



# Moving Data Through Disconnected Networks Delay-Tolerant Networking and the IC (U//FOUO)



June 2012

The overall classification of this briefing is:  
TOP SECRET//COMINT//REL TO USA, FVEY



Derived From: NSA/CSSM  
1-52

Dated: 20070108

Declassify On: 20360901



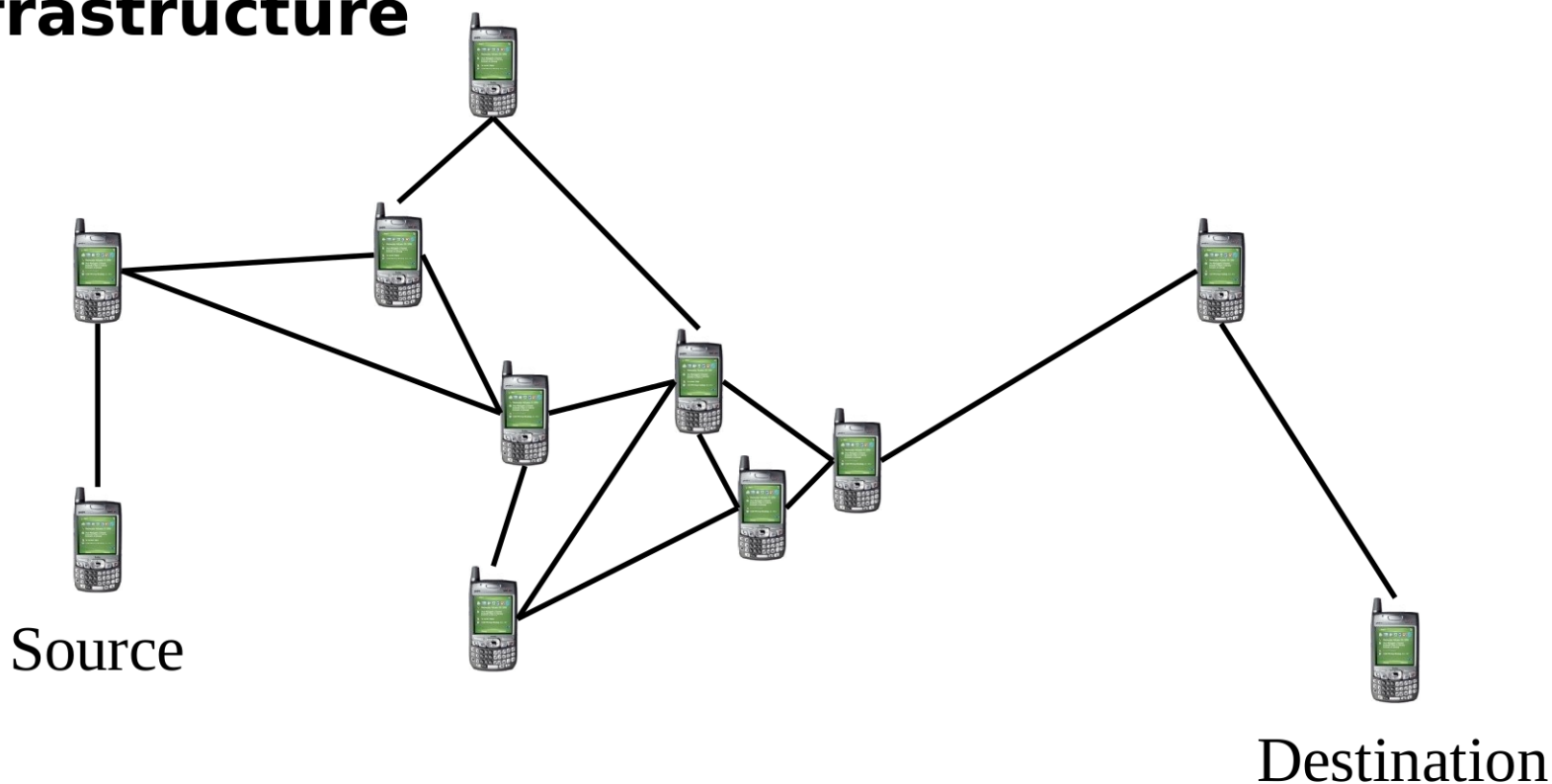
# Outline

1. (U) Delay-Tolerant Networking intro
  - i. Outside world: protocols and software
  - ii. IC Applications of DTNs
2. (TS//SI//REL) Summary of R4 work
  - i. CHIMNEYPOOL integration
  - ii. Wireless testing
3. (TS//SI//REL) Interesting details
  - i. DTN Routing
  - ii. DTN Security



# Mobile Ad-Hoc Networks (U)

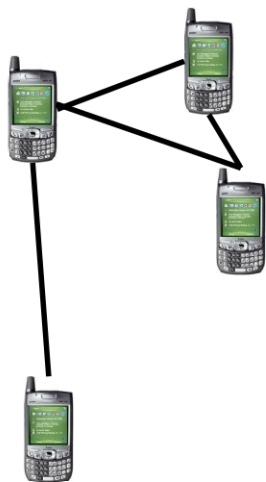
- **(U//FOUO) A wireless network with no infrastructure**



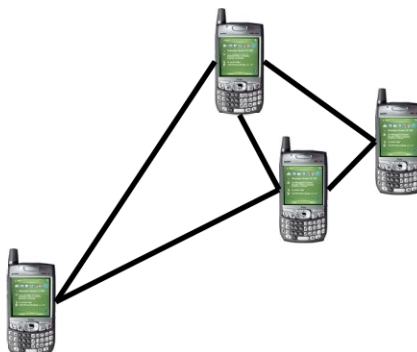


# Intermittently Connected Network (U)

- **(U//FOUO) Many wireless networks will not have end-to-end connectivity**



Source

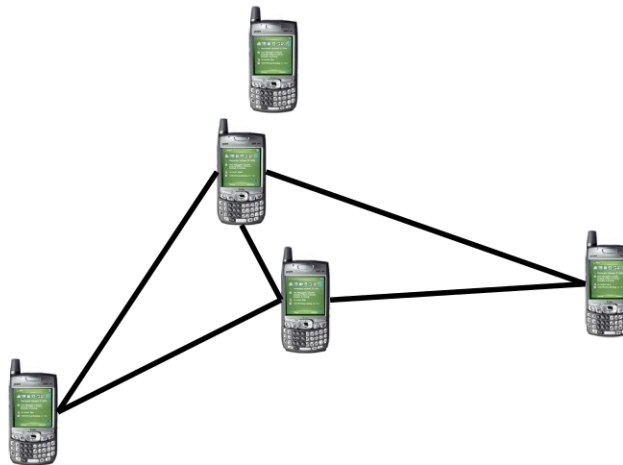
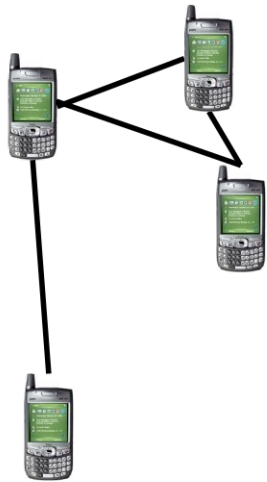


Destination



# Delay-Tolerant Networks (U)

- **(U//FOUO) DTNs use a store-carry-forward approach to take advantage of node mobility**



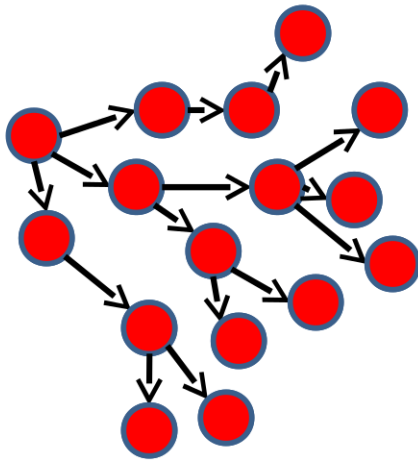
Destination



# Beginnings of DTN (U)

2000: Epidemic Routing  
Vahdat and Becker

1990s: Interplanetary Network  
NASA, JPL



2002, 2004: ZebraNet  
Juang, Oki, Wang, Martonosi, Peh, Rubenstein

2002: Mobility Increases Capacity in Ad-hoc Wireless Networks  
Grossglauser and Tse

2003: A DTN Architecture for Challenged Internets  
Kevin Fall

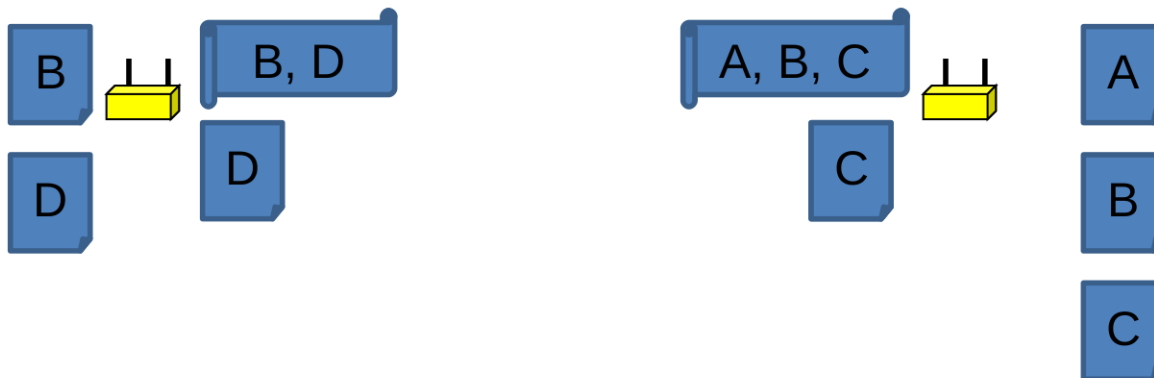
2003: DataMULEs  
Shah, Roy, Jain, Brunette

2003: Probabilistic Routing in Intermittently Connected  
Networks  
Lindgren, Doria, Schelen



# Beginnings of DTN: Epidemic (U)

- 2000: Epidemic Routing - Vahdat and Becker



- Nodes exchange “summary vectors”
- Each node sends the data that the other node lacks
- Summary vectors implemented as a Bloom Filter
- Followed by Immunity concept: *Resource and performance tradeoffs in delay-tolerant wireless networks*, 2005; Small and Haas



## Beginnings of DTN: ZebraNet (U)

- Wildlife tracking project at Princeton
- GPS + other info gathered by collars on zebras
- Data migrated back to base using “History-Based” routing

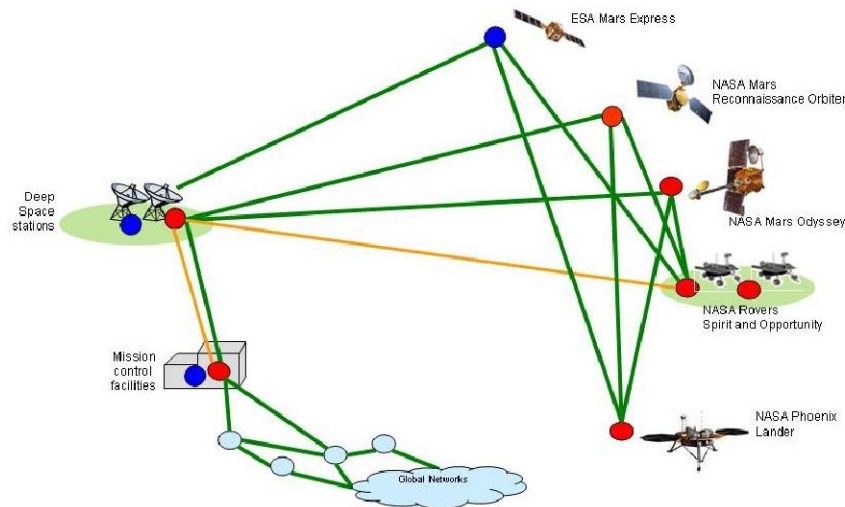






# Beginnings of DTN: IPN (U)

- Inter-Planetary Network
- Long distances  $\Rightarrow$  long propagation delays
- Intermittent connections
- Known contact schedule  $\Rightarrow$  Contact Graph Routing
- Worked on since the 1990s by NASA, JPL, incl Vint Cerf



[Figure taken from Vint Cerf's 2010 presentation: "When Intuition Fails"]



# Beginnings of DTN: DataMULEs (U)

- *Data MULEs: modeling a three-tier architecture for sparse sensor networks*
- 2003 Paper by R. C. Shah, S. Roy, S. Jain, W. Brunette
- Has mobile MULEs relaying data from sensors to well-connected Access Points
- Similar: *A Message Ferrying Approach for Data Delivery in Sparse Mobile Ad Hoc Networks*, 2004; Zhao Ammar, Zegura





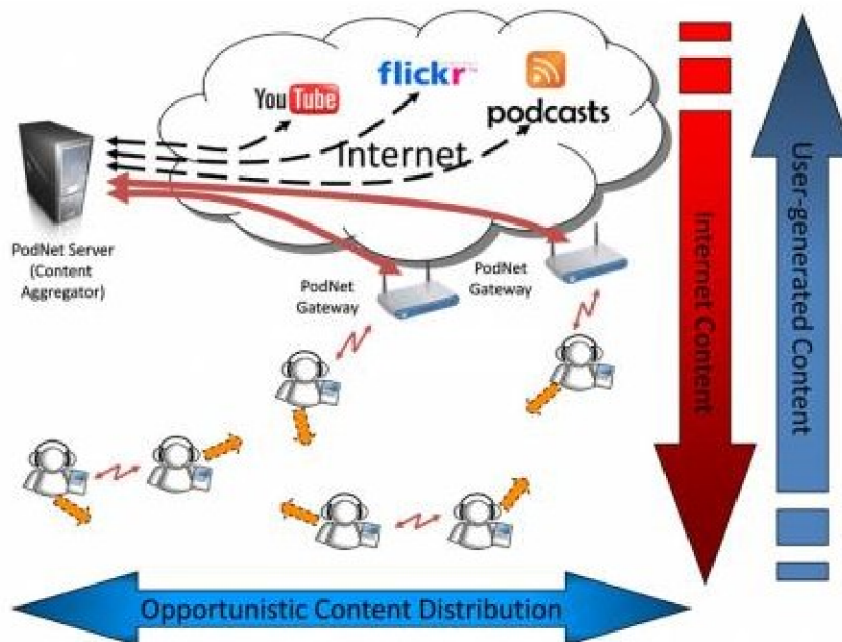
# What's a DTN For? (U//FOUO)

- Wildlife tracking
  - ZebraNet, SWIM, TurtleNet
- Outer space
- Under water
- Underground (mines)
  - [*DTN Communication in a Mine*, 2010 Ginzboorg, Kärkkäinen et al]
- Rural areas
  - N4C, DakNet, KioskNet, TIER, Bytewalla
- VANETS, Public transit
  - DieselNet, Braunschweig, NICT
- Battlefields/disaster areas
  - DARPA DTN Program
- Sensor nets
- Heterogeneous networks
  - [*Integrating Multiple and Heterogeneous Challenged Networks for Large-sized Data Transfer*, 2009 Nagata et al]



# What's a DTN for II (U//FOUO)

- Content dissemination
  - [PodNet, 2006 - Present; Legendre, Lenders, May, Karlsson]
  - Hagggle Project
- Social Networking
- Distributed Storage
  - [TierStore, 2008; Demmer, Du, Brewer]
  - [DTN-based Content Storage and Retrieval; Ott, Pitkanen]

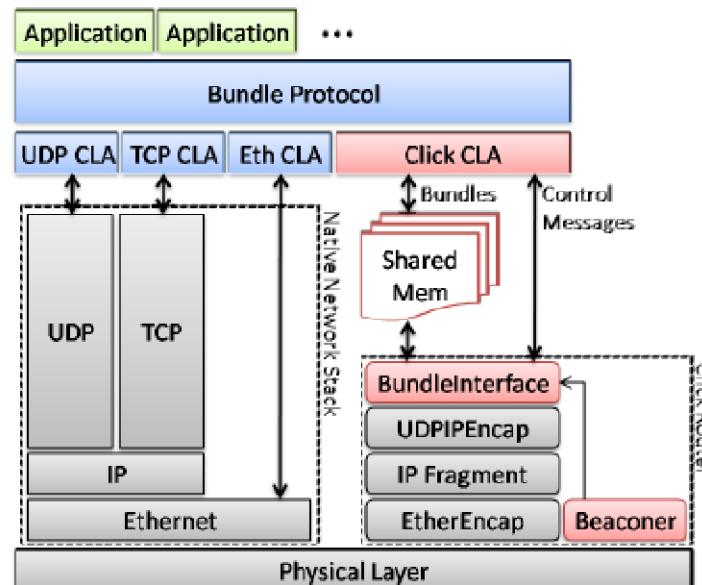


- Cellular Traffic Offloading
  - [Cellular Traffic Offloading through Opportunistic Communications: A Case Study, 2010; Han, Hiu et al]



# Standardization Activities\* (U)

- DTNRG has been part of the IRTF since (at least) 2002
- RFC 5050 defines the Bundle Protocol
- Application-layer overlay that moves “bundles” of data
- Convergence Layers move bundles over different networks





## Protocol Highlights (U//FOUO)

- Modular architecture
  - Convergence layers
  - Routers
  - Neighbor discovery
- Security extensions
- Persistent storage
- Hop-by-hop and end-to-end reliability possible



# Bundle Protocol Architecture (U//FOUO)

Bundle  
Layer

Bundle Protocol Agent (BPA)

Convergence  
Layer

TCP CL

UDP CL

File CL

AX.25  
CL

...



# Bundle Protocol Stack Landscape

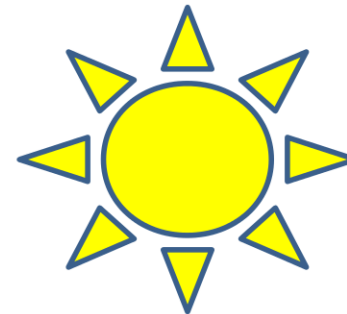
Vapor



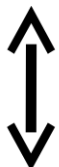
Aalto  
Java stack



iPhone  
TCPCL  
GA Tech  
C# stack



SPINDLE



Bytewalla



Cisco  
Java stack



pydtn

DTN2 Reference  
Implementation



IBR-DTN



dtns60



ION

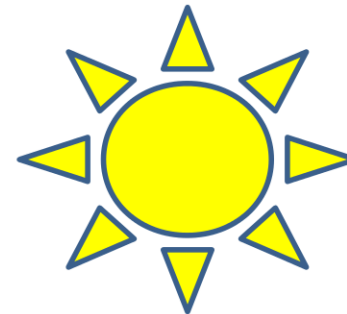
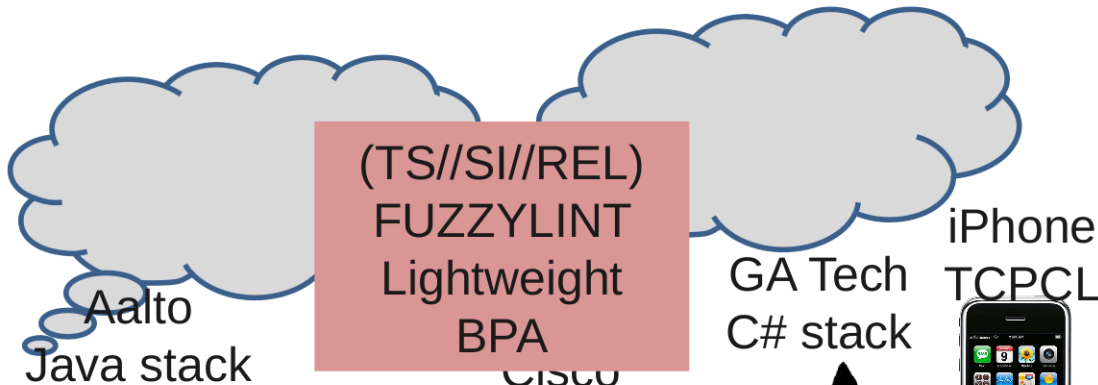
Real





# Bundle Protocol Stack Landscape

Vapor



SPINDLE



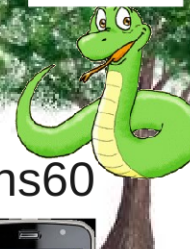
Bytewalla



.



pydtm



DTN2 Reference Implementation



IBR-DTN



dtms60



Real

# **Summary of Intelligence Community Applications (U//FOUO)**



## Covert Communications (TS//SI//REL)

- (TS//SI//REL) Provide covert comms in denied areas where no infrastructure exists, or where using the infrastructure would compromise the operation.
- (S//REL) Several “brush-pass” wireless hand-offs as an untraceable alternative to scheduled meetings, dead drops.
- (TS//SI//REL) DTN provides an open-source solution running on commercial handheld devices = Unattributable.



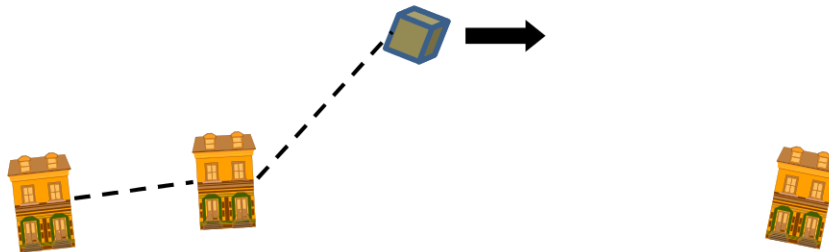
## Close Access (TS//SI//REL)

- (TS//SI//REL) Implant in a secure facility or denied area
- (TS//SI//REL) Need to transfer data and commands over two or more hops
- (TS//SI//REL) May rely on mobile nodes and unwitting data mules



# NRO/MSD Collaboration

- (TS//SI//TK) Moving data between ground stations using CubeSats. Coverage every ~1.5 hours. Need DTN
- (TS//SI//TK) They use DTN2, ION, contact graph routing





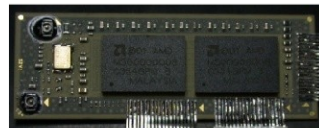
# Crowd Sourcing (U)

- (TS//SI//REL) Provide data flow in and out of closed nations during internet shut-down
- (U) Ambitious BIG idea
- (U) Proposed CONOP not far from current work
- (U) Proposed internally and externally
- (U) State Dept-funded project had an article in NYT



## Tagging Tracking & Locating (U)

- (U) Insert GPS trackers in cars or electronics, but we may never see them again
- (TS//SI//REL) Migrate data back to collection point via DTN
- (TS//SI//REL) Original CONOP for RAPTORGALAXY





# Summary of IC applications (U//FOUO)

CovComm	Close Access	NRO CubeSat Comms	Crowd-Sourcing	Tagging Tracking & Locating
<p>Unattributable</p> <p>COTS handsets</p> <p>Open-source</p>	<p>Data exfiltration from isolated networks and denied areas</p> <p>TSV field test</p>	<p>Comms between ground stations that only have occasional satellite coverage</p> <p>Use inexpensive CubeSat platform</p>	<p>Provide data flow in and out of closed nations</p> <p>Ambitious BIG idea</p> <p>Proposed CONOP can be done <i>now</i></p> <p>Proposed internally and externally</p>	<p>Very small hardware</p> <p>Record locations and encounters</p> <p>Use DTN to migrate data back to collection points</p>



# **DTN work at R4**



# Things We Have Done (U)

- Porting FOS DTN software to mobile devices





## Things We Have Done (U)

- Porting FOS DTN software to mobile devices
- Developing friendly user interface software so anyone can use it





# What We Have Been Building (U)

- Porting open source DTN software to mobile devices
- Developing friendly user interface software so anyone can use it
- Testing – determining what actually works
- Field testing different configurations and scenarios
- Implementing security features
- Building new routing modules
- Adding geo-tagging/tracking features
- Experimenting with new neighbor discovery methods

# **FUZZYLINT and CHIMNEYPOOL integration (TS//SI//REL)**



# (Not So) Close Access

- (TS//SI//REL) Retrieving data from an implant without visiting the implant ourselves
- (TS//SI//REL) Need to add DTN link capability to the implant
- (S//REL) Data mule may be unaware of their role
- (TS//SI//REL) Rough prototype demoed at Trident Spectre



# STRAITBIZZARE (U)

- (TS//SI//REL) Cross-platform implant built using TAO's CHIMNEYPOOL framework
  - Ports for Linux, Windows, etc..
  - Endpoint-centric : focused on file exfil from a PC
  - Remote Procedure Call (RPC) based
- (TS//SI//REL) FRIEZERAMP protocol provides covert networking
  - CHIMNEYPOOL comms module
  - Similar to IP, IPsec
  - Only supports static network configuration
- (TS//SI//REL) FRIEZERAMP links are adapters to converge FR packets onto the transport layer below
  - Examples : https, udp, smtp, etc.



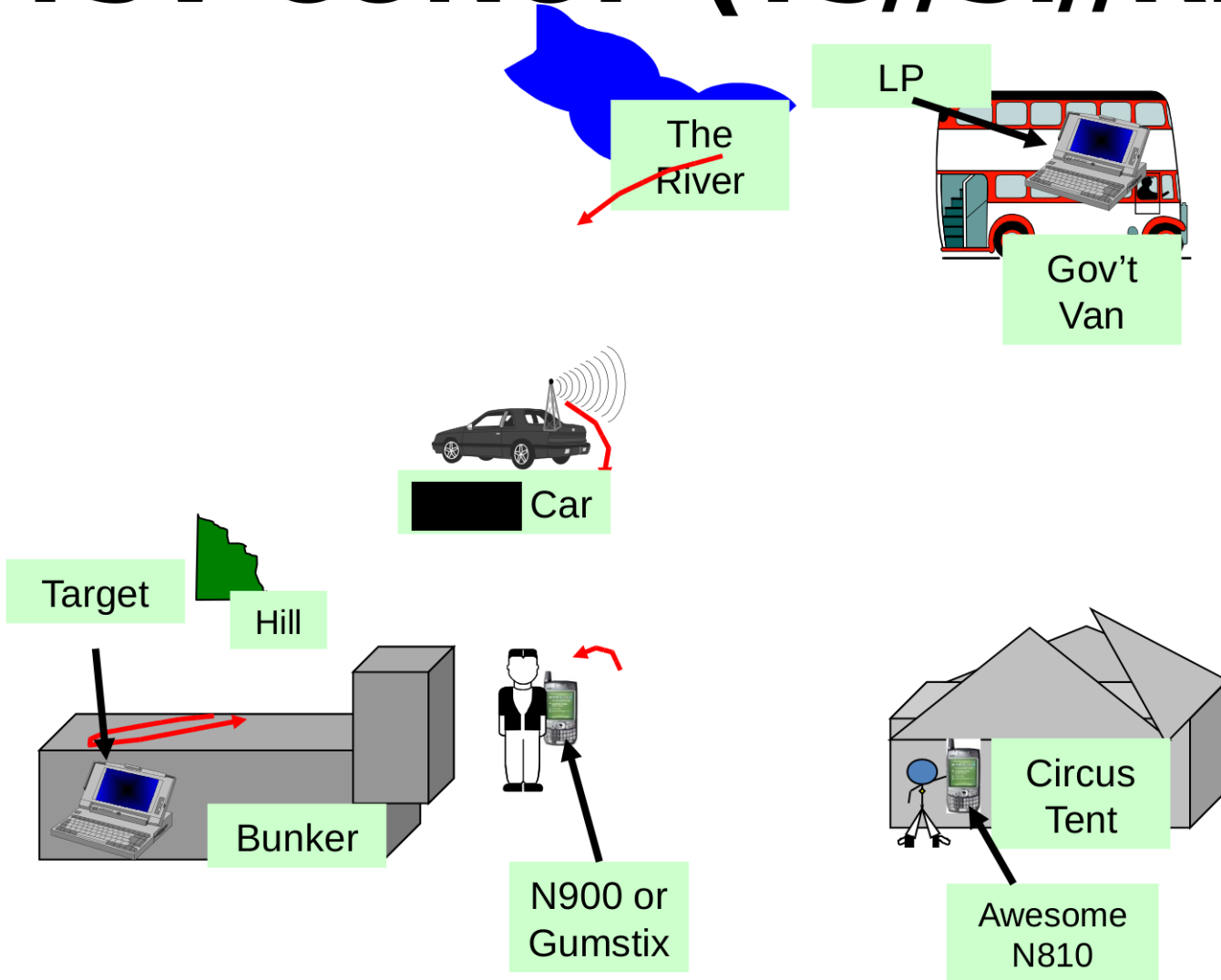
## Put SBZ on each device ... right? (TS//SI//REL)

- (TS//SI//REL) File exfil CP modules and FRIEZERAMP treats reliability as **only** an end-to-end issue
  - FR retransmissions are requested by the receiver and only the sender can retransmit
  - Hop-by-hop reliability is desirable
- (TS//SI//REL) Persistent storage module only waits until link is available then “send and forget”
- (U//FOUO) All routes are static and setup a priori
- (TS//SI//REL) Operationally, SBZ on each device is undesirable in some CONOPs





# TSV CONOP (TS//SI//REL)



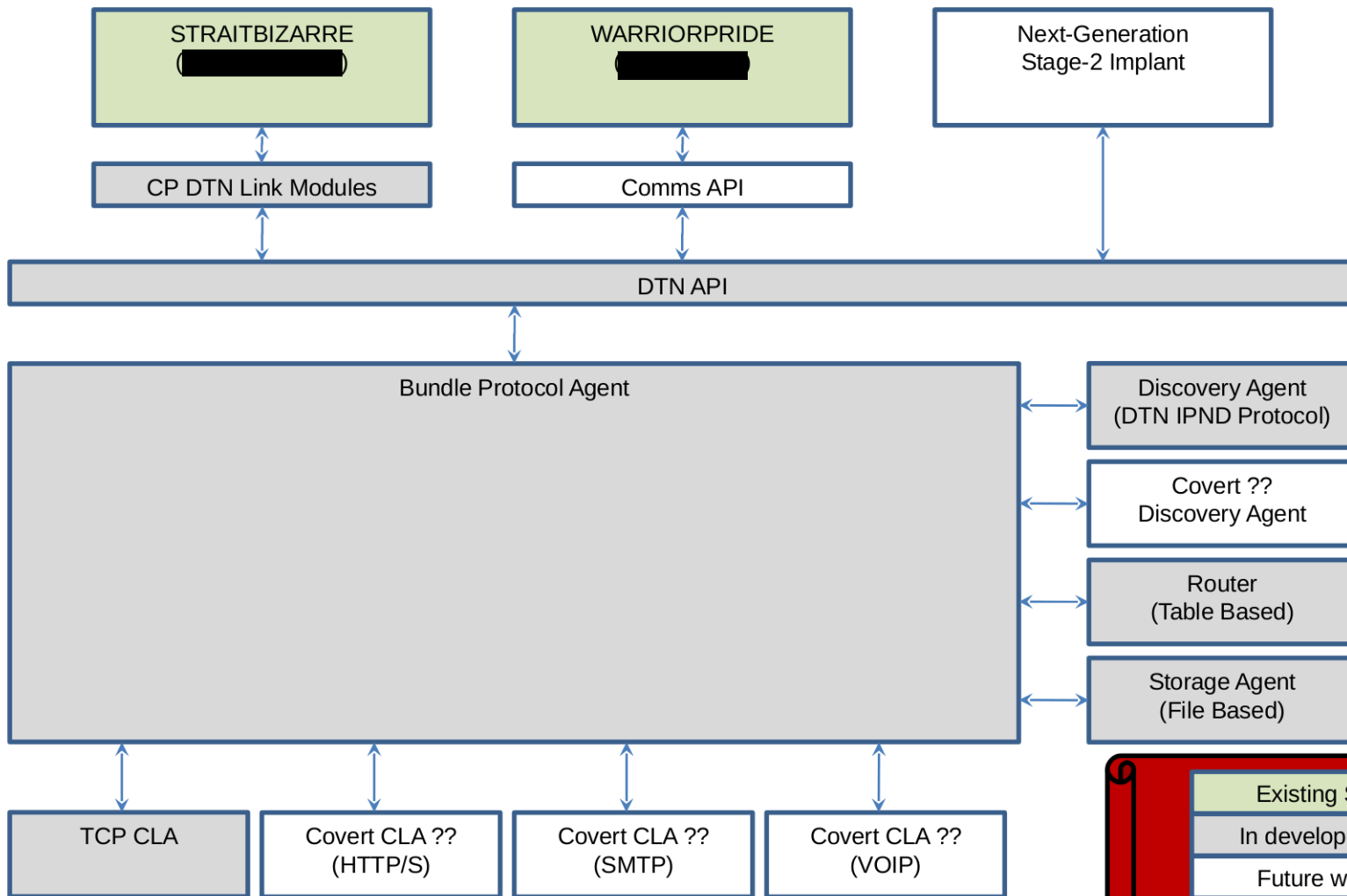


# Ultra-lightweight BPA (TS//SI//REL)

- (TS//SI//REL) [REDACTED] has been building an ultra-lightweight BPA that can act as a CP link to a DTN
- (U//FOUO) Locally provides data persistence, discovery, routing, convergence layers
- (TS//SI//REL) FR packets are already fragmented, so this BPA does not need to be as flexible as others
- (S//REL) Can add covert Convergence Layer Adapters



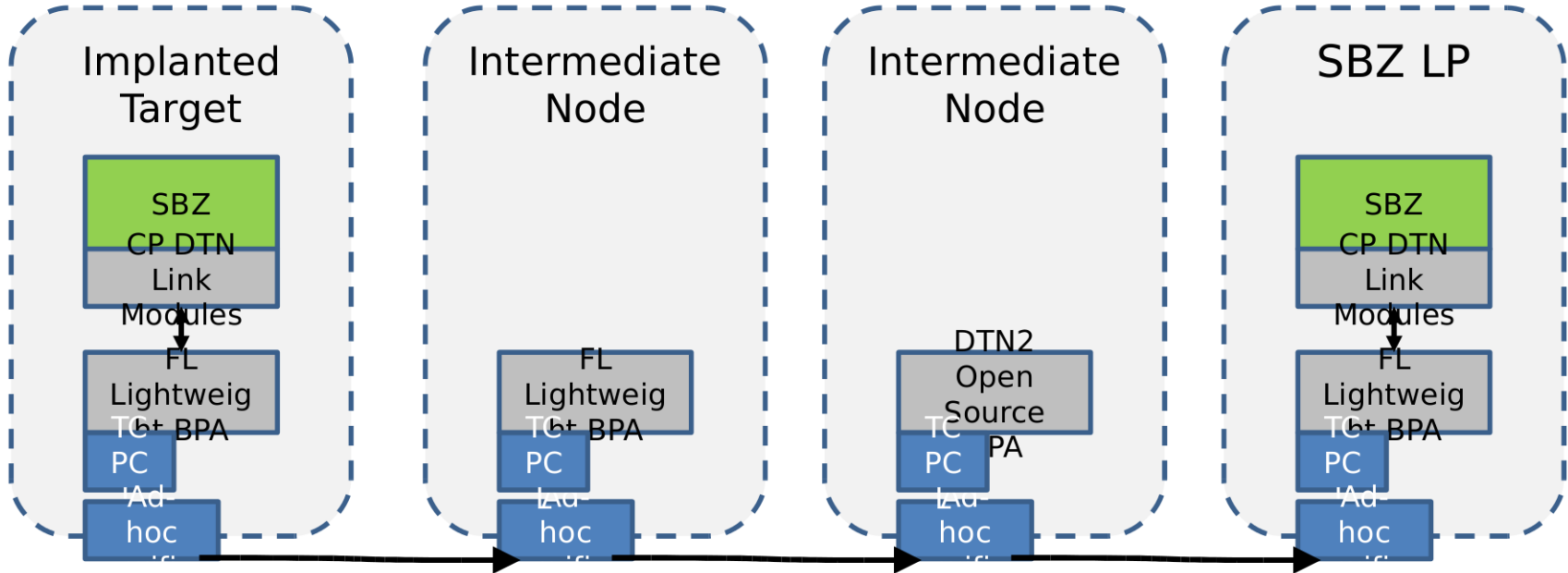
# TAO-Specific DTN Stack (TS//SI//REL)



Existing SW
In development
Future work



# TSV CONOP (TS//SI//REL)





# Platforms and Capabilities (TS//SI//REL)

	Linux netbook	Maemo	iPhone	Gumstix	Android	Windows and Java
DTN2	✓	✓	✓	✓	✓	
IBR-DTN	✓	✓	✓	✓	✓	
FUZZYLINT	✓				✓	✓

Current Effort



# **Wireless testbeds (U//FOUO)**



# Reality Ninja (U//FOUO)

Reality

The image shows a screenshot of a computer application window titled "Fruit". The main area of the window displays a game scene with a dark brown wooden background. In the top-left corner, there is a small red watermelon slice. In the top-right corner, there are three blue plus signs. In the center, there is a yellow fruit and a brown fruit. In the bottom-left corner, there is a small red and black insect-like character. On the left side of the window, there is a vertical stack of seven colored boxes representing a protocol stack:

- Application (light green)
- Presentation (light green)
- Session (bright green)
- Transport (light yellow-green)
- Network (light yellow)
- Data Link (yellow)
- Physical (orange)

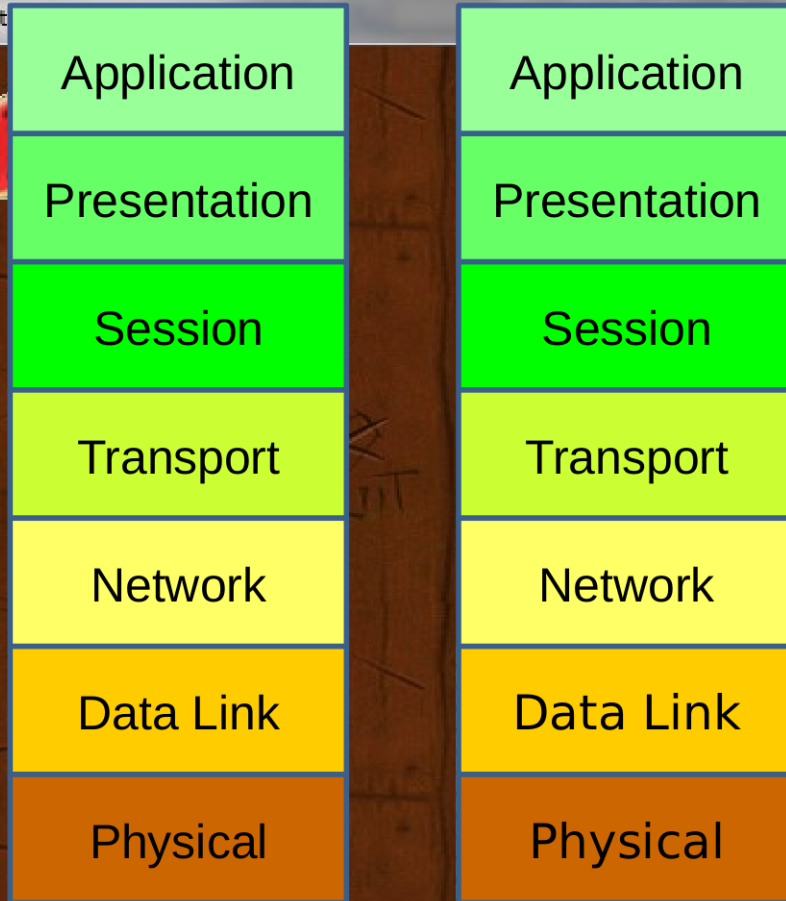
The "Session" layer is highlighted in a darker shade of green. At the bottom of the screenshot, there is a green bar with the text "UNCLASSIFIED // FOR OFFICIAL USE ONLY".



# Reality Ninja (U//FOUO)

Reality

Network Emulators





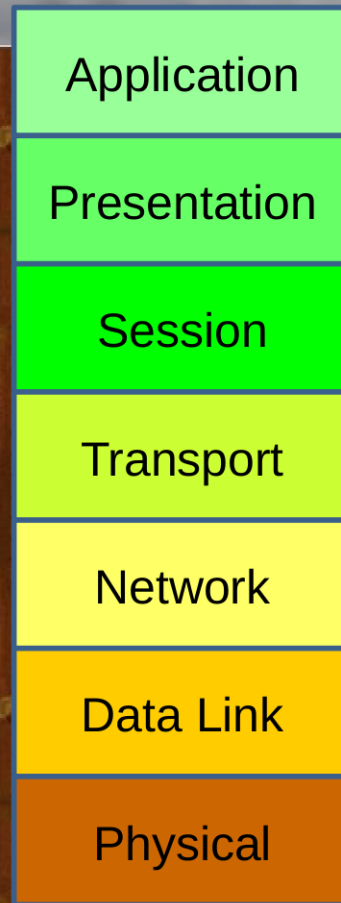
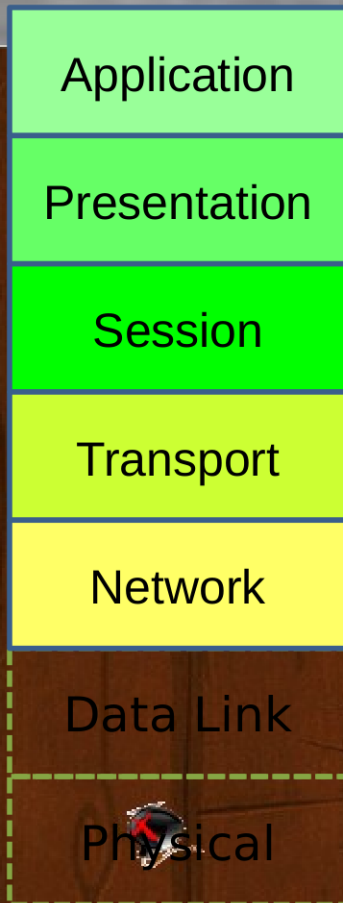
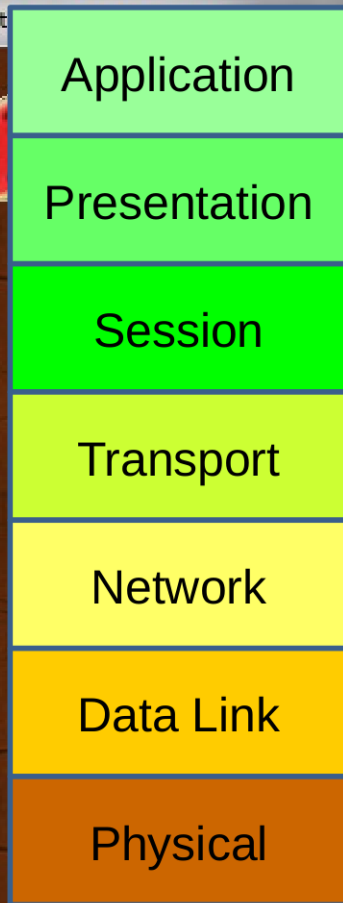


# Reality Ninja (U//FOUO)

Reality

Network Emulators

Simulation





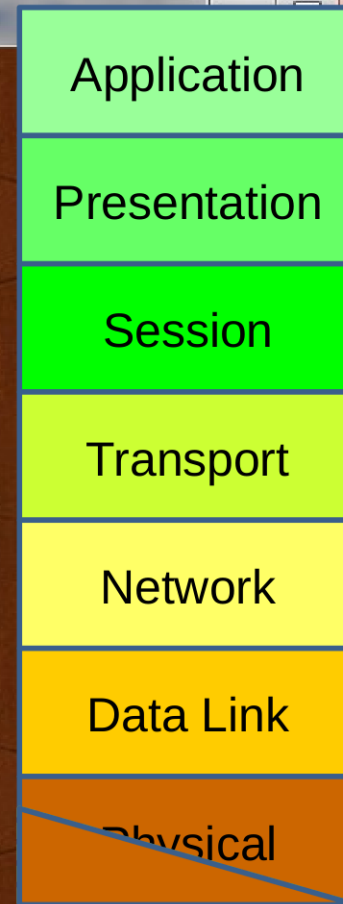
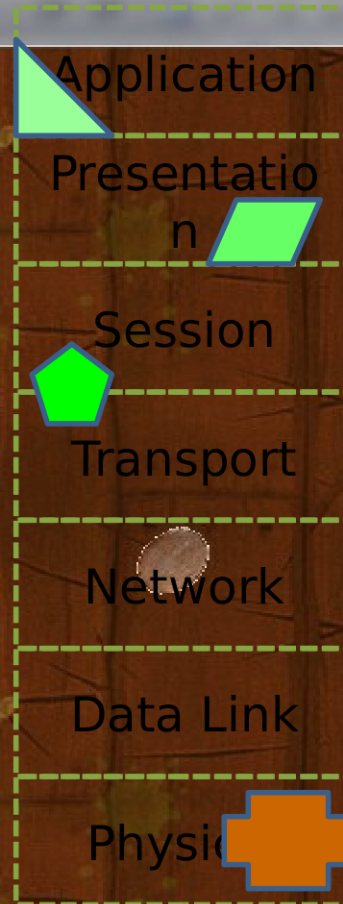
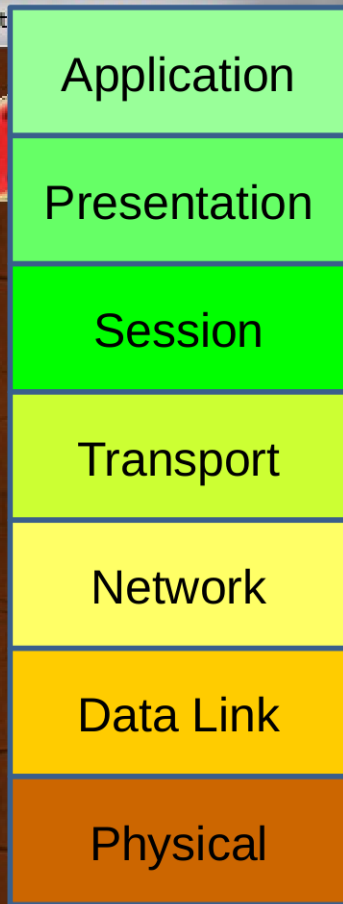
# Reality Ninja (U//FOUO)

Reality

Network Emulators

Simulation

MeshTest





# Mobile Wireless Testbed (U//FOUO)





# Mobile Wireless Testbed (U//FOUO)

**Layers**

- Stars
- Sky
- NASA Blue Marble Image
- Blue Marble (WMS) 2004
- i-cubed Landsat
- USDA NAIP
- MS Virtual Earth Aerial
- USGS Urban Area Ortho
- Political Boundaries
- Nodes
- Place Names
- World Map
- Scale bar
- View Controls
- Compass
- OpenStreetMap

**VMI WorldWind Controls**

**Connection** | Node Controls

Host  
10.51.4.6

Port  
3306

Database Name  
VirtualMeshTest

Edge Database Name  
EDGELIST

User ID

Database Password  
.....

Connect to Host

Start Experiment

Disconnect from Host/Stop Experiment

Sat Jun 04 17:06:04 EDT 2011

**World**

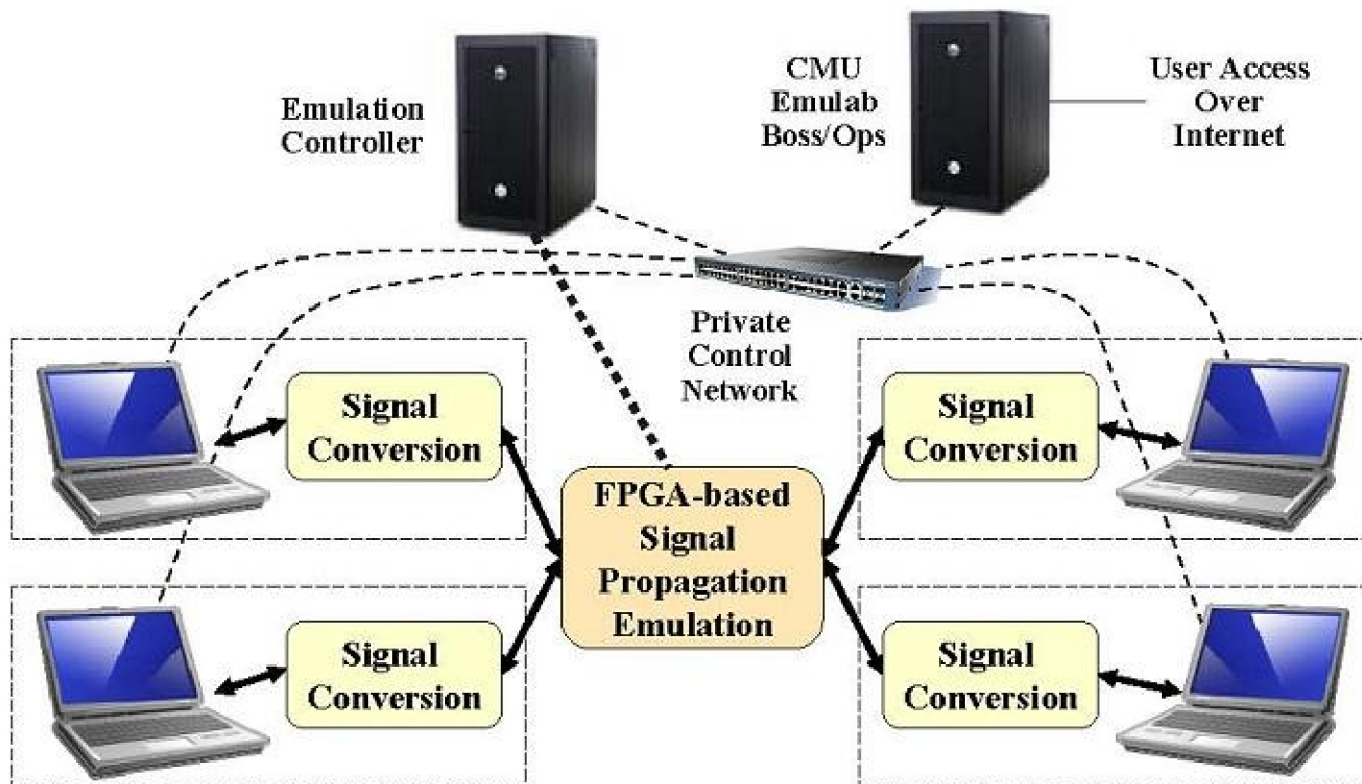
Round  Flat

Projection: Mercator

Altitude 10 km      Lat 37.7800°      Lon -122.4735°      Elev 51 meters      Downloading



# CMU Wireless Emulator (U//FOUO)





# Detailed Channel Modeling (U//FOUO)

Project hierarchy: ... Project view: (Rosslyn Tutorial)

Project: Edit View Output Select Help

Project: Rosslyn Tutorial

- Antennas
- Features
- Images
- Graphs
- Output filters
- Receiver sets
- Requested output
- Study areas and Output
  - Area: myarea1
    - Point to point
    - Point to multipoint
      - Complex E-Field
      - Complex impulse response
      - E-field X magnitude
      - E-field X phase
      - E-field Y magnitude
      - E-field Y phase
      - E-field Z magnitude
      - E-field Z phase
      - E-field RMS
      - E-field total X magnitude
      - E-field total X phase
      - E-field total Y magnitude
      - E-field total Y phase
      - E-field total Z magnitude
      - E-field total Z phase
      - E-field total RMS
      - Excess time of arrival
      - Free-space power without antenna
      - Free-space power with antenna
      - Path gain
      - Path loss
      - Propagation paths
        - Rooftop Single Tx Point
        - Rooftop LOS Tx Point
        - Added Single Rx Point**
        - Received power
        - Time of arrival
- Transmitter sets
  - Views
  - Waveforms

Calculation log: ...

Rosslyn Tutorial

Propagation model parameters

- Study area number: 1
- Short description: myarea1
- Propagation model: full3d
- Ray spacing (deg.): 0.250
- Maximum reflections: 20
- Maximum transmissions: 0
- Maximum diffractions: 1
- Maximum reflections before first diff: 1
- Maximum reflections between diff: 1
- Maximum transmissions before first diff: 1
- Maximum transmissions between diff: 1
- Ray tracing method: SBR
- Ray tracing acceleration: auto
- Using partitions
- Available Memory (MB) = 1797.63
- Maximum Memory Used (MB) = 1

Calculation mode before checking

Calculation Mode = 6  
completed reading e-field records

mode after checking status of path

Calculation Mode = 6

Start combining fields and writing c

Writing point-to-many output

10 Percent Completed 0h 0m  
20 Percent Completed 0h 0m

start interference analysis  
finish interference analysis

Finish combining fields and writing

Timing results for study area myarea

Combining Fields and Writing Out  
Study Area Run Time: 0h 0m 2s

Finished

Warning Messages  
None

Stop time: 16:21:48 6/6/2011  
Elapsed time: 25 seconds

Calculation finished. Elapsed time: 00:00:25

Selection: Rooftop LOS Tx Point, point #1 -> Added Single Rx Point [Propagation paths]

-114.5 dBm -71.8 dBm

X: 682.48 m  
Y: 515.19 m  
Z: 42.00 m

Features Images Study areas Transmitters Receivers Comm. systems Materials Antennas Waveforms Requested output Output Output filters

Active	Visible	Description	Type	No. points	Spacing	Antenna	Waveform	Collection ra...	Bounding box	Filename
No	Yes	Lynn St	route	59	5.00 m	Vertical dipole	*908-5 MHz	Auto	Auto	C:\Documents and Settings\Its\My Documents\...
No	Yes	N Moore St	route	62	5.00 m	Vertical dipole	*908-5 MHz	Auto	Auto	C:\Documents and Settings\Its\My Documents\...
No	Yes	N Kent St	route	42	5.00 m	Vertical dipole	*908-5 MHz	Auto	Auto	C:\Documents and Settings\Its\My Documents\...
No	Yes	N Nash St / 19th St	route	112	5.00 m	Vertical dipole	*908-5 MHz	Auto	Auto	C:\Documents and Settings\Its\My Documents\...
No	Yes	Ft. Myer Drive	route	64	5.00 m	Vertical dipole	*908-5 MHz	Auto	Auto	C:\Documents and Settings\Its\My Documents\...
Yes	Yes	Added Single Rx Point	points	1	N/A	Vertical dipole	908-5 MHz	Auto	Auto	C:\Documents and Settings\Its\My Documents\...

Selection: Rooftop LOS Tx Point, point #1 -> Added Single Rx Point [Propagation paths]

start 4:25 PM

- Routing and Reliability Issues
- Security Issues

# **Some Interesting Details (U)**

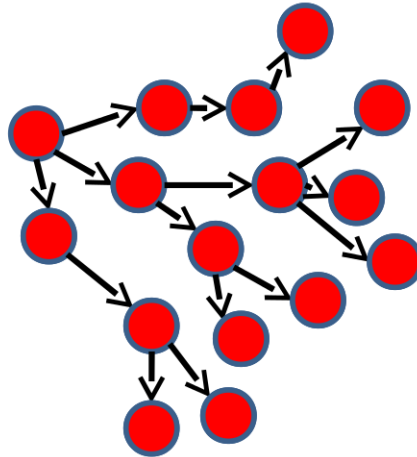
# Routing in DTNs (U)





# Flood Routing and Epidemic (U)

- 2000: Epidemic Routing [Vahdat and Becker]





# Static Routing Background (U)

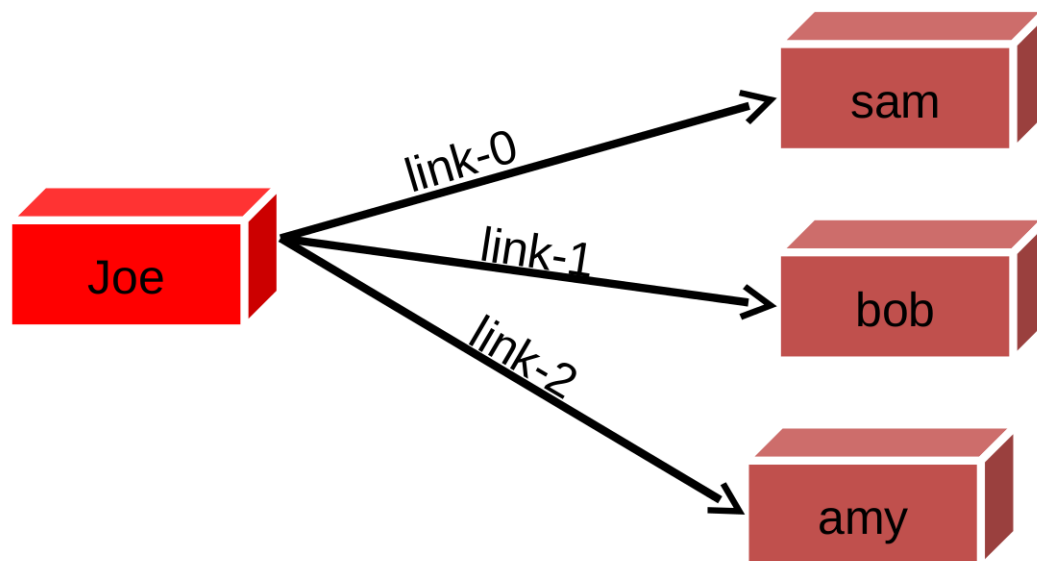
- Bundle Protocol Nodes are identified by Endpoint Identifiers (EIDs) that look like:
  - dtm://dtmbone.umd.edu.dtm/
  - dtm://nodea.dtm/
  - ebr://group5.dtm/
- Convergence Layer connections to neighbors are called “Links”
  - For example a TCP connection to a neighbor is a link
- Each link knows the EID of the neighbor associated with it



# Static Routing Tables (U)

One-hop "Direct Delivery"

Destination	Next hop	Action
dtn://sam.dtn/	link-0	FWD
dtn://bob.dtn/	link-1	FWD
dtn://amy.dtn/	link-2	FWD

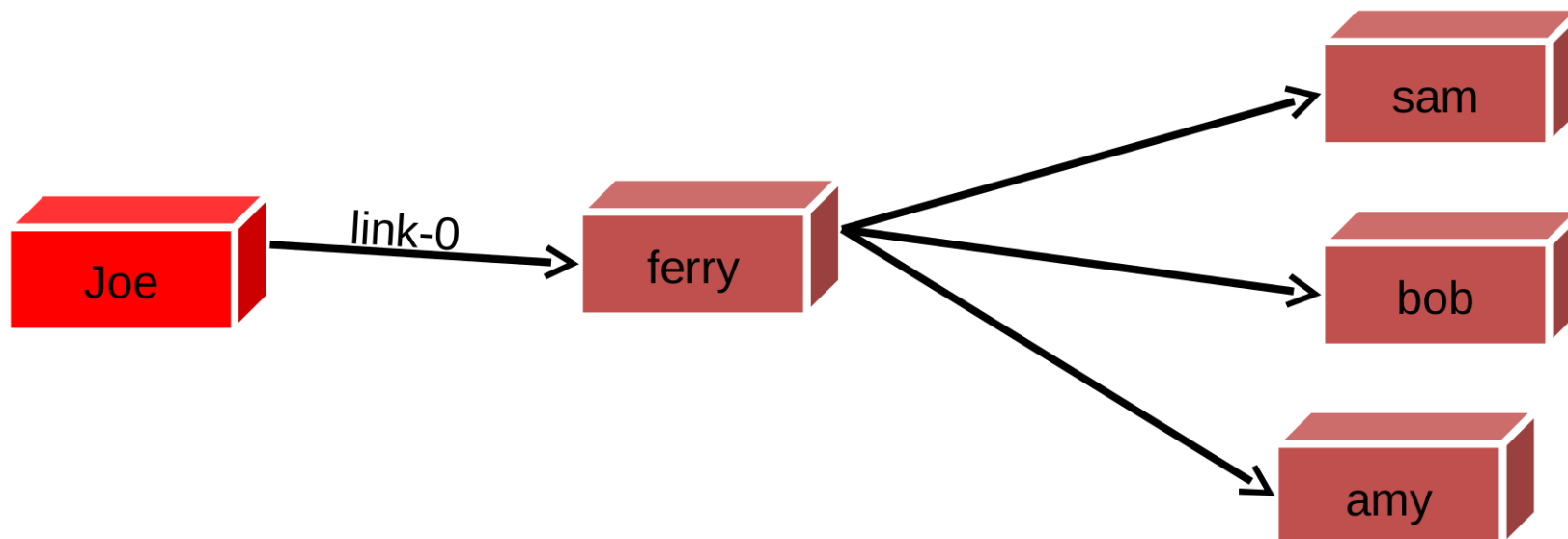




# Static Routing Tables (U)

## Two-hop "Bundle Ferry"

Destination	Next hop	Action
dtn://sam.dtn/	dtn://ferry.dtn/	FWD
dtn://bob.dtn/	dtn://ferry.dtn/	FWD
dtn://amy.dtn/	dtn://ferry.dtn/	FWD
dtn://ferry.dtn/	link-0	FWD

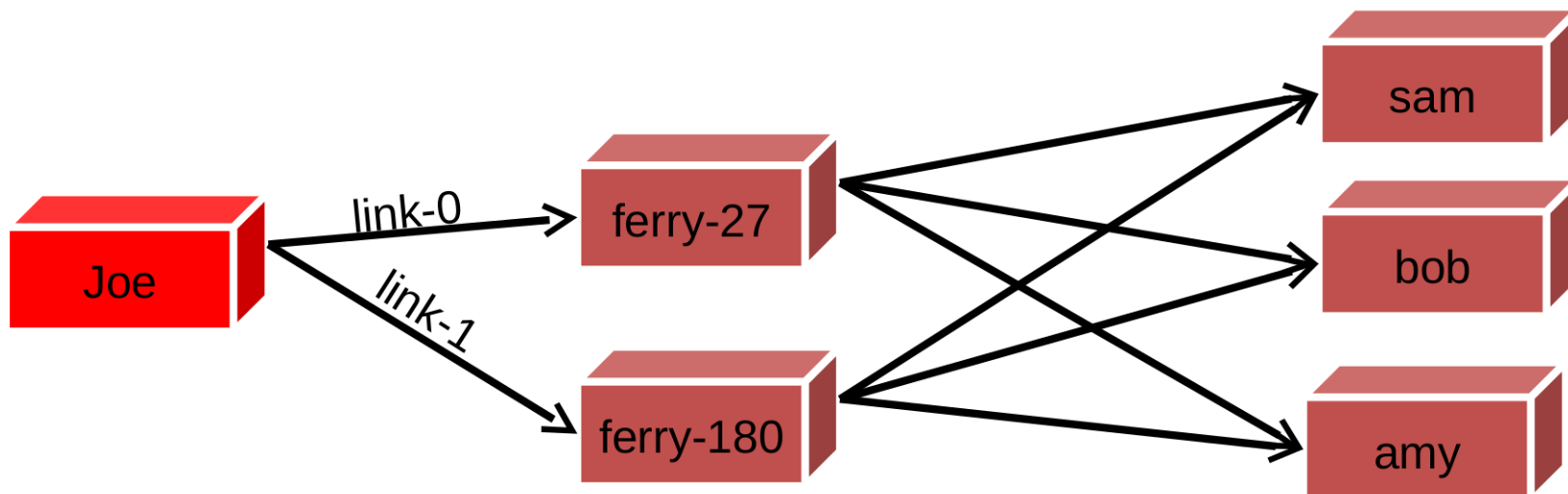




# Static Routing Tables (U)

Two-hop “Bundle Ferry” with wildcards

Destination	Next hop	Action
dtn://sam.dtn/	dtn://ferry-*.dtn/	FWD
dtn://bob.dtn/	dtn://ferry-*.dtn/	FWD
dtn://amy.dtn/	dtn://ferry-*.dtn/	FWD
dtn://ferry-27.dtn/	link-0	FWD
dtn://ferry-180.dtn/	link-1	FWD

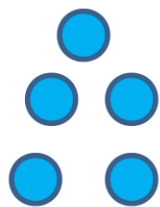
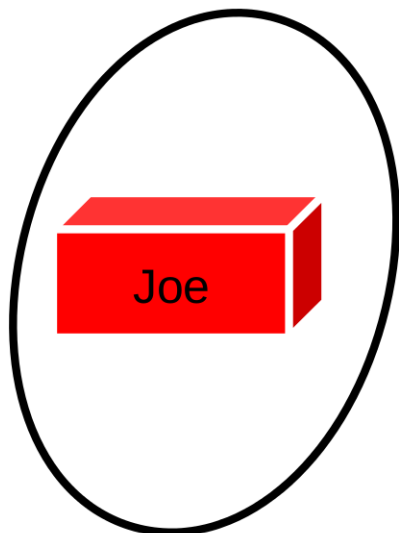




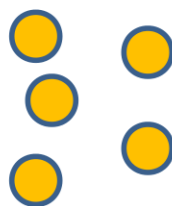
# Static Routing Tables (U)

Multi-hop “Tiered routing”

Destination	Next hop	Action
dtn://twitter.dtn/	dtn://tier1-*.dtn/	FWD
dtn://twitter.dtn/	dtn://tier2-*.dtn/	FWD
dtn://twitter.dtn/	dtn://tier3-*.dtn/	FWD
dtn://twitter.dtn/	link-0	FWD



Tier 1



Tier 2



Tier 3





# DTN Routing Bonanza (U)

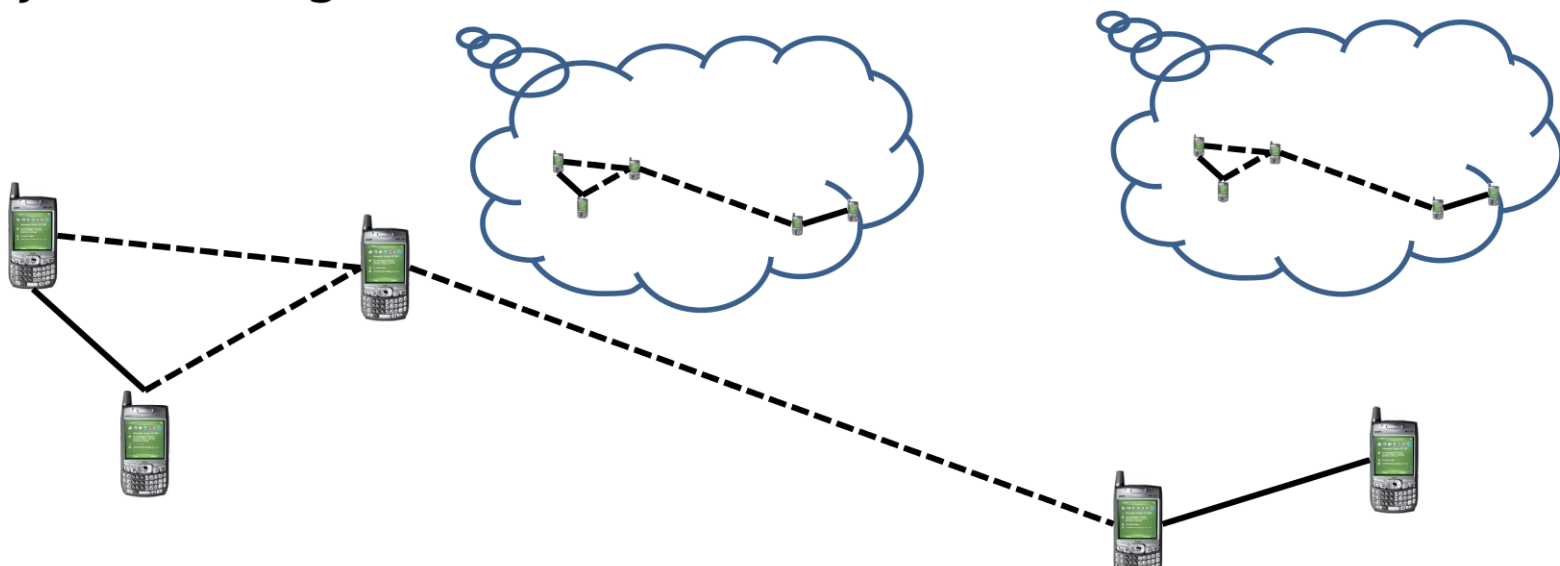
- (U//FOUO) People propose routing protocols for many different environments and purposes.
  - Sometimes with novel applications, sometimes with no real need
- (U) Has inspired the phrase “Yet Another Routing Protocol”

Static  
Flooding  
Static with copy links  
Neighborhood  
Epidemic  
Endemic  
Epidemic with Immunity  
mphone  
TIERStore  
DTLSR  
Simple Geometric



## DTLSR (U)

- (U//FOUO) Delay-Tolerant Link State Routing
  - Assumes a mostly stable contact graph
  - Nodes all flood their recent contacts
  - Each node maintains an internal picture of the network, and makes routing decisions based on Dijkstra's alg







# “Intelligent” Routing: PRoPHET (U)

- *Probabilistic routing in intermittently connected networks*, 2003; A. Lindgren, A. Doria, and O. Scheln
- Probabilistic Routing Protocol using History of Encounters and Transitivity (PRoPHET)

sam	amy	0.9
	bob	0.0
	joe	0.0

bob	amy	0.0
	sam	0.0
	joe	0.4

amy	sam	0.9
	bob	0.0
	joe	0.0



# “Intelligent” Routing: P<sub>RO</sub>PHET (U)

- *Probabilistic routing in intermittently connected networks*, 2003; A. Lindgren, A. Doria, and O. Scheln
- Probabilistic Routing Protocol using History of Encounters and Transitivity (P<sub>RO</sub>PHET)

amy	amy	0.4
	bob	0.9
	joe	0.4

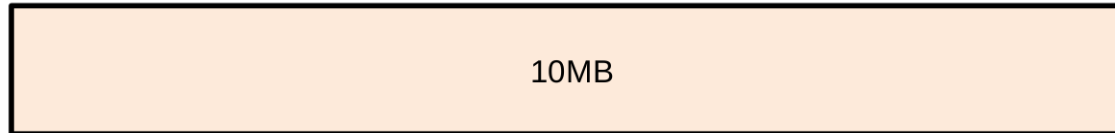
bob	amy	0.4
	bob	0.9
	joe	0.4

sam	amy	0.9
	bob	0.9
	joe	0.2



## Network-Coding in DTNs (U)

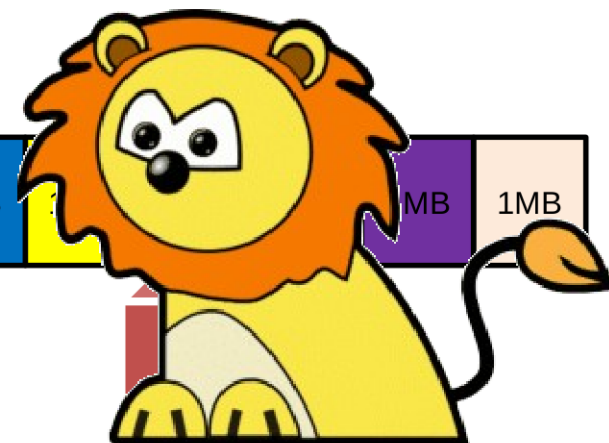
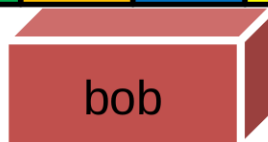
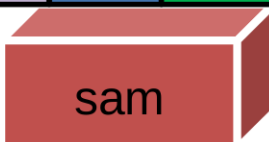
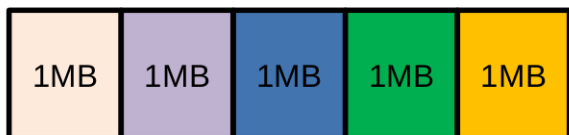
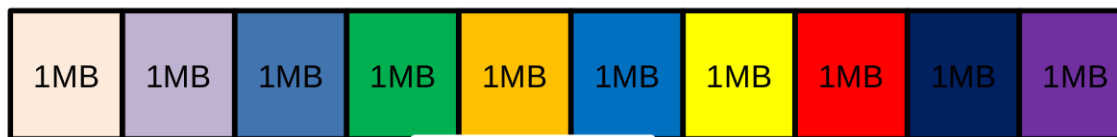
- Imagine trying to distribute a 100MB bundle in a DTN
- Idea:





## Network-Coding in DTNs (U)

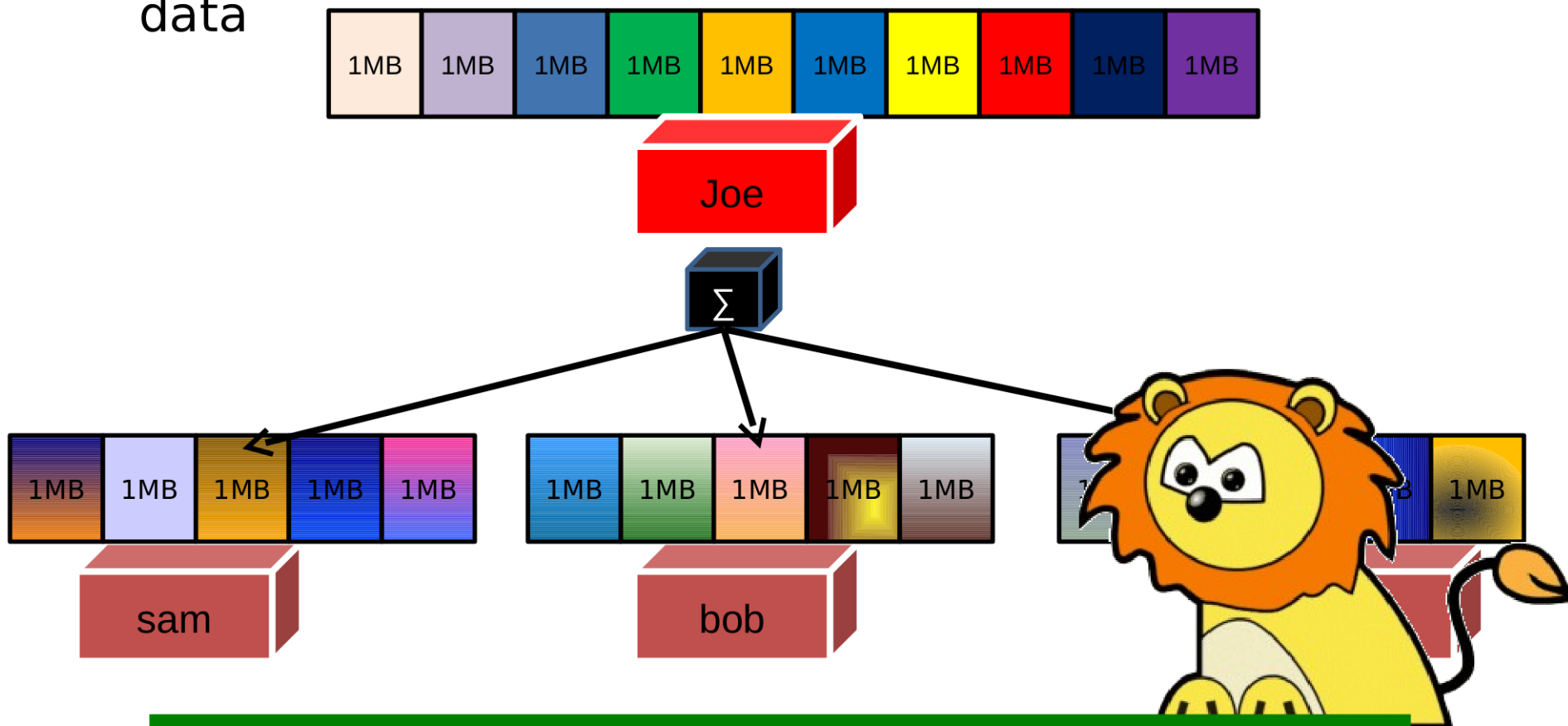
- Imagine trying to distribute a 100MB bundle in a DTN
- Idea: fragment into 1MB pieces





## Network-Coding in DTNs (U)

- Send linear combinations of fragments
- A receiver can collect **any** ten pieces and recover the data



# Security in DTNs (U)



# Security Threats (U)

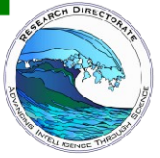
- (TS//SI//REL) Protecting against rogue bundles being injected into the network
- (TS//SI//REL) Prevent an adversary from modifying legitimate bundles
- (S//REL) Protection against eavesdroppers
- (S//REL) Authenticate neighbors before establishing links
- (TS//SI//REL) Low Probability of Detection / Intercept



## Bundle Security Protocol RFC 6257 (U)

- (U) Provides bundle-layer encryption, authentication, and data integrity
- (U) Lack of connectivity affects choice of algorithms and services
- (U) Security policies may be directional
- (U//FOUO) Managing keys and their accompanying policies is a challenge





# Bundle Authentication (U)

- (U) Hop-by-hop Authentication
- (U) Requires each device to generate a shared secret with each of its neighbors
- (U//FOUO) Establishing these keys is a challenge



## Bundle Authentication (U)

- (U//FOUO) End-to-end authentication
  - RSA digital signatures
- (U) Intermediate nodes can verify the signature
- (U) Cannot assume connectivity to an external Certificate Authority
- (U) For signatures, the certificate can be appended to the message



## Bundle Encryption (U)

- (U//FOUO) Payload data encrypted with AES in Galois Counter Mode (GCM)
- (U) Provides data integrity
- (U) AES key is encrypted with the destination's RSA public key



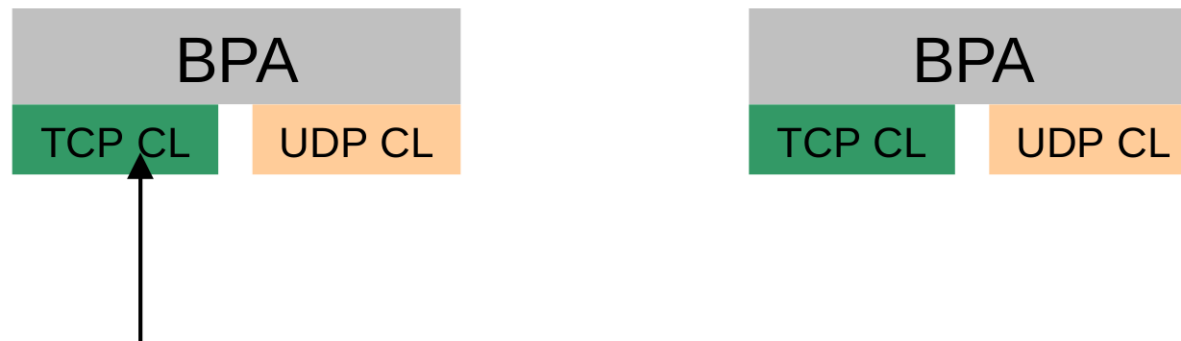
# Key Management Issues (U)

- (U) How to distribute public keys securely
- (U//FOUO) One option: pass certificates between devices
- (U//FOUO) Another option: pre-placing certificates
  - Memory issues
- (U) Revoking keys of compromised devices



## Link-Layer Security (U)

- (U//FOUO) Even with BSP, CL is wide open
- (U//FOUO) Develop a mechanism to authenticate neighbors before allowing them to connect
  - Enables dropping unwanted bundles
  - May prevent DoS through too many connections
- (U//FOUO) Enable different groups of nodes to operate in the same area but maintain separation





## Link-Layer Security (U)

- (U) Constraints
  - Lightweight
  - Low setup latency
  - Limited bandwidth consumption
  - Minimal provisioning/maintenance
  - Compatible with short session durations

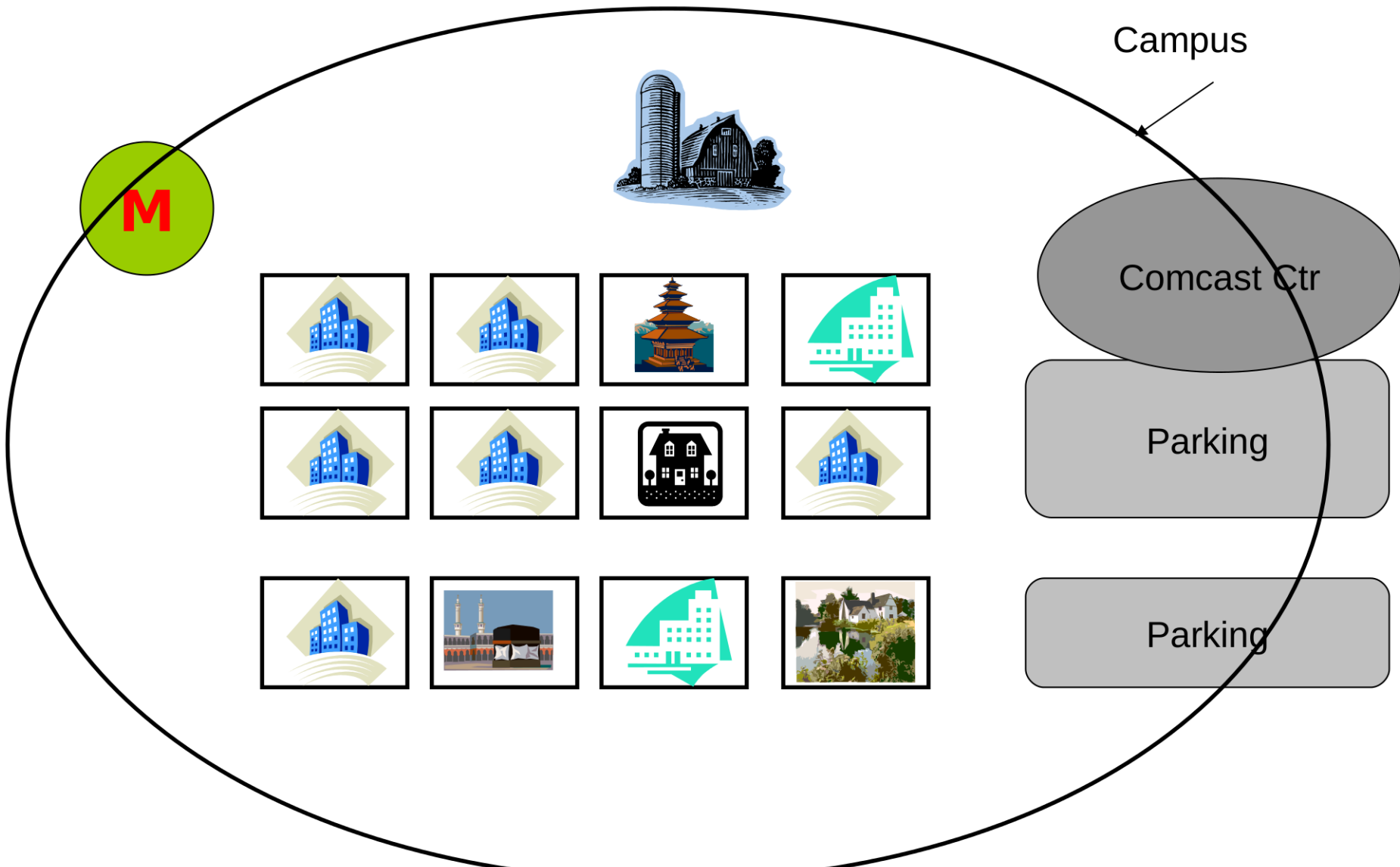


## Covert Discovery (S//REL)

- (TS//SI//REL) Have set up external triggers for establishing DTN links
- (S//REL) Similar work being done outside to reduce power consumption
- (U) Example: Bluetooth beacons triggering a wifi connection
- (S//REL) Another option: use our own radios for some hops

# **Surveillance-oriented Demo (U)**





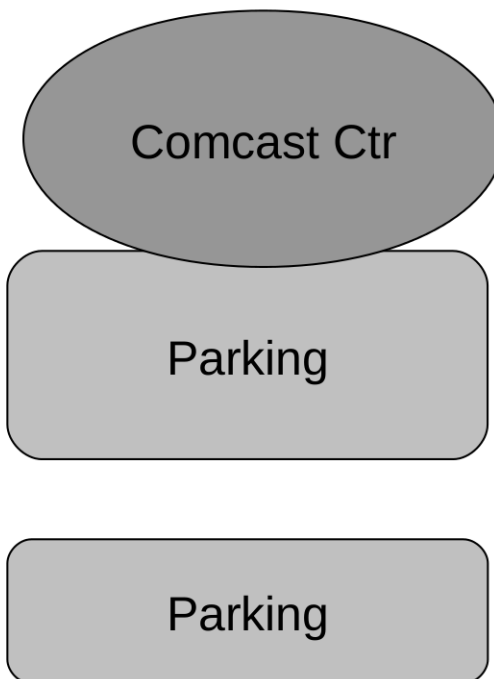
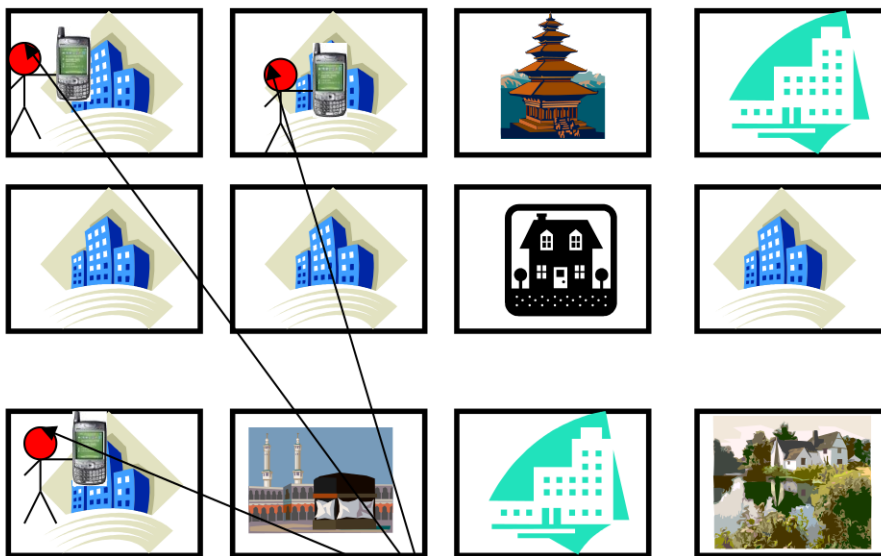
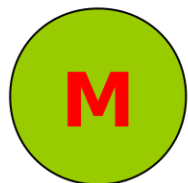
Campus

M

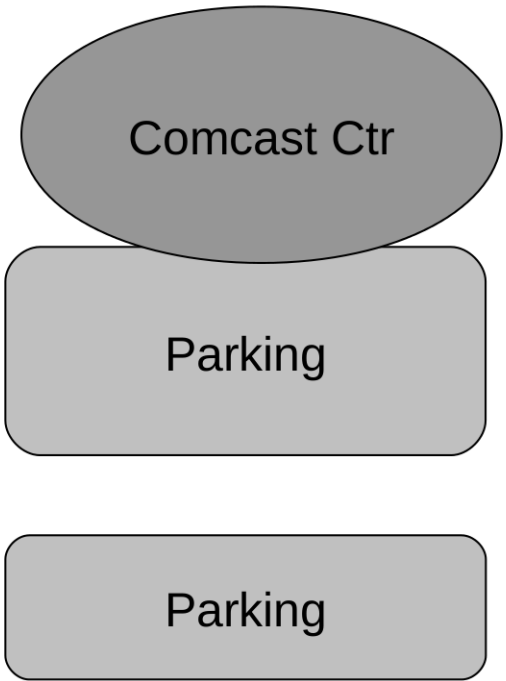
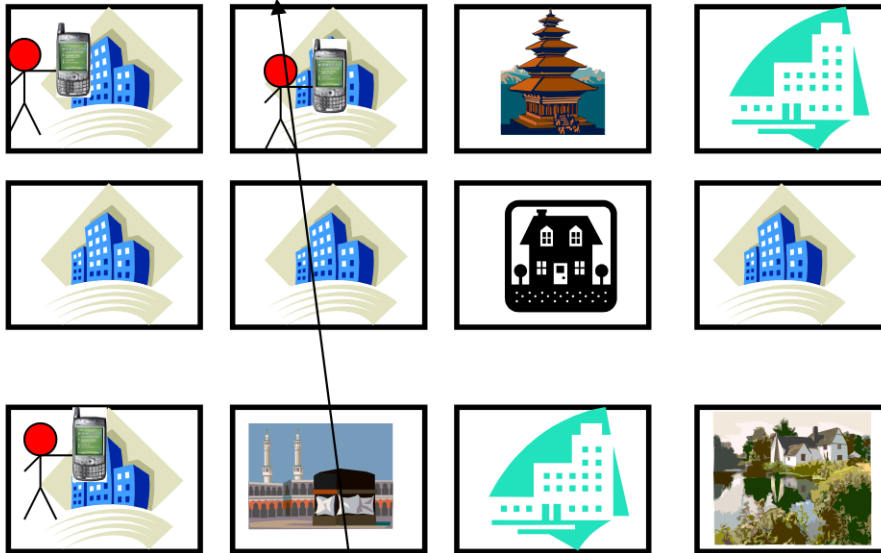
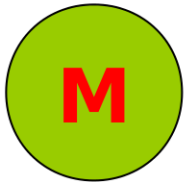
Comcast Ctr

Parking

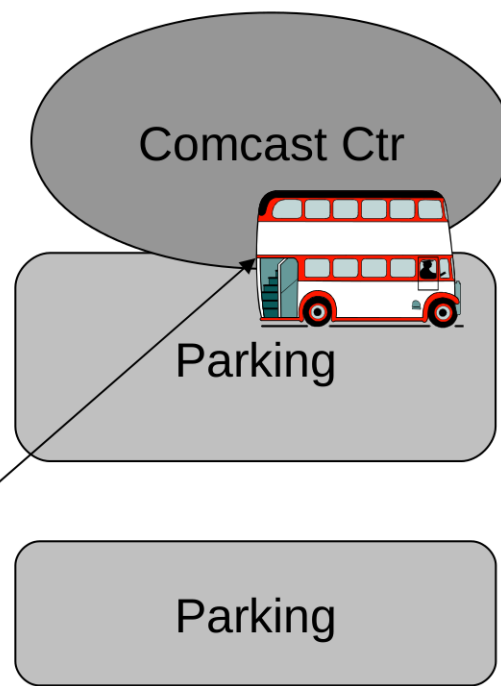
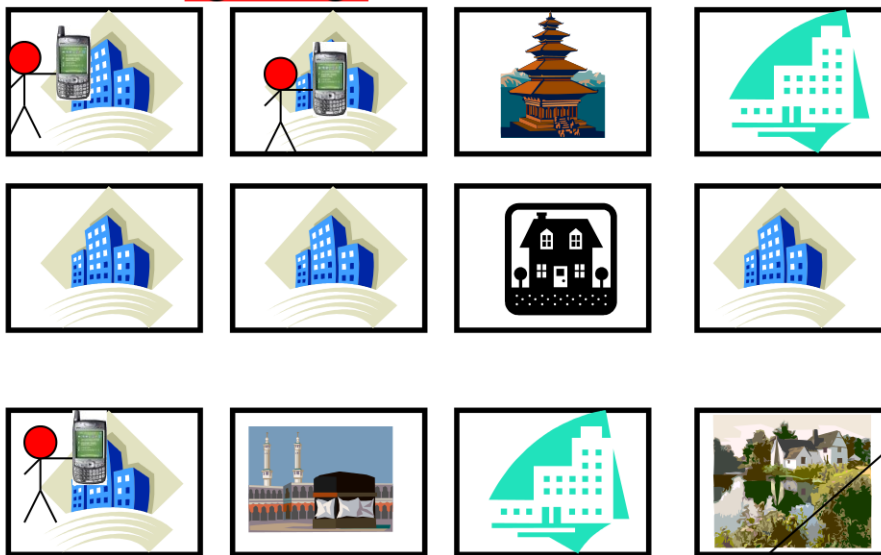
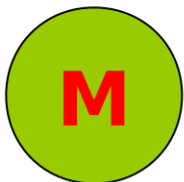
Parking



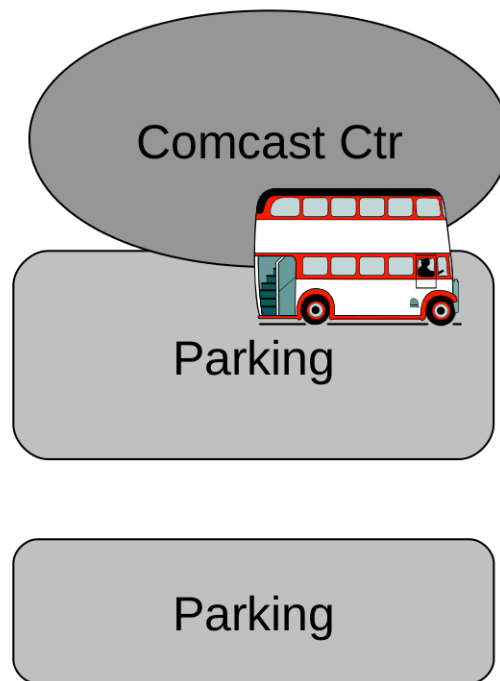
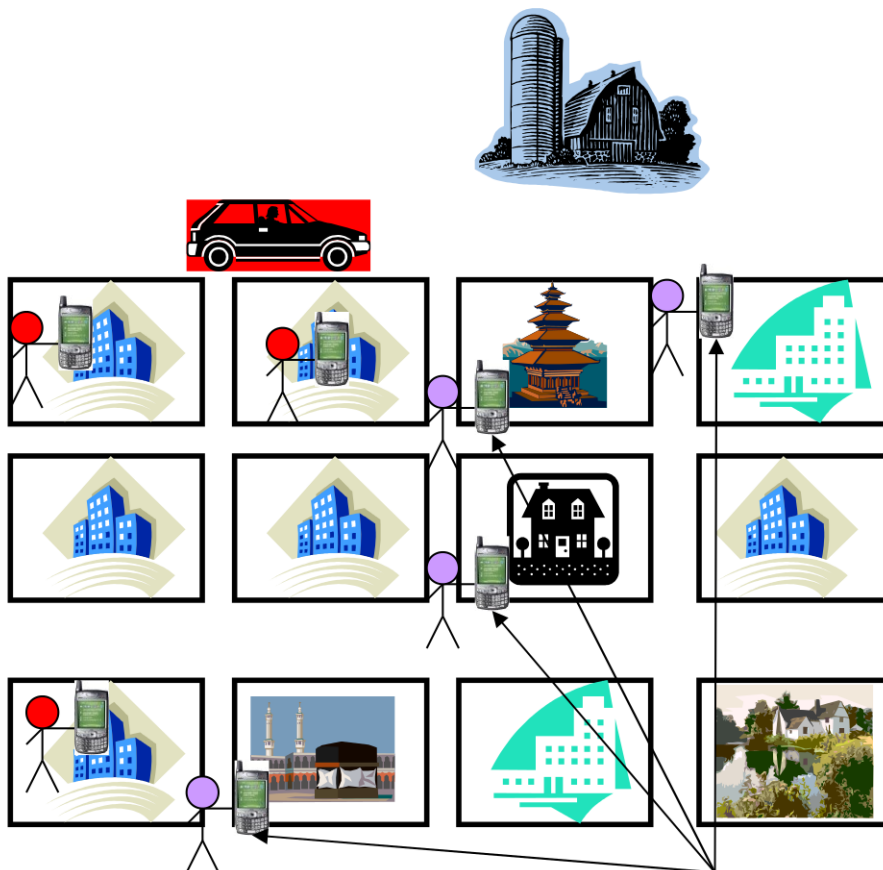
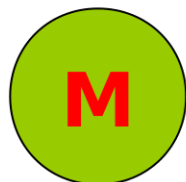
Data sources at "secret" locations on campus. Queue up or generate data.



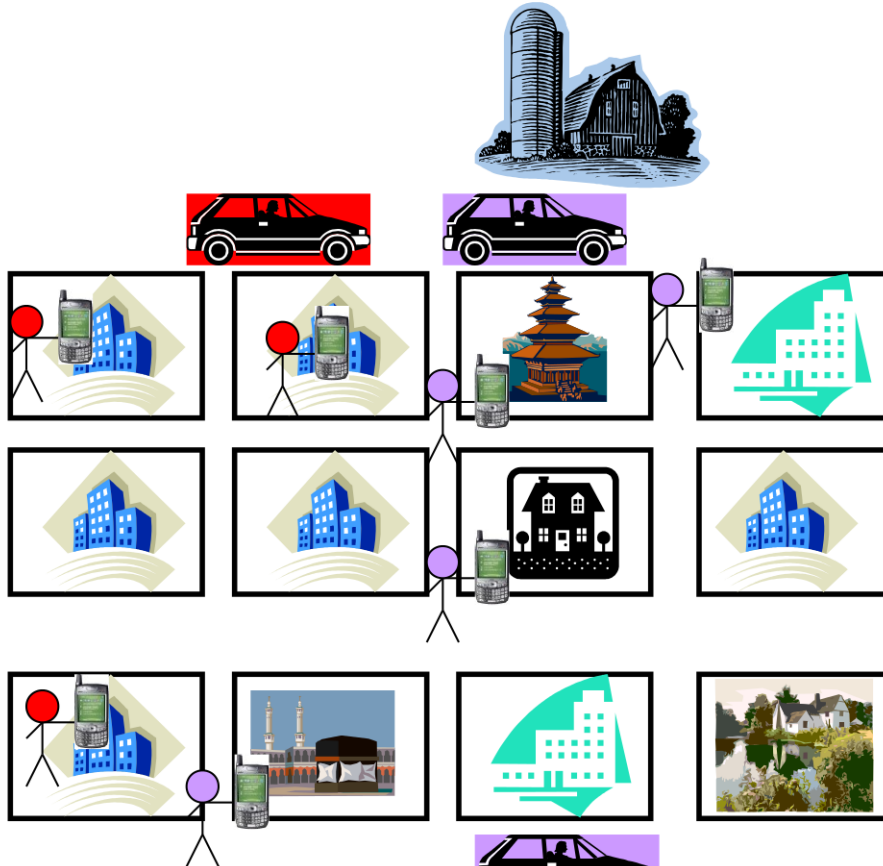
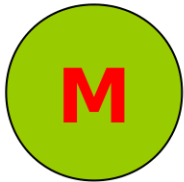
Mobile data generator in a car sending segments of audio



Destination node in parking lot by the Comcast Center



Pedestrian relays walk around, and pick up data from source nodes



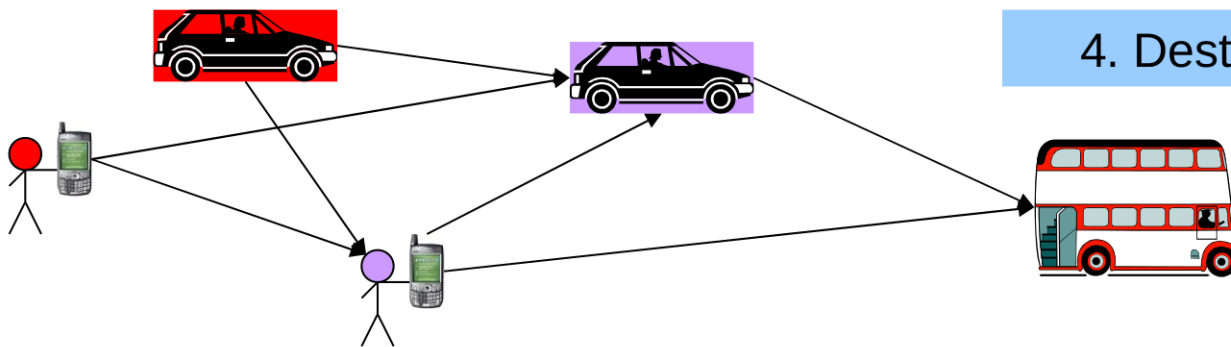
Car Players are typical data ferries. They relay data to the destination.



1. Sources

3. Relays

4. Destination



2. Relays



# Questions?