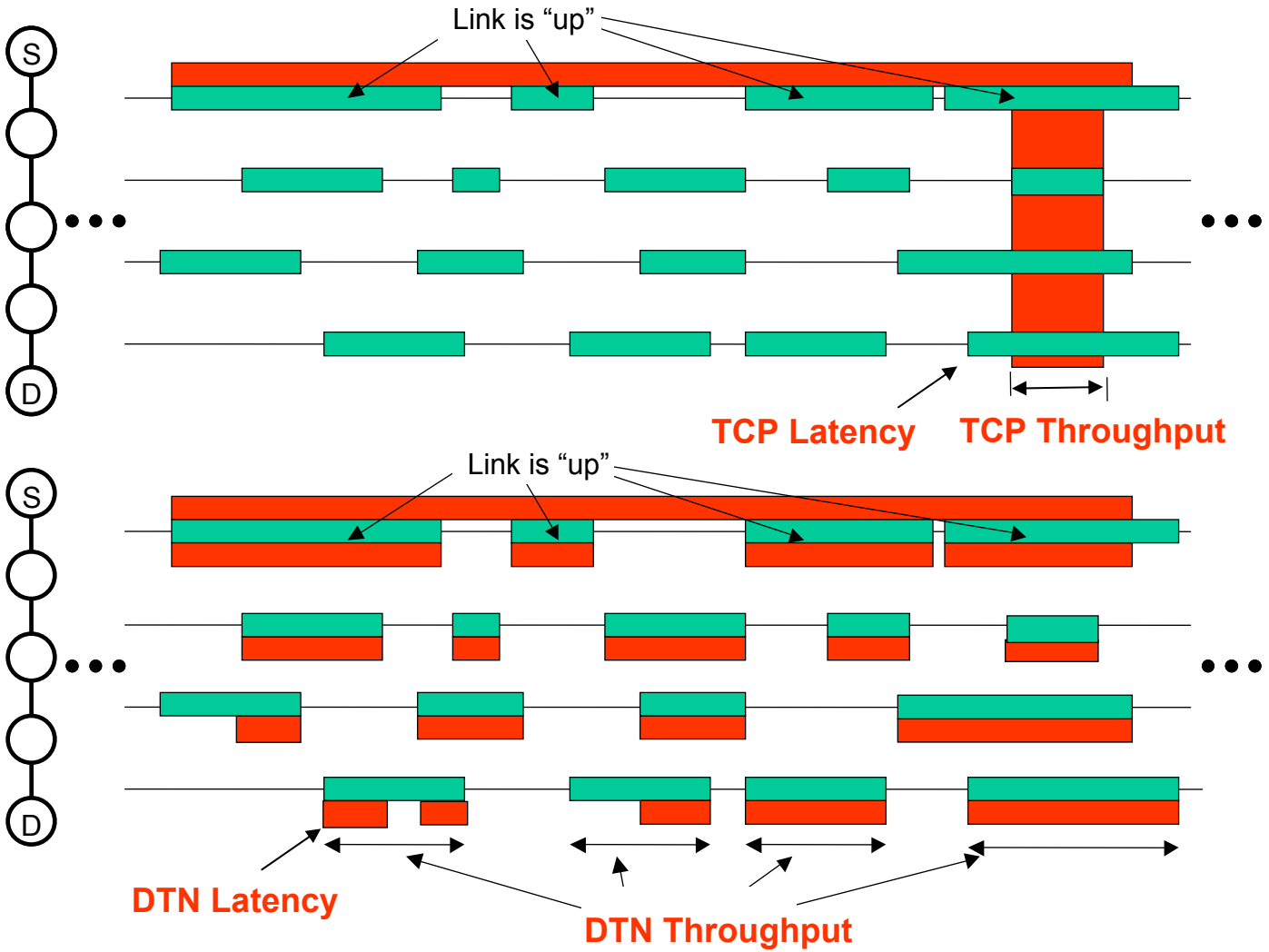
DTN can operate over non-IP Paths and Hold Data During Periods When All of Path is Not Available



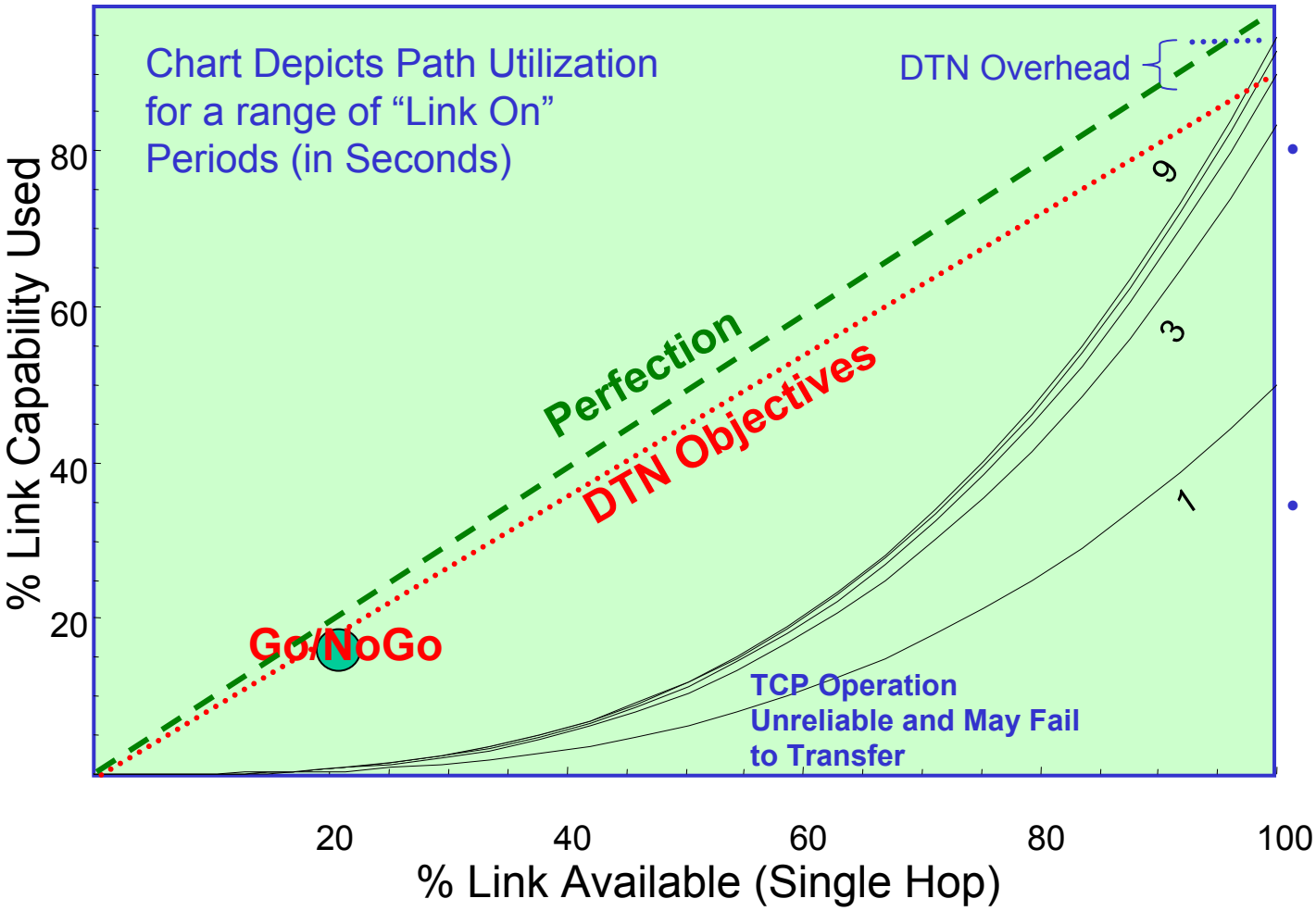
How Is DTN Different than the Internet?

	Internet	DTN Enhancement
Scope	Must have Global Awareness of All Nodes/Routes	Operate with Only Local Node/Topology Awareness
Connectivity	Must be End to End	May be Episodic
Network Complexity	Extremely Simple	Introduces Very Complex Elements
Network Delivery Responsibility	None – Applications Must Assure Delivery	Bundle Intermediaries take Delivery Responsibility
Fundamental Unit	Data-Driven Packet	Information-based Bundle
Trust	None	All Bundles Include Certificate

DTN vs TCP Performance



DTN Effectiveness



- **TCP Is Ineffective when Paths Do Not have High Availability (and Reliability)**
- **DTN loses some Efficiency (due to increased overhead) as Availability is Reduced, but Efficiently uses short opportunities to get data through.**
- **DTN Will Leverage TCP Services when End-to-End Availability is High**
  - **Best of Both Worlds**
  - **Common Programming API**

DTN Technology Objectives

Manage Impact of Disruption To:

1. Provide Delay Tolerance
   - Organize Information flow into Bundles
   - Create "Intelligent Networks" that Can Manage the Delivery of Bundles
   - Allow Messages to Pass through Network with Successive Responsibility (Rather than End to End Acknowledgement)
   - Opportunistically Leverage Connectivity, Multiple Routes, …
2. Provide Dynamic Networks Naming and Routing
   - Late-Binding of Bundles (or Packets) to Specific Nodes or Delivery Paths
   - Avoid Forcing All Parts of the Network to be Aware of All other Parts
   - Matches Tactical Unit Deployment

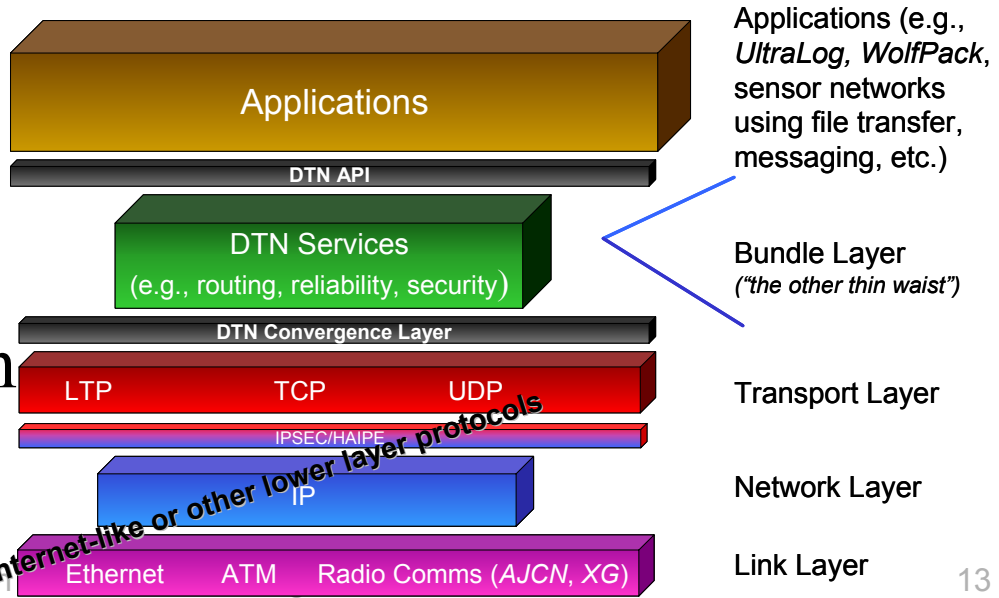
• IP Created a Common Low Level Service
• DTN Creates a Common High Level One

DTN Technologies

- **Bundling** – Organizing information into "Bundles" that can be Delivered by Network
- **Fuzzy Scheduling** – Making Network Routing Decisions in the Presence of Uncertainty about Available or Optimal Paths
- **Policy Cognitive Operation** – Moving Intelligence into Network to Make "Best" Choices on Delivery
- **Deferred / Hierarchical Address Binding** – Enable Network to Deliver Traffic Without End to End Address and Routing Info

Technology Challenges
Bundle Layer

- Develop Technology for Custodial Transfer Across Network
- Demonstrate Stability in "Deterministic" Operation
- Security -- Develop Certificate "Trust" as Minimum
  - Confidentiality -- Develop Agent-Based Mechanism for End to End Key Formation (Existing Technology Not Feasible if Network not Connected)
- Multicast – Extend Delivery and Security Architecture to Multiple Addressees
- Incremental Authentication for "Cut Through" Delivery



Technology Challenges
Fuzzy Scheduling

- DoD Technology Needs More Complex than NASA
  - NASA IPN Bundling Concept Based on Celestial Mechanics
    - Highly Predictable (Kepler, et al)
- Military Applications Have Wide Range of Scheduling
  - Some Are Somewhat Predictable
    - UAVs, UGS Operation, Vehicle Movement, …
  - Some Not Predictable At All
    - Combat Contact, "Mote" Movement
- Need A General Theory of Route Scheduling
  - Replace Existing Internet Single "Shortest Path" with Multiple Hypothesis Routing, Replication, and Bundle Processor Coordination
  - Examine applicability of Epidemic, Gossip Techniques, Commodity Flow Analysis principles, Bayes Nets, …
  - Awareness of All Potential Delivery Assets
  - Cost, Utility, Power, Opportunity, Perishability Security Trades

Extend Current Network Thinking to non-Deterministic Routing Decisions

Technology Challenges
Policy Cognitive Operation

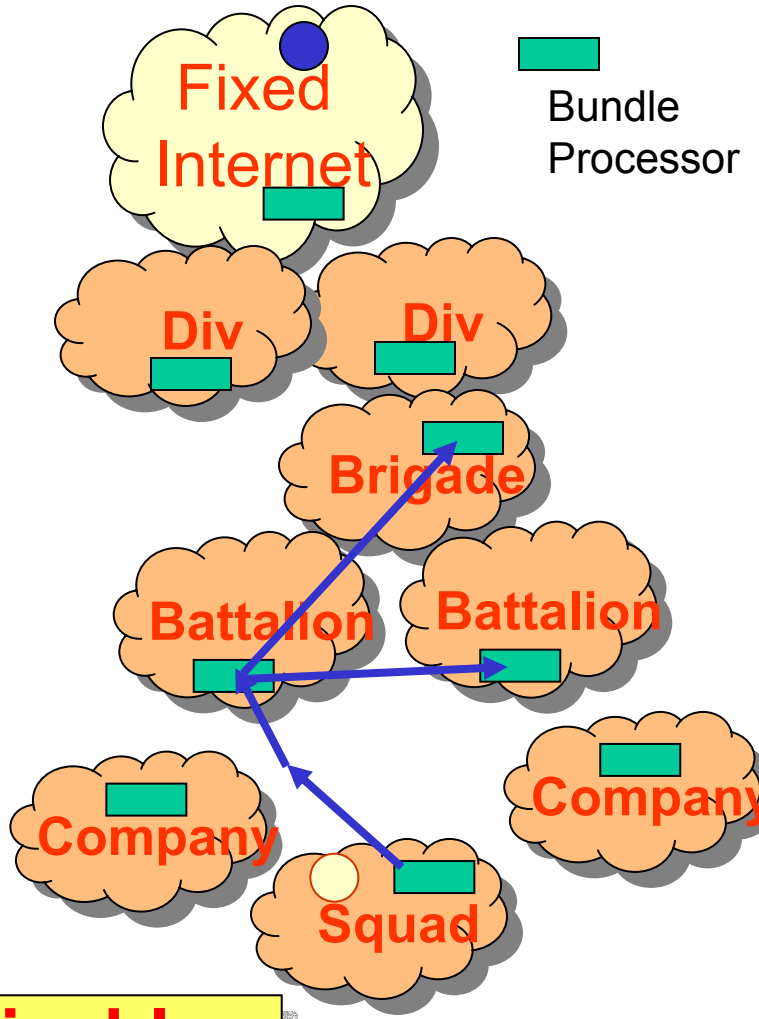
- **Choices of Routing, Storage, Multiple Replication Highly Complex**
  - Classical Approach – Develop Large Code-Based Algorithm Set
    - Limited Extensibility to Unforeseen Uses
- **Proposed Approach – Adopt Cognitive Technology to Provide Goal Seeking Behaviors**
  - Use Ontology (DAML/OWL) Framework to Control Operations of Bundle Mechanisms
    - Complex Interactions Bounded by Capability, Policy, Probability, …
  - Allow Different Users of DTN to Extend DTN by Loading Policies via DAML Framework
    - Link Provable Assertions to Network Behaviors
    - Similar to JAVA Extending Web by Adding Behavior – without IA Risk
    - Policy Metaphor Resolves Inconsistencies between Multiple Sources
  - *Fundamental Technology for Extending Networks* After they Are Developed
- **When Successful, Basis for Migration of Many Network Operations to Cognitive Processes**

Cognitive Networks Next Technology Hurdle for Managing Complex Networks

Cognitive Networks

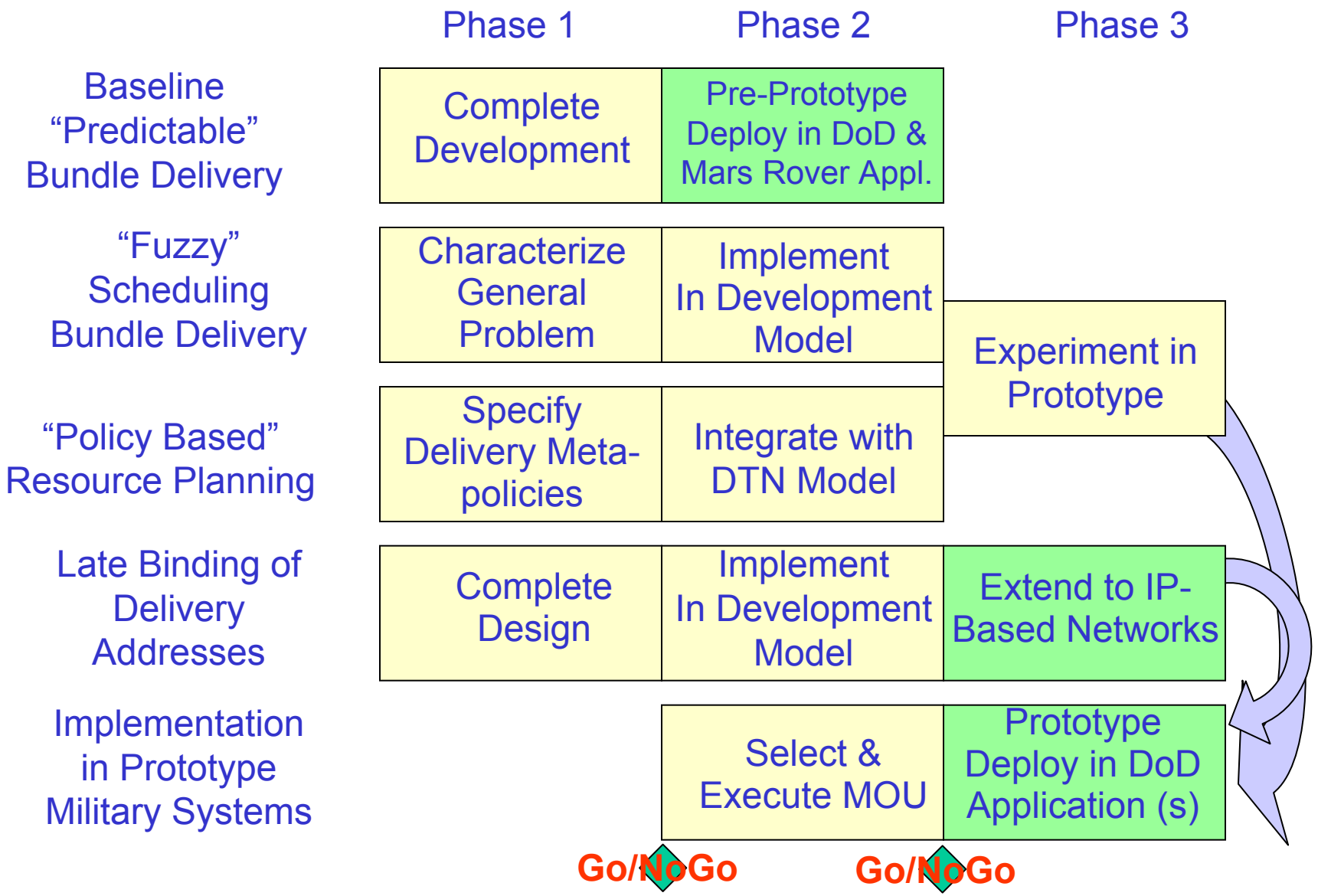
Technology Challenges
Deferred and Hierarchical Binding

- **IP Built On Assumption of Stable Routes and Network Presence**
  - Need Technology to Allow Nets to Move Connectivity, Change Internal Structure, or Appear and Disappear, and "Hide" Structure
  - IP v6 Enables Million times more Addresses!
- **Deferred Binding**
  - Delays Associating Bundle to Specific Address
  - Destination May not Even Be Resolvable (Present) at Time of Message Initiation
  - Allow Address to Change During Interaction
  - Allows for Role-based Addressing and Multiple Internet namespaces
- **Hierarchical Binding**
  - Layered Resolution of Address and Routing Info
  - Consistent with Military Organization, and Original Intent of IP DNS
- **Believe Extensible to IP-Based Networks**



Fundamental Technology Applicable to Any Dynamic Network

DTN Program Plan



Milestones

Phase I

- Demonstrate Bundle Delivery Mechanism with 80 % Utilization and 100 % Reliability on Links of less than 20 % Availability
- Demonstrate Trusted Delivery
- Establish NASA and DoD Program MOA for IPN Demonstration

Phase II

- Demonstrate Bundle Mechanism in IPN
- Demonstrate Late Binding of Bundle Messages
- Demonstrate Policy Language Control Over Delivery Choices
- Maintain Phase 1 Metric
- Establish MOA for Implementing Phase III in Typical Military System

Program Objectives (End of Phase III)

- Demonstrate Integrated Bundling and Late Binding in Military Applications
- Demonstrate late Binding in IP Networks

DTN BAA

- BAA Due out Shortly
  - Will Allow At least 45 Days for Response
- Technical Task Area Content
  - Fuzzy Scheduling and Bundle Delivery
  - “Policy Based” Resource Planning
  - Late Binding of Delivery Addresses
- Can Bid One, Two or All

DTN BAA Phase Scope