



Disruption Tolerant Networking (DTN)



Program Review

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Preston Marshall

Preston.marshall@darpa.mil

703-696-5273



DTN Phase 2 Results



- **Demonstrated Enhanced Reliability in Military Scenarios**
 - 100% message delivery across SATCOM and heterogeneous networks
- **Demonstrated New Capabilities**
 - Reliable On-The-Move to On-The-Move Over the Horizon Comms
 - Reliable delivery when the destination is disconnected / unknown
 - Reliable delivery to units who don't need the information now, don't know they will need the information, but *will* need the information later
- **Demonstrated Lower Bandwidth for Given Number of Tracks**
 - 5x reduction in required bandwidth for tactical application
 - 3.5x increase in capacity over tactical radio
 - ⇒ *Potentially up to 17x capacity increase for typical military applications .. savings should extrapolate to other client-server apps*
- **Demonstrated Networking without Infrastructure**
 - Delivery from edge caches *further* reduces demands on long-haul tactical links
 - Delivery without servers or pre-established names, roles, nets, ...



DTN Phase 2 Results (2)



- **Demonstrated robustness thru 2000 hours of operation in DieselNet (GaTech/UMass), 1500 hours of operation in ElevatorNet (BBN)**
- **Worked with DTNRG to Stage DTN Specifications thru IETF Process towards RFCs – Critical to COTS/vendor Strategy**
- **DTN Implementations Interoperated at IETF Nov 2006 – new interop today**
- **Demonstrated DTN operation in scenarios modeled on service CONOPS, Nov 15th at Fort AP Hill, following 3 weeks of field exercises**

**DTN Delivers Information from the Edge, to the Edge –
Reliably & WHEN It's Needed**



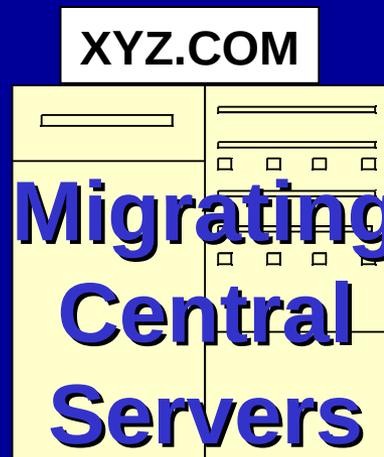
DTN Fundamental to Infrastructureless Networks



No Cell Towers

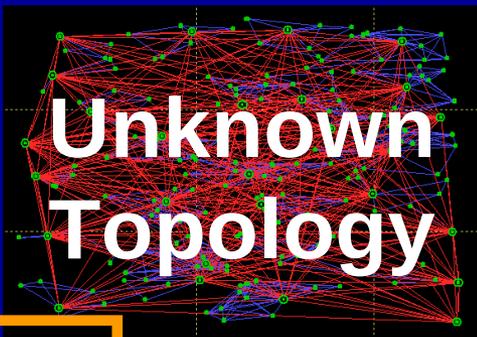
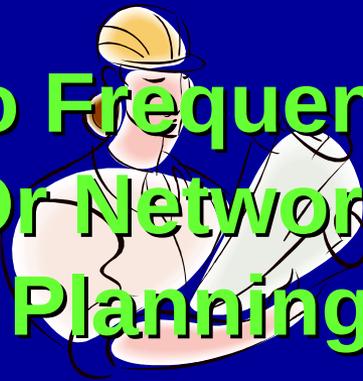


Finite Energy



Migrating Central Servers

No Frequency Or Network Planning



Unknown Topology

Distributing Cache Servers

Distributed Index Services



No Fiber, No Wires





Fort AP Hill Field Exercises

29 Oct - 15 Nov



Basic DTN & "Advanced" DTN Components

- Scenarios based on USMC Scenarios
- USMC HMMWVs, SATCOM & Tactical Radios w / DTN in USMC laptops
- BBN Created DTN "Futures" Demo
 - Developed scenarios, provided stand-ins for military systems, developed "futures" software
- Ground truth via telemetry backhaul over EVDO

Demo Day, 15 November

- Presentations from USMC, DARPA, & DTN Performers incorporating live field demos
- Standalone sidebar posters, demos & briefings from DTN performers
- Service and DoD Community Attendance



Summary of Military System Exercise Results at Fort AP Hill



- **Showed that DTN integrated into tactical comms provided reliability & forwarding**
- **Achieved 100% OTM message delivery across SATCOM with existing military procedures**
- **Demonstrated superior reliability of DTN vice end-to-end TCP across long comms outages**
- **Demonstrated reliable OTM edge-to-edge comms using alternate routing to advantaged node**
- **Demonstrated military app retrofitted with DTN for reliable delivery**
- **Demonstrated bandwidth savings using (reliable) state at both ends of connection**
 - **4.7x reduction in application-generated network loading**
- **Demonstrated 3.5x capacity improvement in tactical network**
 - **Potentially 17x capacity improvement similar applications over tactical networks**



DTN Enables OTM-to-OTM Comms and Reliably Delivers Data



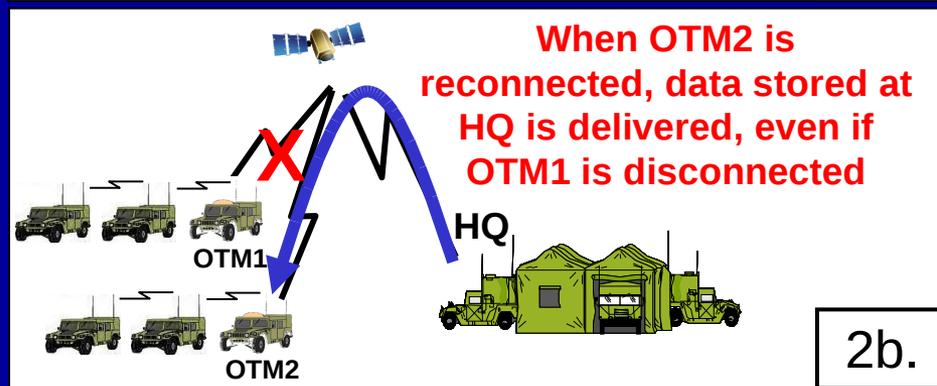
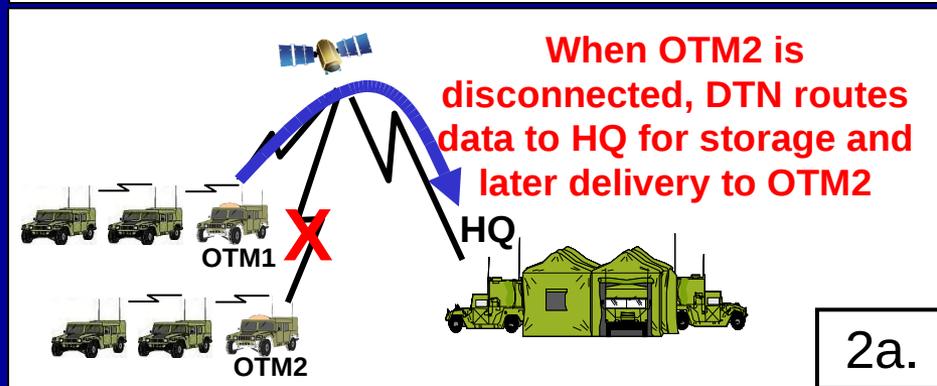
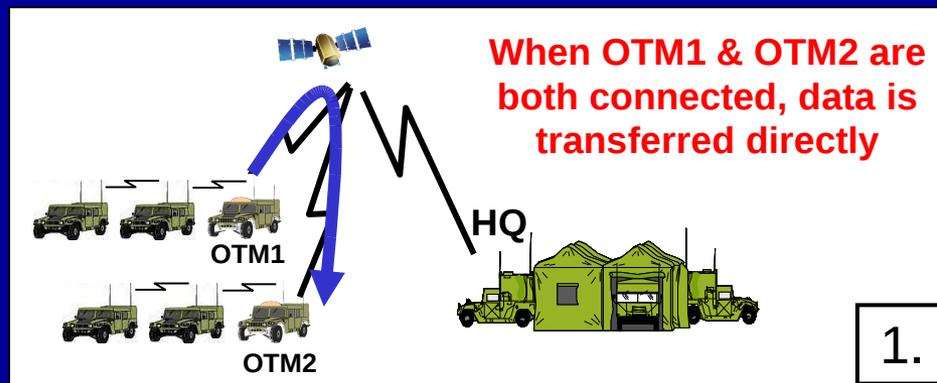
Dynamic Routing Alone Can't Exploit Future Connections – DTN Enhances Dynamic Routing with Storage for Delivery over Disconnected Paths

DTN Delivers:

1. Along direct paths when they exist
 - 2a. To advantaged nodes (custodians) when no direct path exists
 - 2b. Custodians deliver data when destination becomes reachable
- Original sender need not be connected to complete delivery!*

DTN routing uses 'advantaged' locations (e.g. HQ) for temporary data storage
Off-shortest-path storage makes reliable delivery possible

DTN Routing & Storage Deliver All Messages that Live Across Link Outages

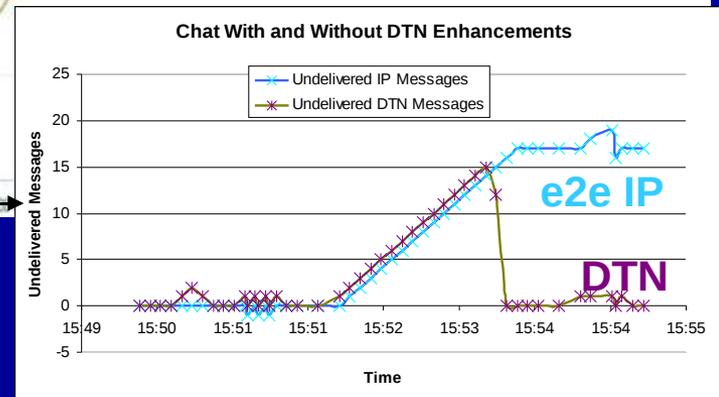
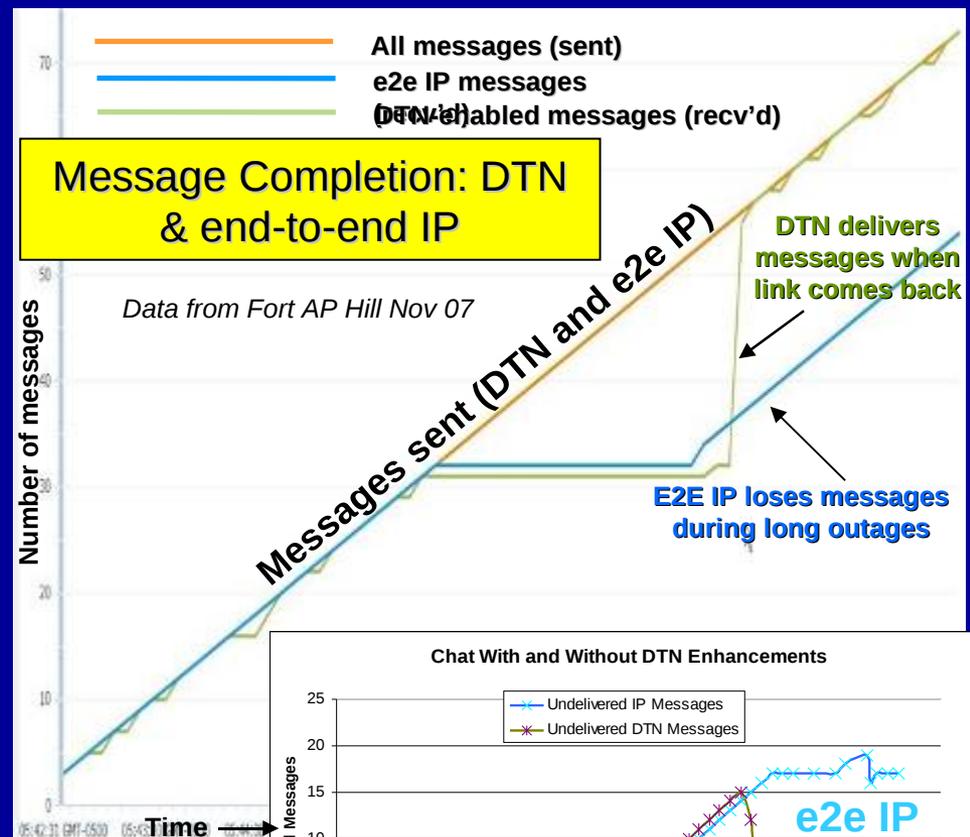
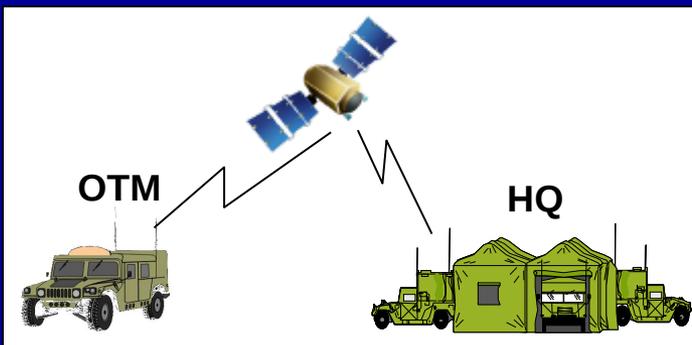




FAPH: DTN Provides Reliable Message Delivery across SATCOM Outages



- With E2E IP, OTM Drops Data when Satellite is Occluded
 - TCP connections break and data is lost on outages >90s
 - No reliability with UDP
- DTN Provides Reliable Message Delivery across Comms Outages:
 - Retains messages when link is down
 - Delivers retained messages when connectivity is restored



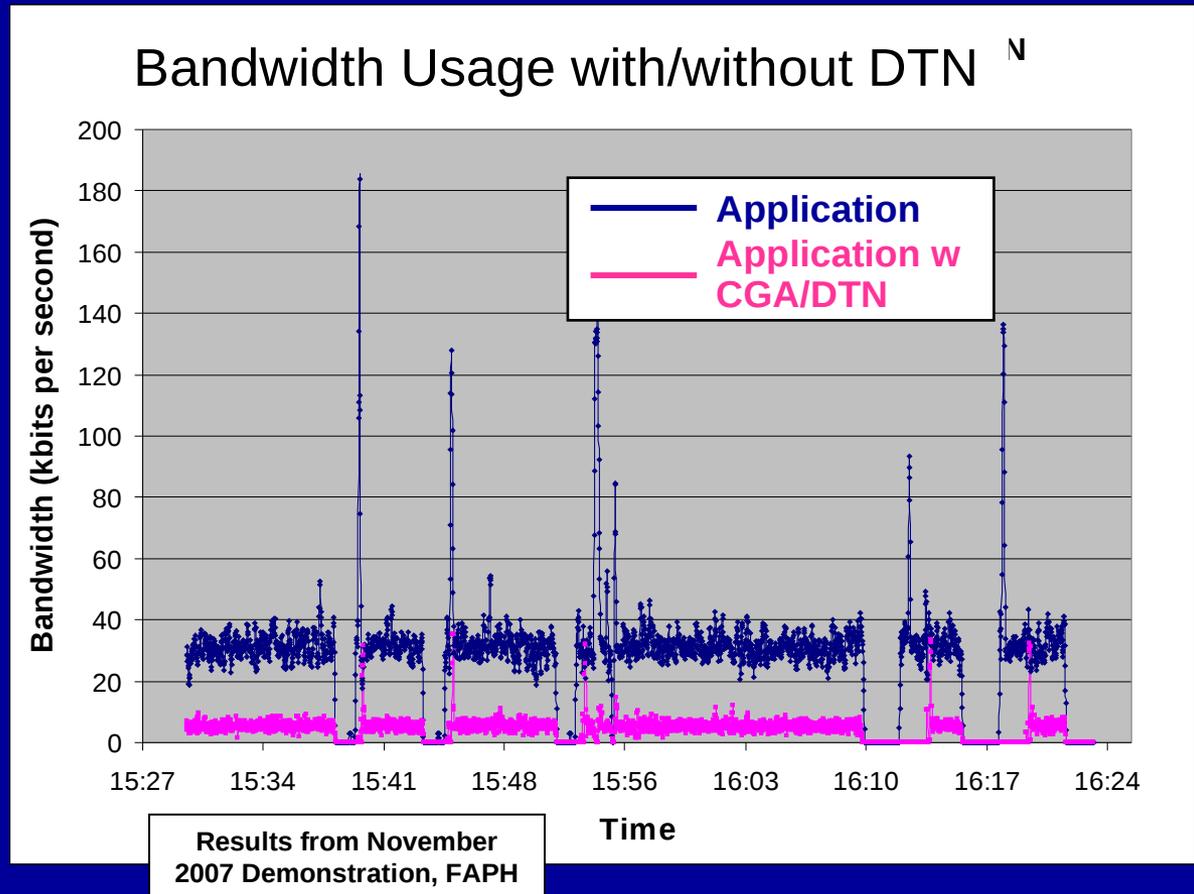
DTN Delivers!



CGA with DTN Reduces Application Bandwidth



- DTN reliable delivery ensures consistent state at each end of the connection
- Consistent state across the connection allows *stateful compression*, reducing latency & traffic across long-haul links, & allowing more tracks
- First Native DTN Tactical Application – CGA/DTN



CGA compression with DTN Reliable State Uses 1/5 the Bandwidth – Relevant to Other Tactical Apps



DTN “Future Technology” Summary of Results



- **Demonstrated reliable end-to-end message delivery in a disconnected and heterogeneous network (5x better delivery in this scenario)**
- **Demonstrated that content caching & serverless dissemination at the tactical edge increase reliability, reduce latency and load on thin links (10x better delivery to edge user with DTN vice e2e IP)**
- **Demonstrated ad hoc creation of delivery networks based on interest, role, location, ...**
 - Enables an increase in the tactical tempo
 - Showed mechanism for dynamic collaboration at edge without network configuration / naming / list management
- **Demonstrated operation over heterogeneous network structures, without requiring IP in the stack**

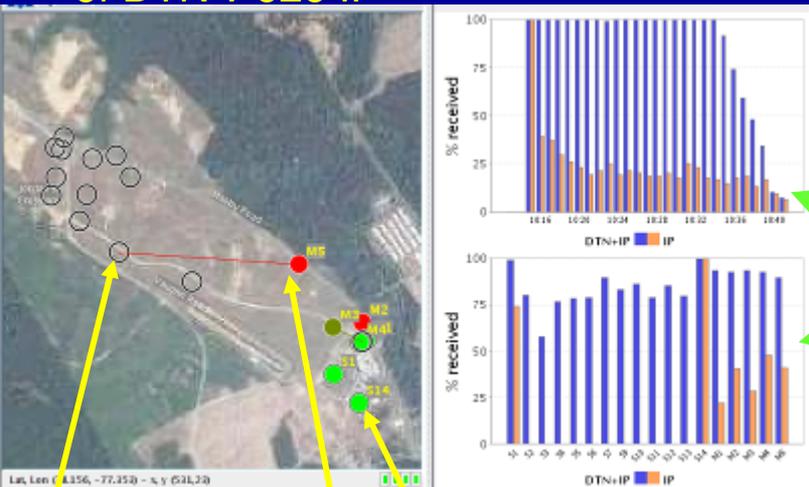
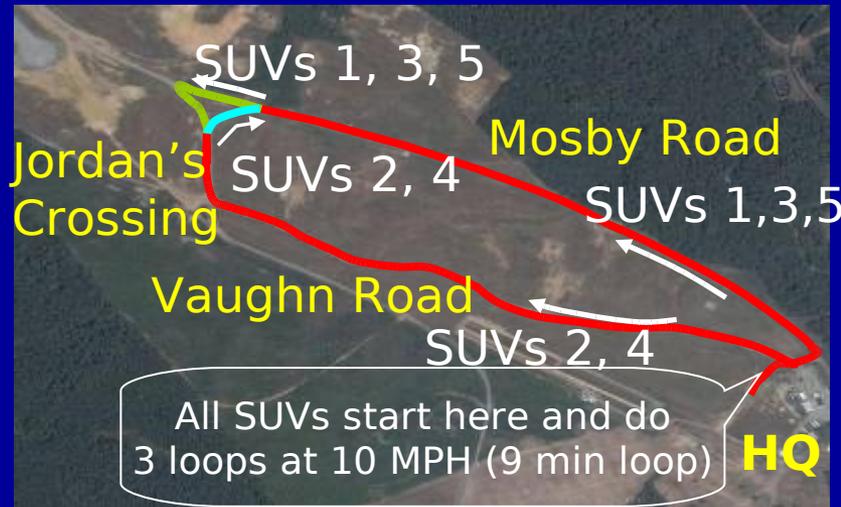


FAPH: Reliable Delivery across heterogeneous and completely disconnected networks



Mobile Ops Scenario with mobiles relaying data from disconnected nodes

- Five mobile nodes
- Fifteen stationary nodes deployed including three at Night Vision Lab
- 802.11 on all nodes; long-haul tactical radios on mobiles
- Nodes send identical messages to HQ via DTN, end-to-end IP, and telemetry net. A-B comparison of DTN v e2e IP

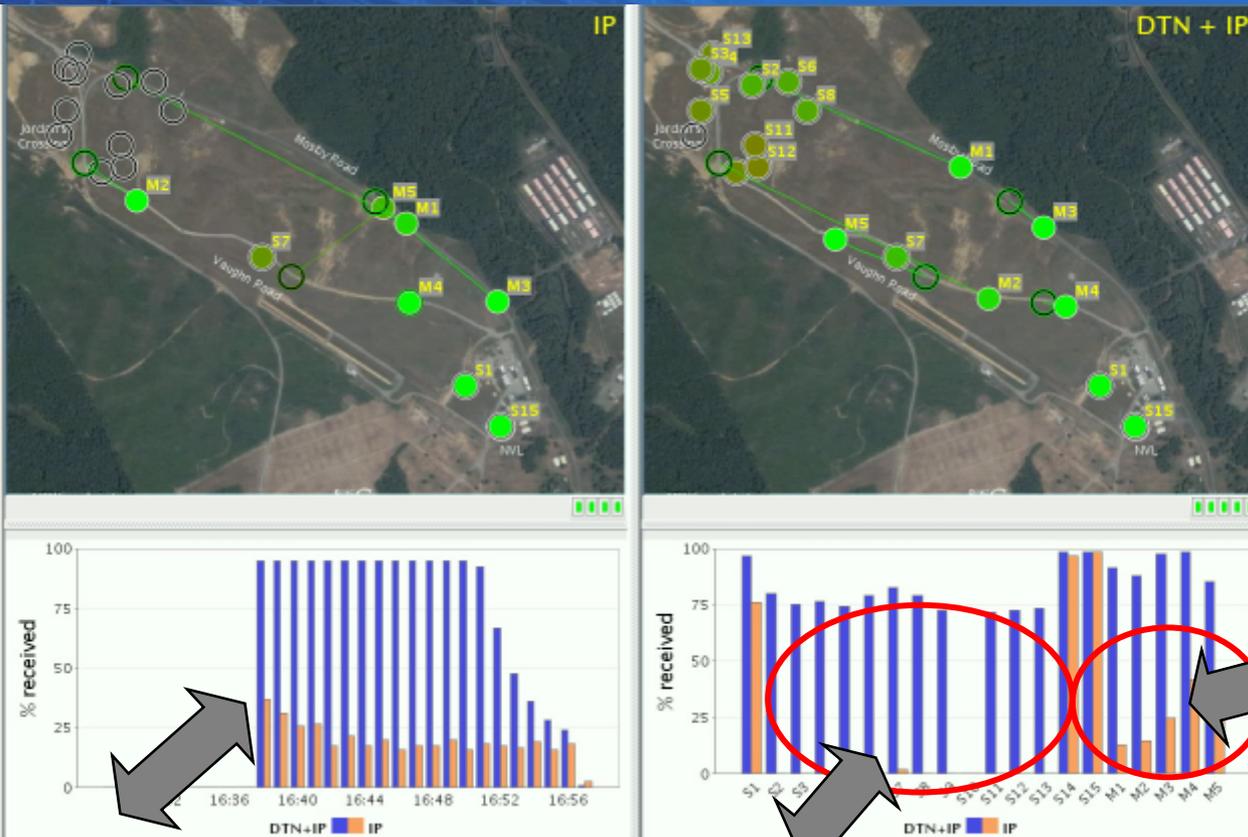


Reception histograms for DTN & E2E IP (blue for DTN, orange for E2E IP)

Delivery ratio for reports v. time

Delivery ratio for reports v. node id

DTN Delivers Even for Stationary Nodes which NEVER have an E2E Path -- IP Can Not



(double click to run movie)

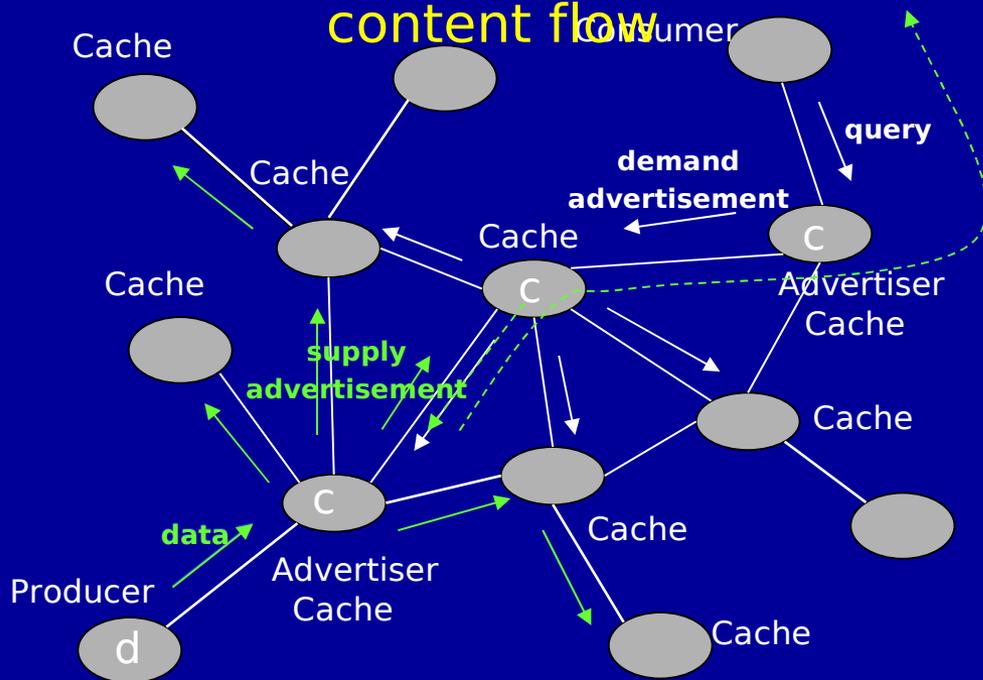
DTN delivers reliably for intermittently connected nodes; IP doesn't

DTN delivers 100% after nominal latency

IP doesn't and can't deliver from disconnected nodes

DTN delivered 100% in one circuit time
IP delivered ~20-25% long-term
IP never delivered traffic for nodes w/o an e2e connection

DTN supports push and pull; appropriate third-party can direct content flow



- Users describe what they want, not where it is stored – DTN moves information where it is needed, *when it is needed*
- Low-latency access to requested information without access to remote servers, if the content is at the edge
- Reduced demand on long-haul thin pipes through distributed caching and local retrieval from cache

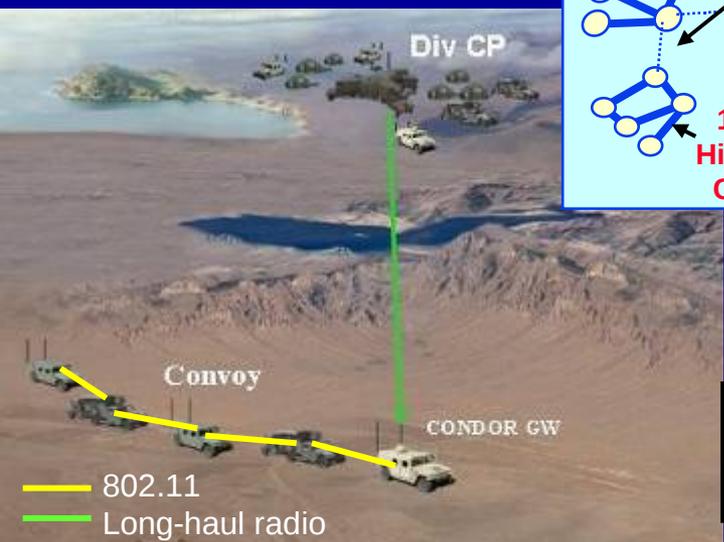
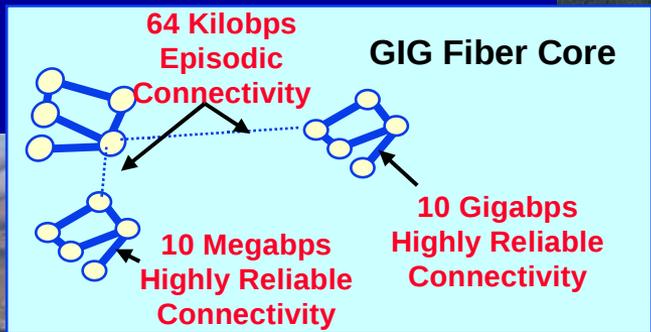
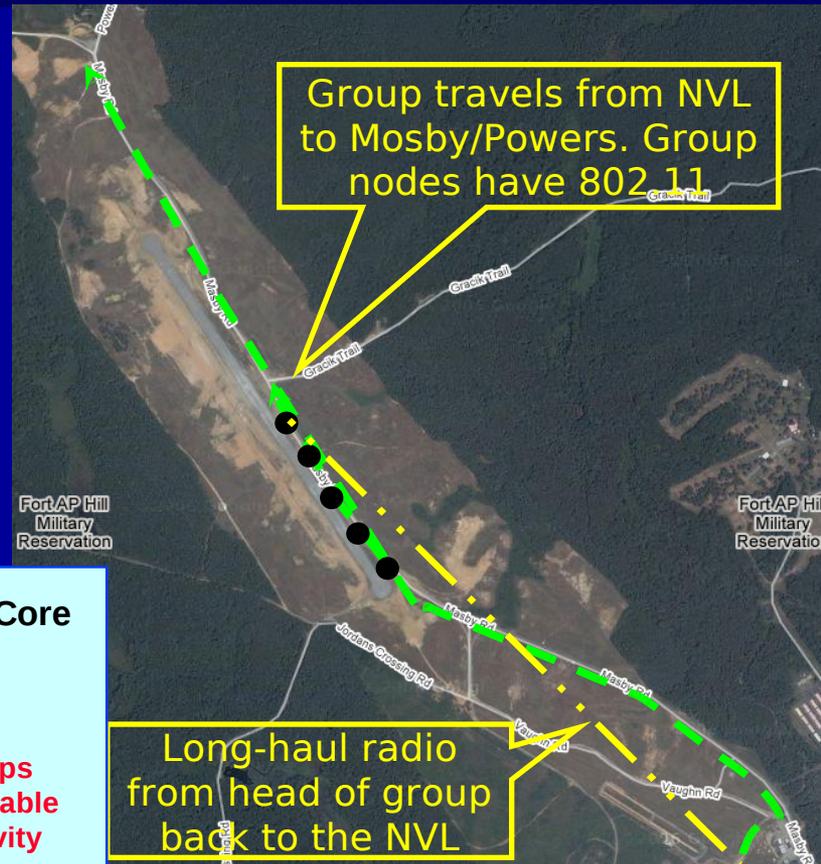
DTN Distributed Serverless Access to Content Enables Access to Information at the Edge, When & Where it's Needed



FAPH: Caching & Content-Based Access Field Demonstration

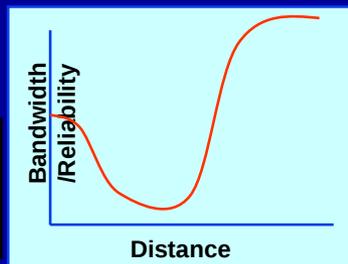


- Demonstrates caching & long-haul bandwidth reduction at the local end of the thin pipe
- Mix of radios in group of mobiles
 - Lead element has long-haul radio for comms to HQ
 - Others have short-range 802.11, so communicate to HQ by routing thru long-haul vehicle
- Each element of the group requests imagery of the region when it enters the region
 - e2e IP: 5 end-to-end transactions with the image server at HQ
 - DTN: 1 end-to-end transaction to the HQ server, 4 queries short-stopped by cache

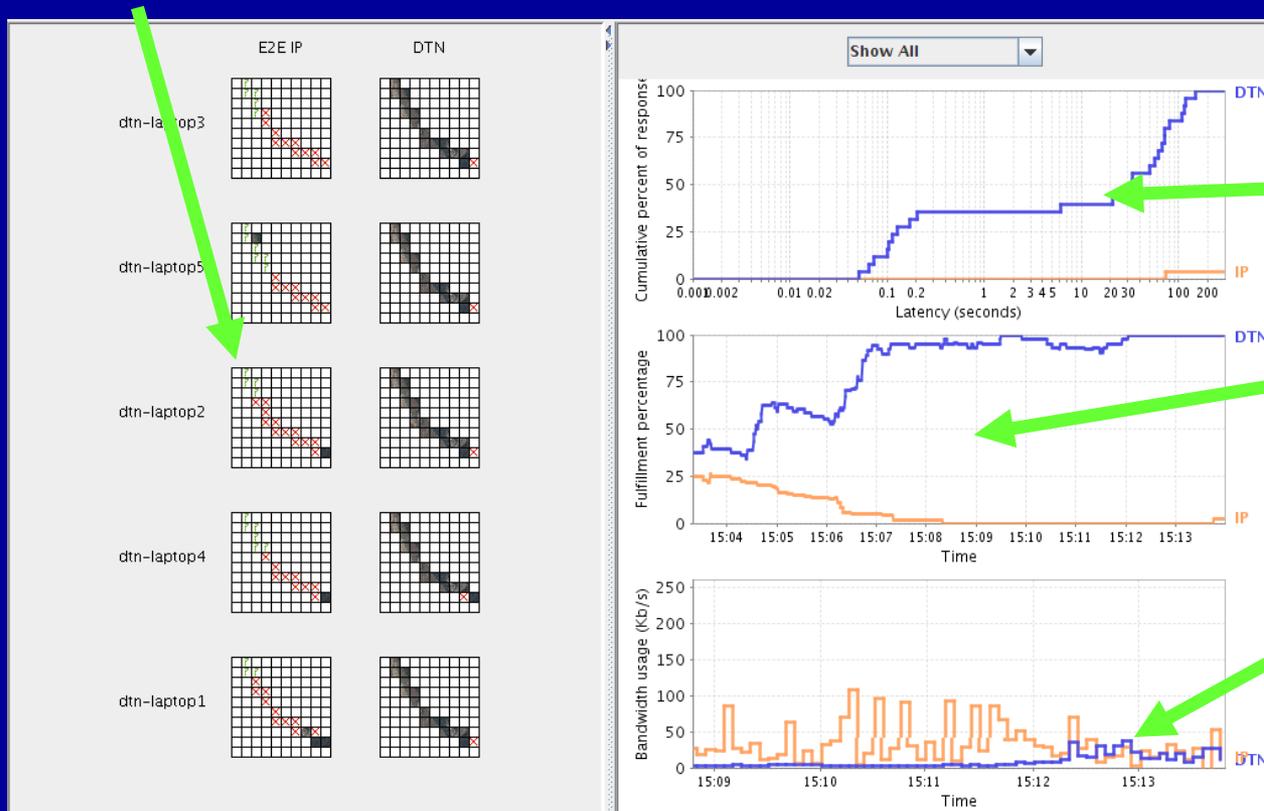


- Backhaul is expensive: \$14/min SATCOM or “high cost” LOS radios
- Local bandwidth is cheap & available

Minimizing backhaul bandwidth enables independent edge ops



- Area is tiled into regions
- When a vehicle enters the region, it asks for imagery for the region; a green question mark appears in the corresponding tile in the display
- When the imagery is received, it is copied into the grid
- If the request expires (5 minutes), a red cross is displayed instead



e2e IP vs. DTN

- Delivery latency
- Delivery ratio v. time
- Bandwidth over Long-Haul Link v. time



Other DTN Program Accomplishments



Standards for Acquisition DTN Architecture & Bundle Protocol Specifications achieved RFC status (RFC 4838, RFC 5050)

- 1st DTN spec to achieve RFC status
- DoD can reference DTN RFC in acquisitions
- RFCs the linchpin of COTS strategy



Content Tag draft published – key for interoperable content-based networking

Implementation of plug-in interfaces released

- Plug-in architecture crucial to military-specific behaviors in COTS boxes
- Router plug-ins, storage plug-ins, and convergence layers released
- Demonstrated “free-space optical” (IRDA) convergence layer operation



DTN2 in DieselNet & ElevatorNet – 3500 hours of testing for robustness in Phase 2, ~ 200K hours of testing by the end of Phase 3

