# Moving Data Through Disconnected Networks

## Delay-Tolerant Networking and the IC (U//FOUO)

[redacted] R4 [redacted]
R4
R4
June 2012

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

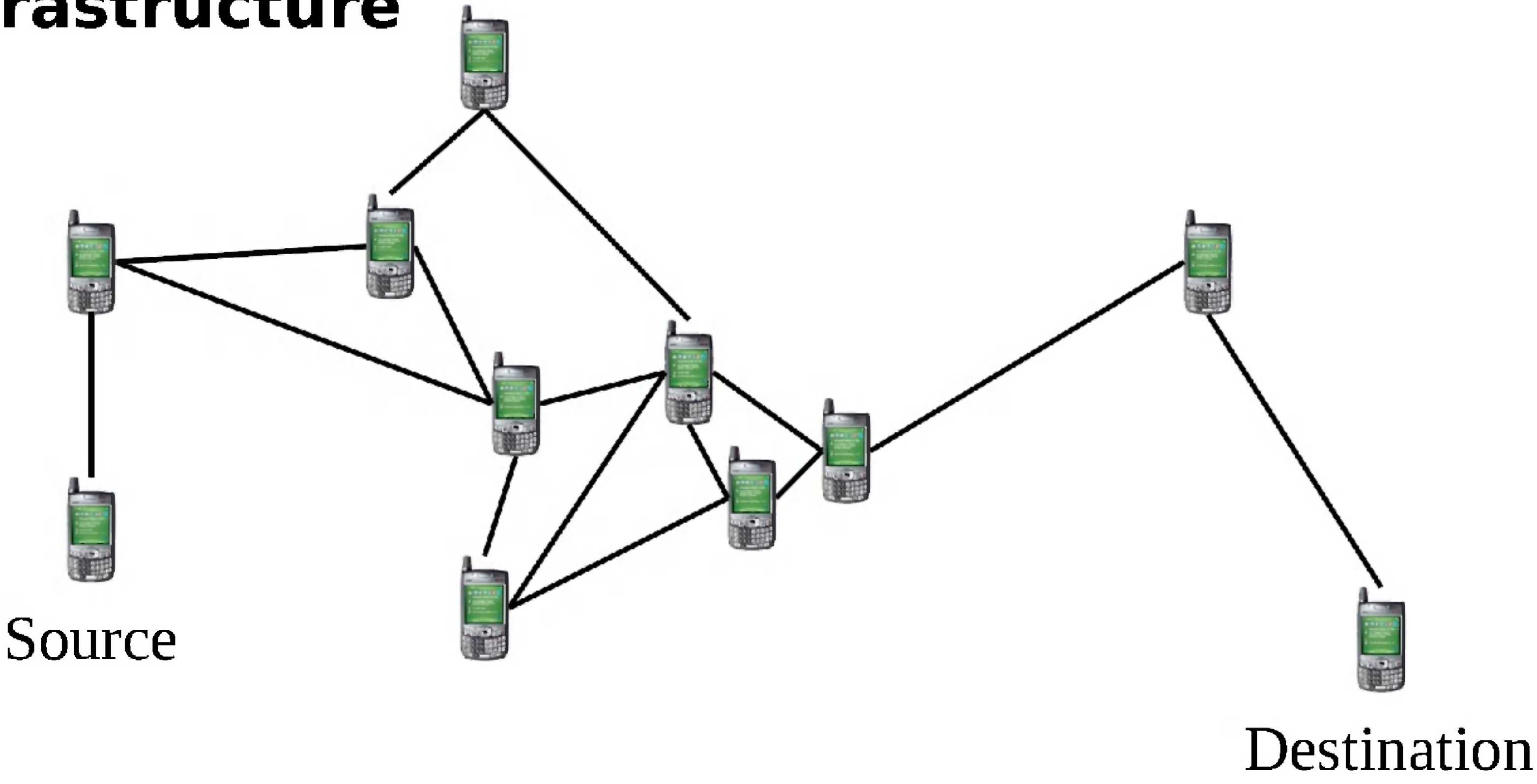
Derived From: NSA/CSSM 1-52
Dated: 20070108
Declassify On: 20360901

# 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

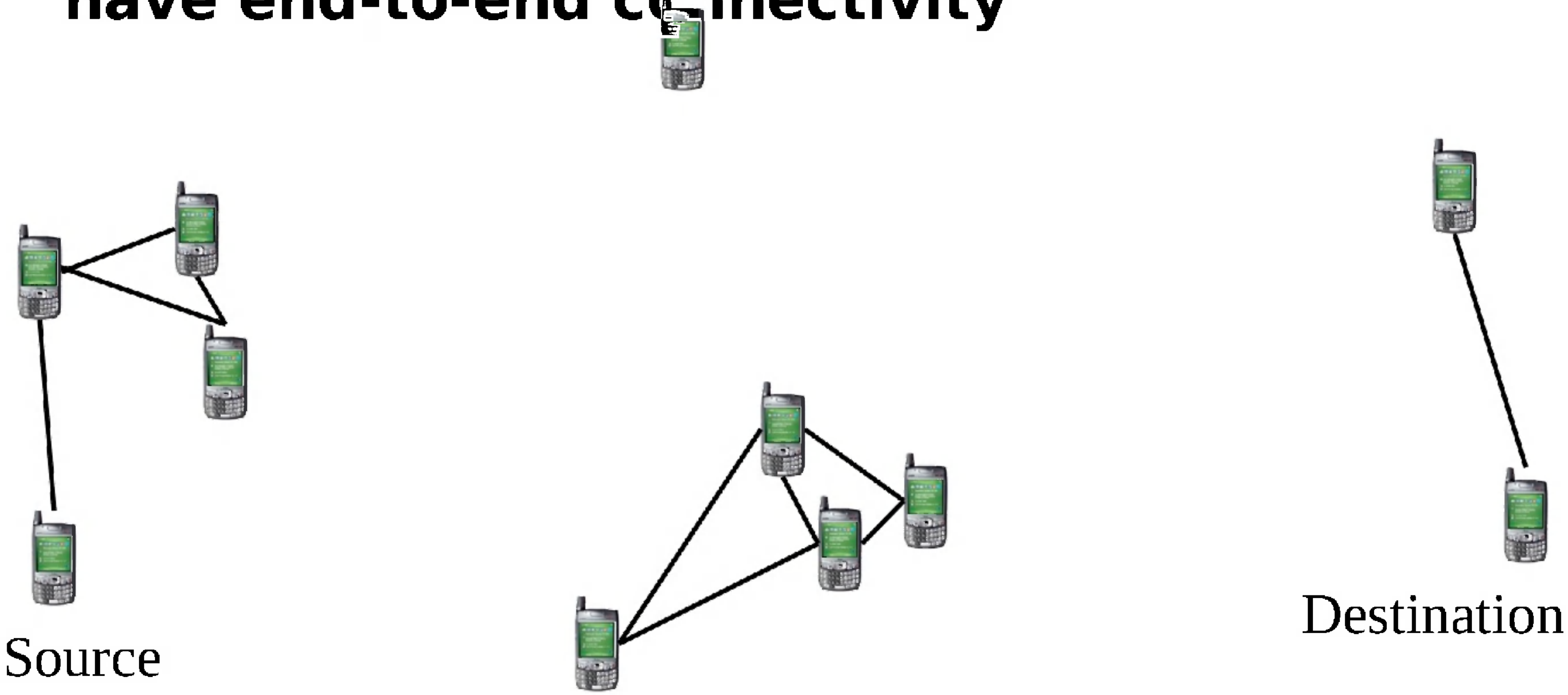
# Mobile Ad-Hoc Networks (U)

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



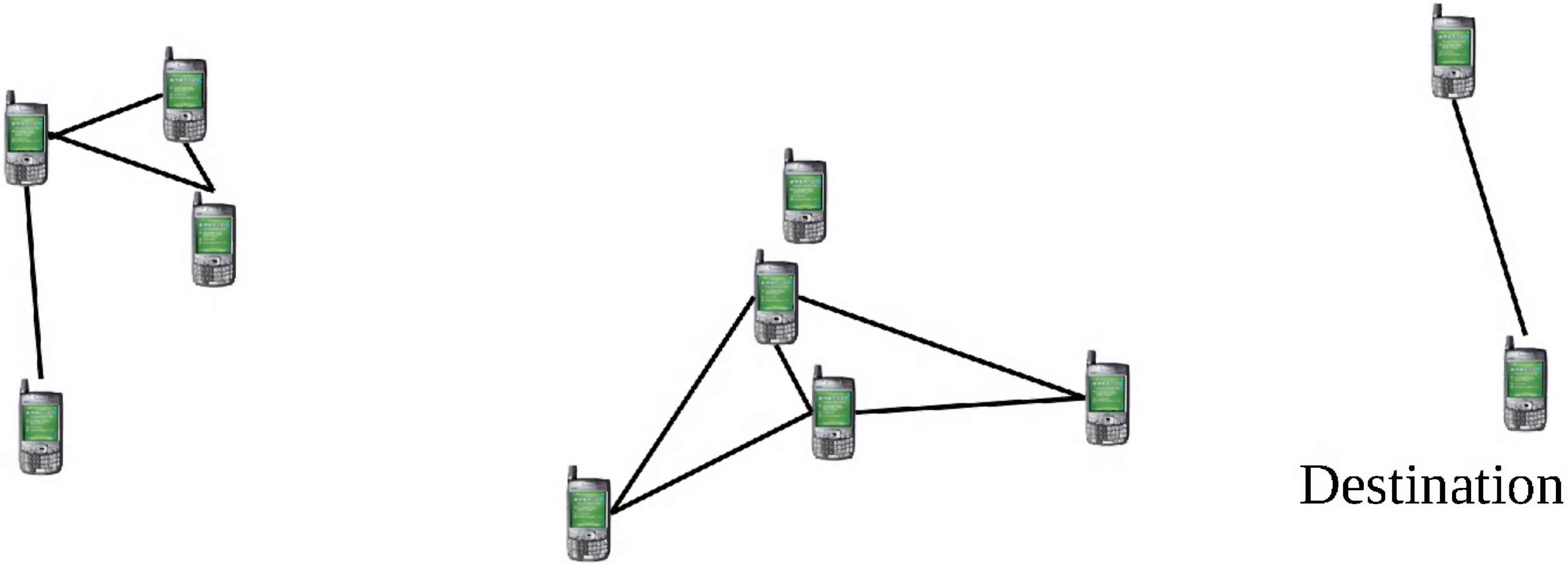
# Intermittently Connected Network (U)

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



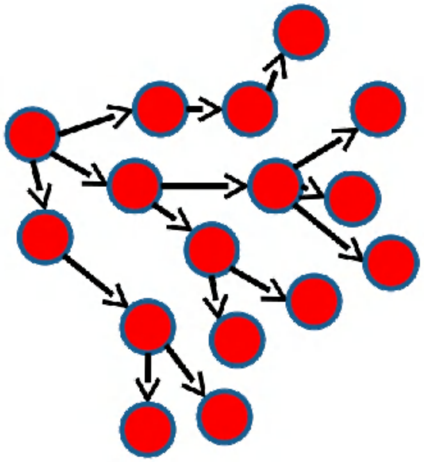
# Delay-Tolerant Networks (U)

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



# Beginnings of DTN (U)

2000: Epidemic Routing
Vahdat and Becker



1990s: Interplanetary Network
NASA, JPL

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

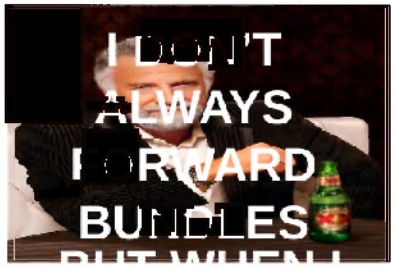
2002: Mobility Increases Capacity in Ad-hoc Wireless Networks
Grossglauser and Tse

2003: A DT:N Architecture for Challenged Internets
Kevin Fall

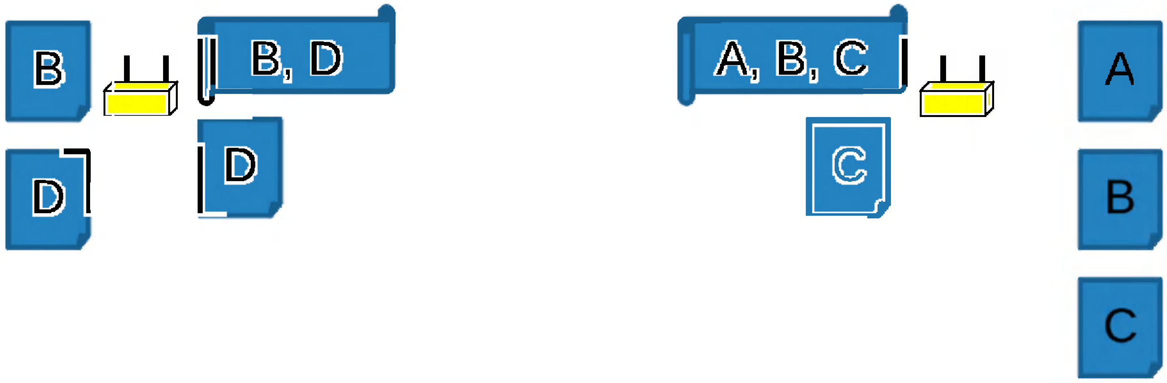
2003: DataMULEs
Shah, Roy, Jain, Brunette

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

# Beginnings of DTN: Epidemic (U)



- 2000: Epidemic Routing - Vahdat and Becker



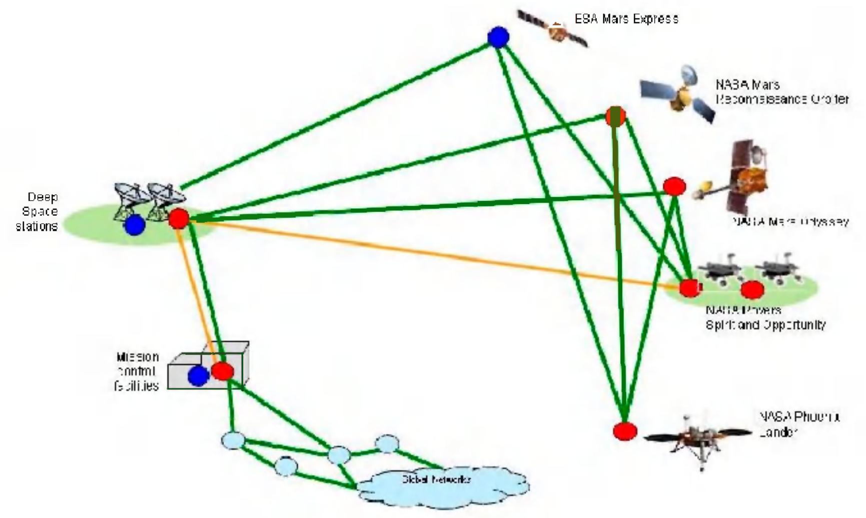
- Nodes exchange “summary vectors”
- Each node sends the data that the other node lacks
- Summary vectors implemented as a Bloom Filter
- Followed by Immunity concept: *Resource and performance tradeoffs in delay-tolerant wireless networks*, 2005; Small and Haas

# 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 ▭ long propagation delays
- Intermittent connections
- Known contact schedule ▭ Contact Graph Routing
- Worked on since the 1990s by NASA, JPL, incl Vint Cerf


ESA Mars Express
NASA Mars Reconnaissance Orbiter
NASA Mars Odyssey
Deep Space stations
NASA Rovers Spirit and Opportunity
Mission Control Facilities
NASA Phoenix Lander
Global Networks

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

# Beginnings of DTN: DataMULEs (U)

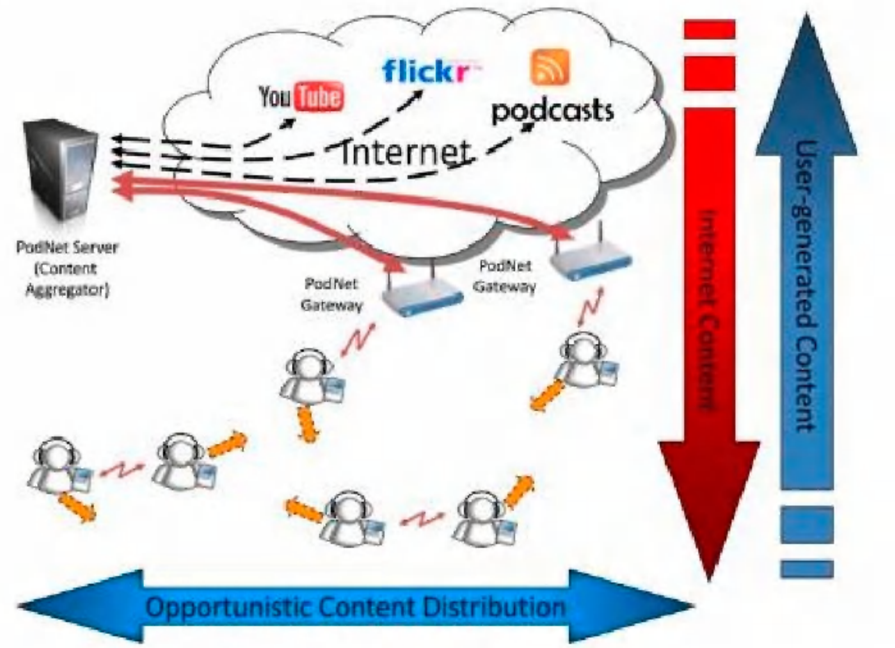
- *Data MULEs: modeling a three-tier architecture for sparse sensor networks*
- 2003 Paper by R. C. Shah, S. Roy, S. Jain, W. Brunette
- Has mobile MULEs relaying data from sensors to well-connected Access Points
- Similar: *A Message Ferrying Approach for Data Delivery in Sparse Mobile Ad Hoc Networks*,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

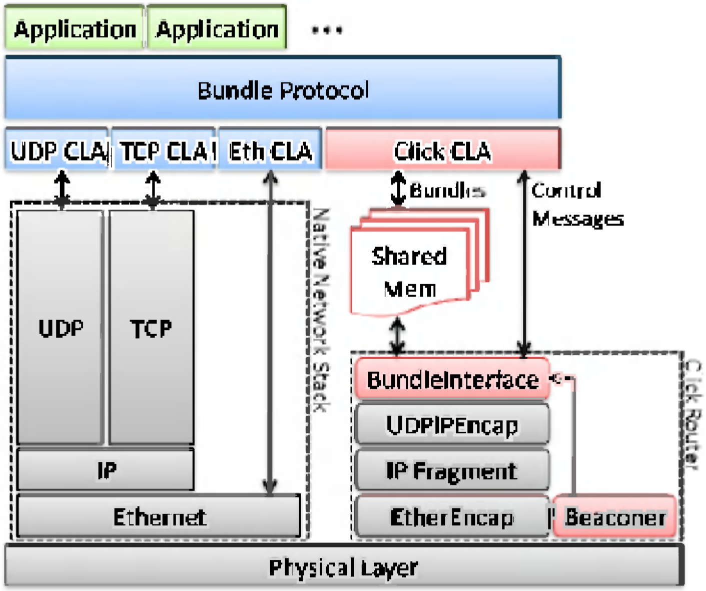
- Content dissemination
  - [*PodNet*, 2006 – Present; Legendre, Lenders, May, Karlsson]
  - Haggle Project
- Social Networking
- Distributed Sotrage
  - [*TierStore*, 2008; Demmer, Du, Brewer]
  - [*DTN-based Content Storage and Retrieval*; Ott, Pitkanen]



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

# Standardization Activities* (U)

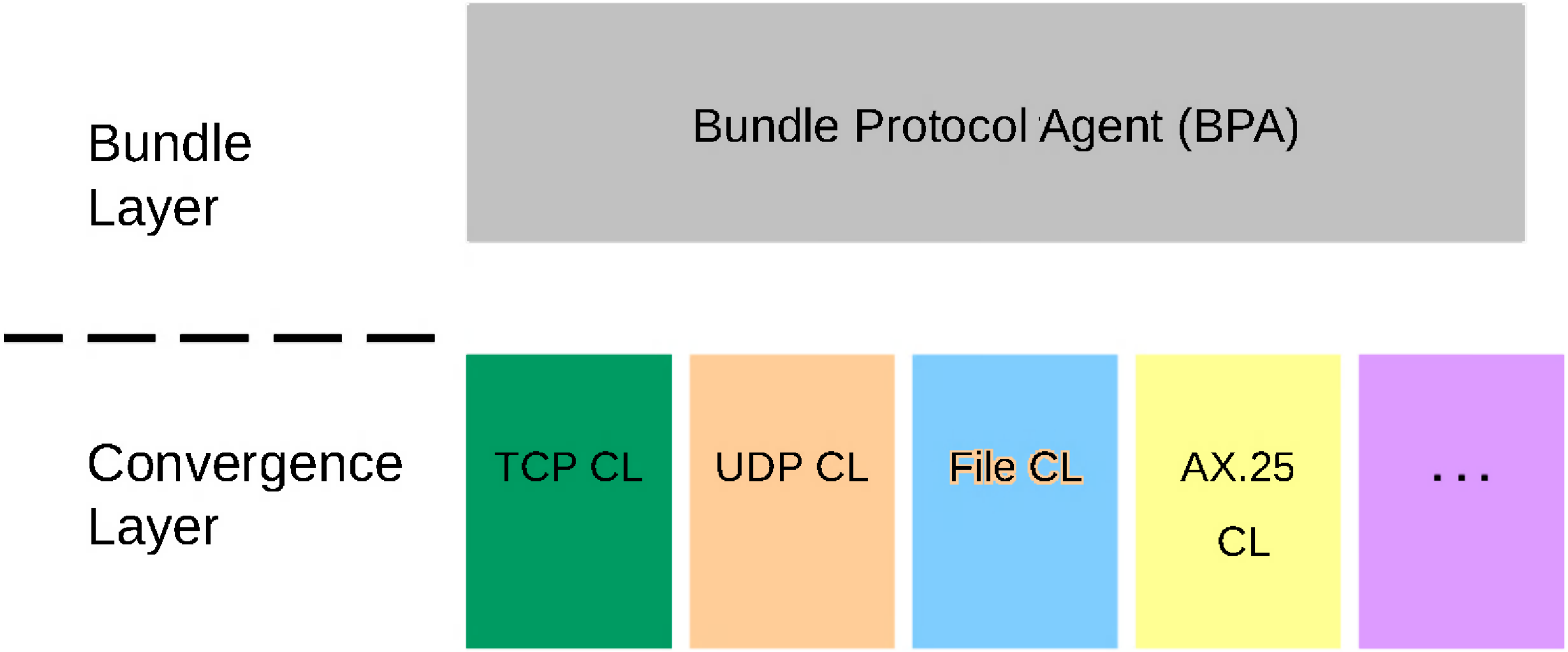
- DTNRG has been part of the IRTF since (at least) 2002
- RFC 5050 defines the Bundle Protocol
- Application-layer overlay that moves “bundles” of data
- Convergence Layers move bundles over different networks



# 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

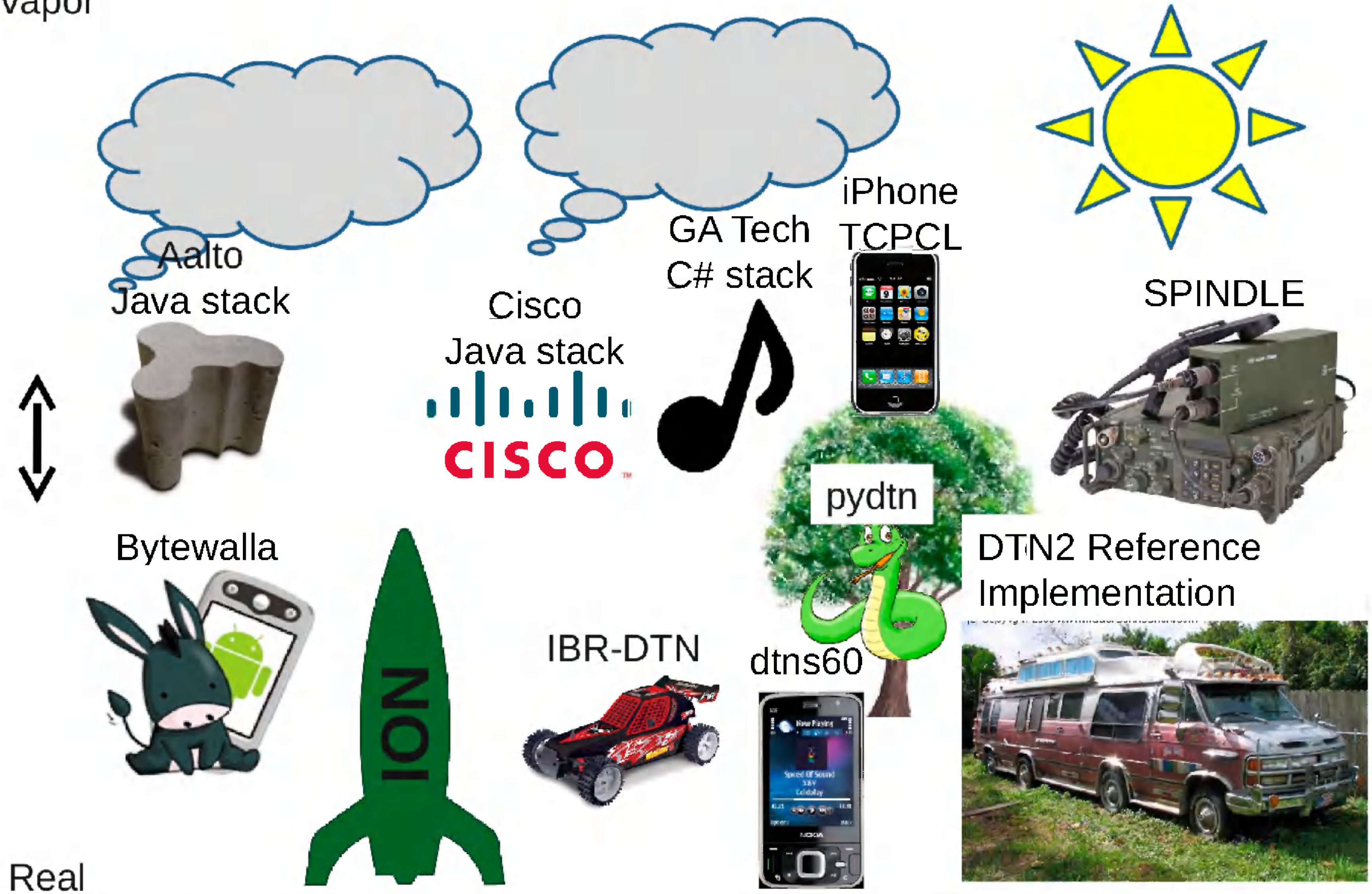
UDP CL

File CL

AX.25 CL

. . .

# Bundle Protocol Stack Landscape



Vapor

Aalto Java stack

Cisco Java stack

GA Tech C# stack

iPhone TCPCL

SPINDLE

pydtn

DTN2 Reference Implementation

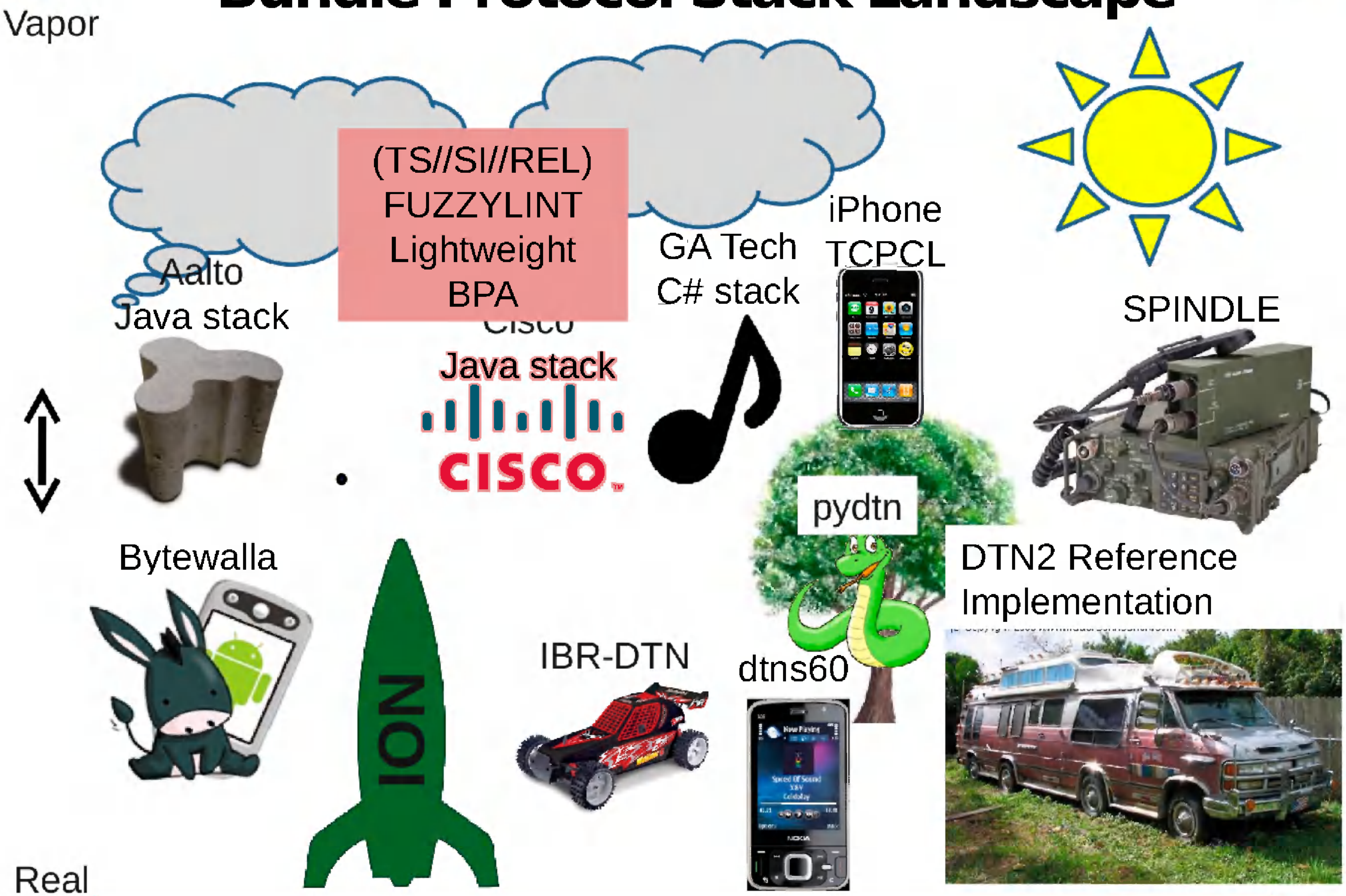
Bytewalla

IBR-DTN

dtns60

Real

# Bundle Protocol Stack Landscape



Vapor

(TS//SI//REL) FUZZYLINT Lightweight BPA

Aalto Java stack

Cisco Java stack

GA Tech C# stack

iPhone TCPCL

SPINDLE

pydtn

Bytewalla

IBR-DTN

dtns60

DTN2 Reference Implementation

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.

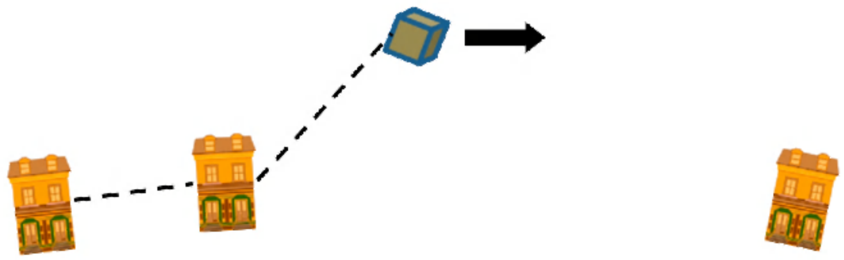
# Close Access (TS//SI//REL)

- (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

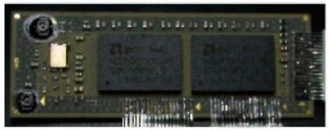


# Crowd Sourcing (U)

- (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



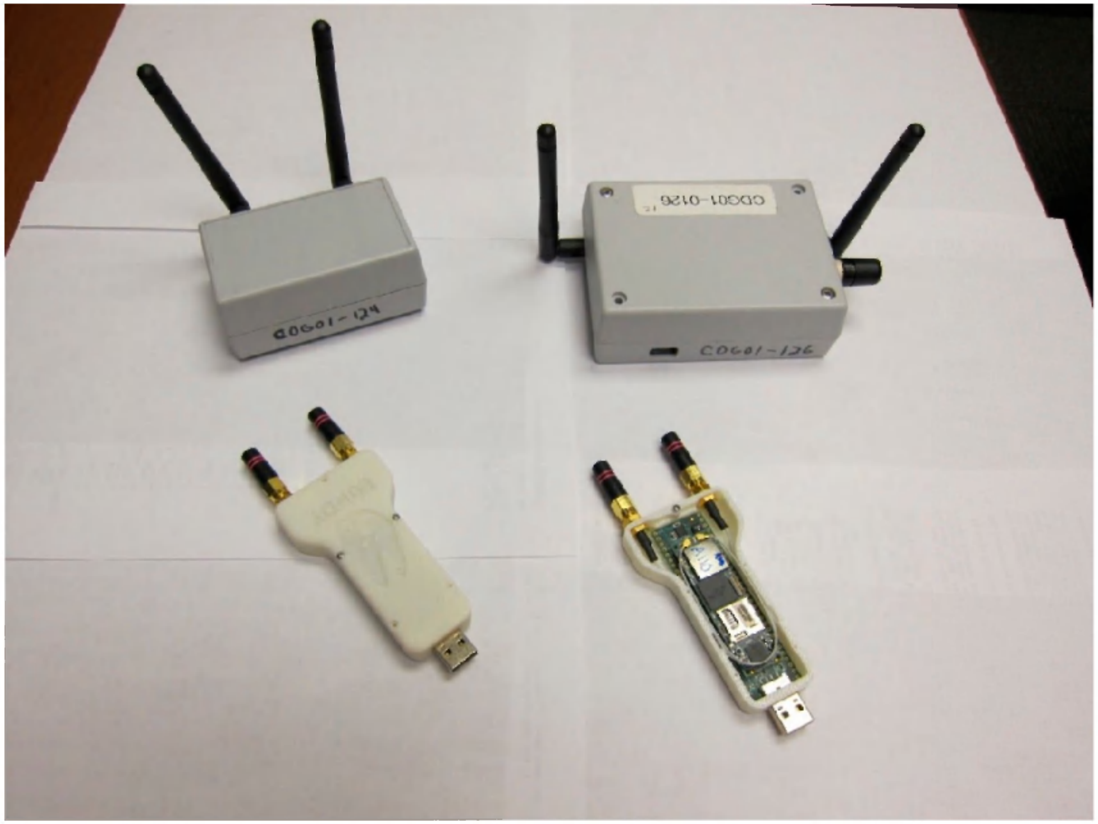
# Summary of IC applications (U//FOUO)

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

# 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

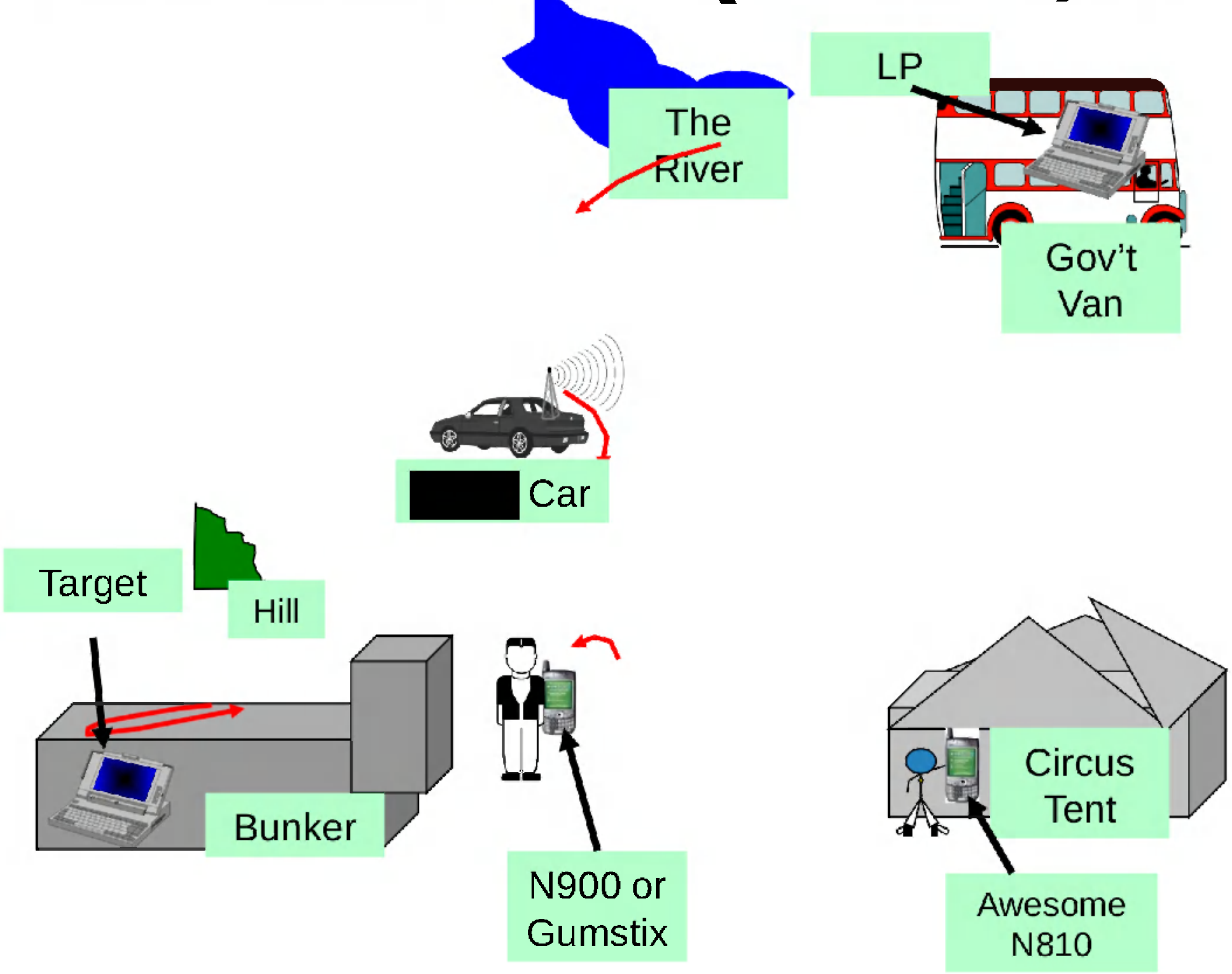
# STRAITBIZZARE (U)

- (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

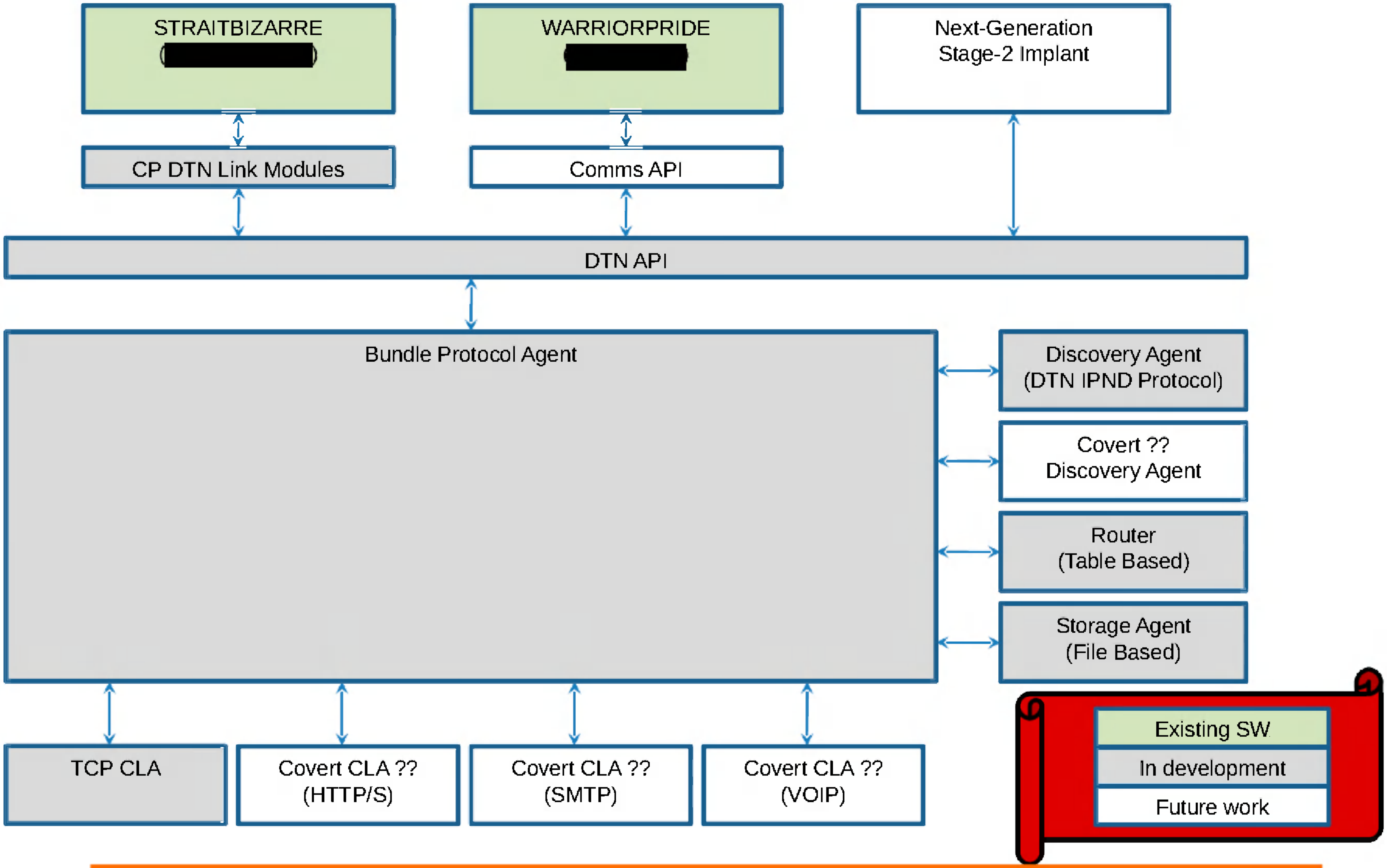
# TSV CONOP (TS//SI//REL)



# 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)



STRAITBIZARRE
[redacted]

WARRIORPRIDE
[redacted]

Next-Generation
Stage-2 Implant

CP DTN Link Modules

Comms API

DTN API

Bundle Protocol Agent

Discovery Agent
(DTN IPND Protocol)

Covert ??
Discovery Agent

Router
(Table Based)

Storage Agent
(File Based)

TCP CLA

Covert CLA ??
(HTTP/S)

Covert CLA ??
(SMTP)

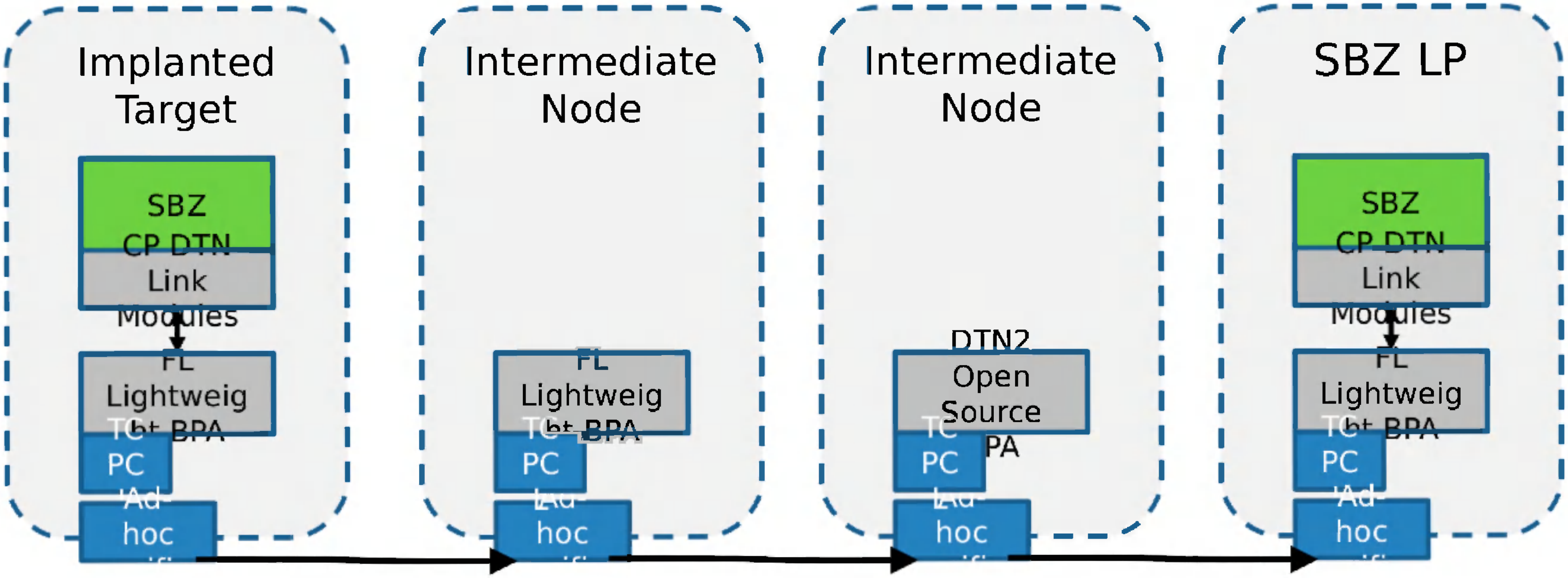
Covert CLA ??
(VOIP)

🟩 Existing SW

▨ In development

□ Future work

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



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

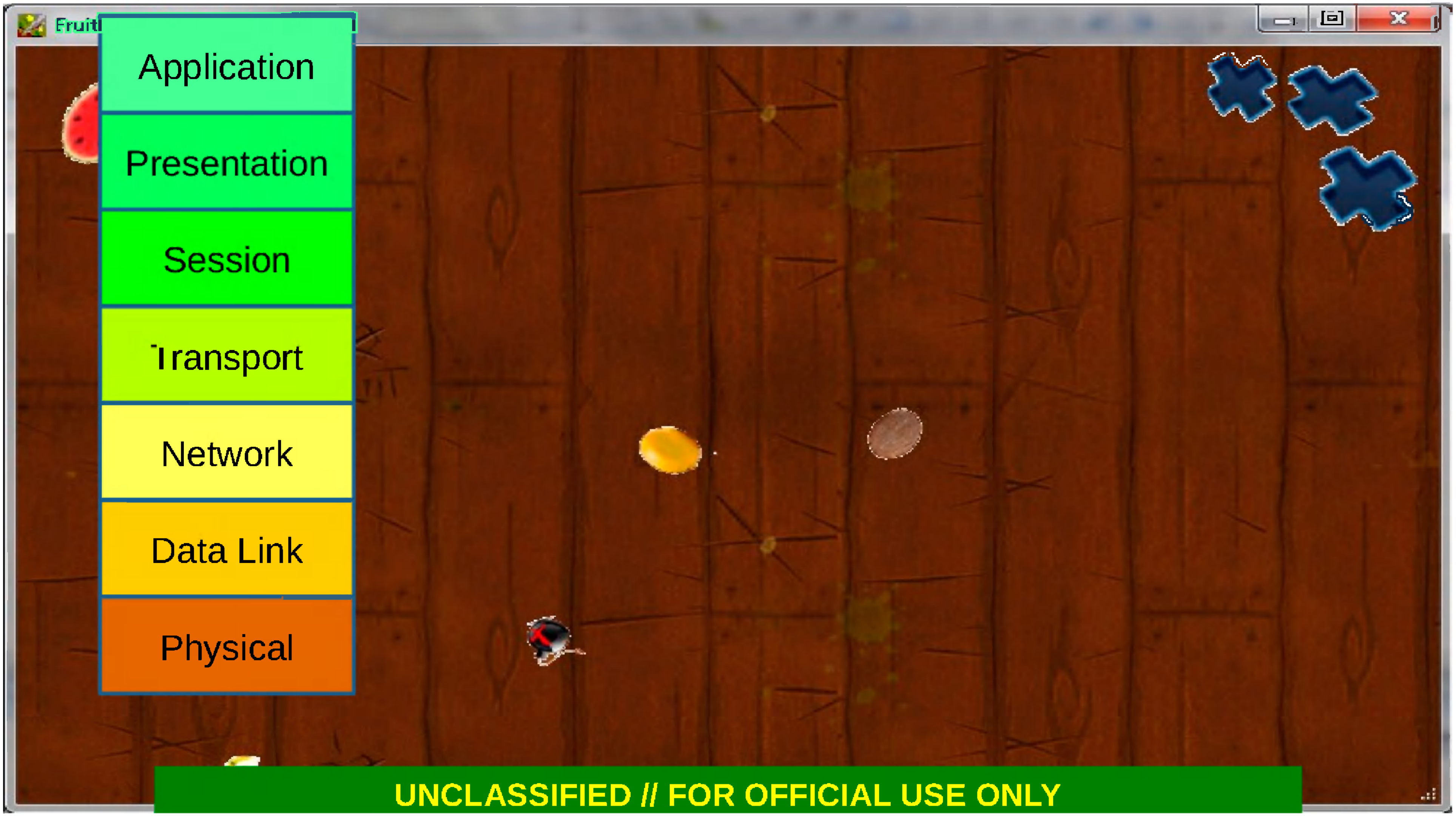
| | Linux netbook | Maemo | iPhone | Gumstix | Android | Windows and Java |
|---|---|---|---|---|---|---|
| DTN2 | 🟧 ✓ | ✓ | 🟧 ✓ | 🟧 ✓ | 🟧 ✓ | |
| IBR-DTN | ✓ | ✓ | ✓ | 🟧 ✓ | 🟧 ✓ | |
| FUZZYLINT | 🟧 ✓ | | 🟧 | | 🟧 ✓ | 🟧 ✓ |

🟧 Current Effort

# Wireless testbeds (U//FOUO)

# Reality Ninja (U//FOUO)

Reality



Application

Presentation

Session

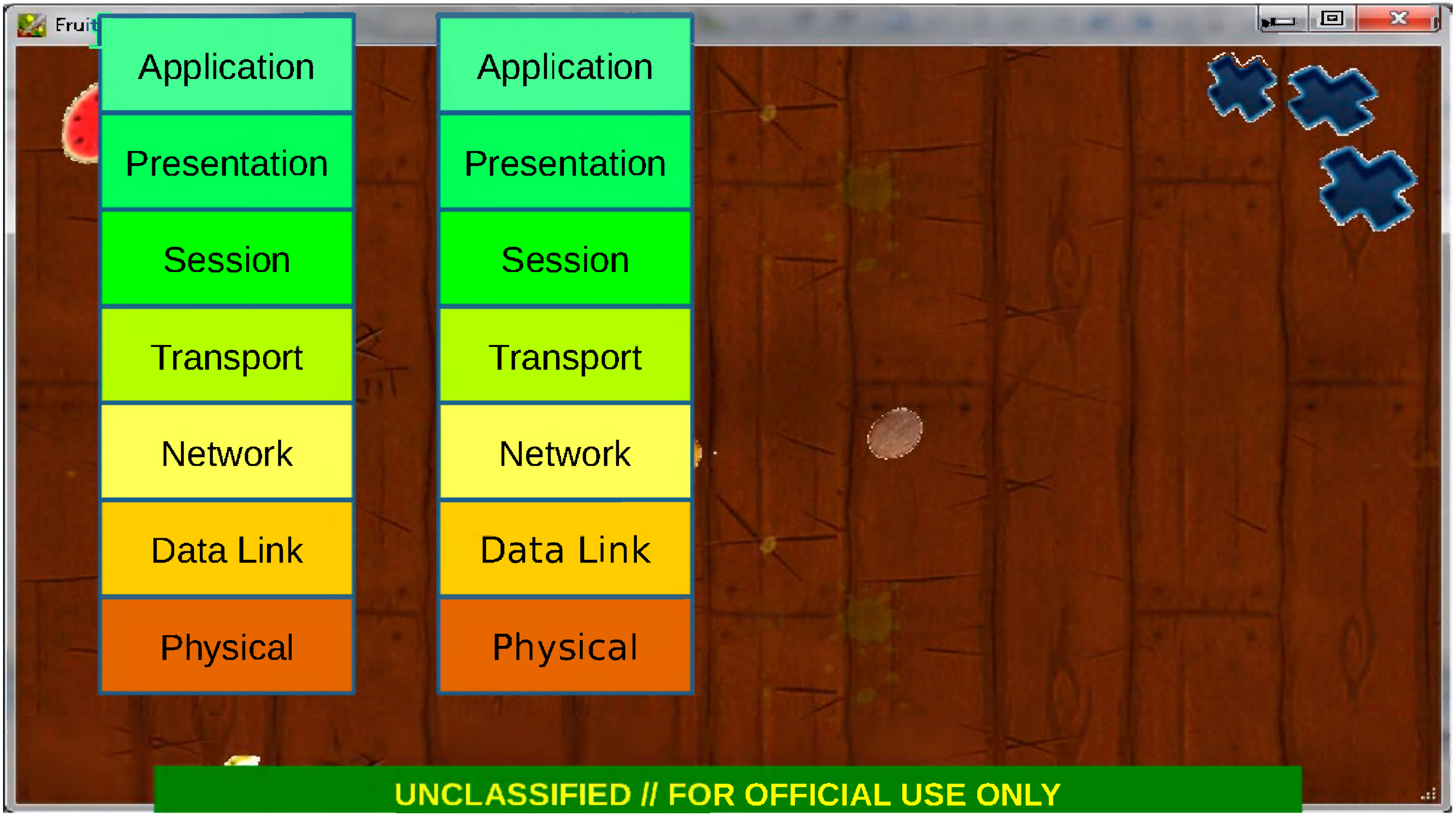
Transport

Network

Data Link

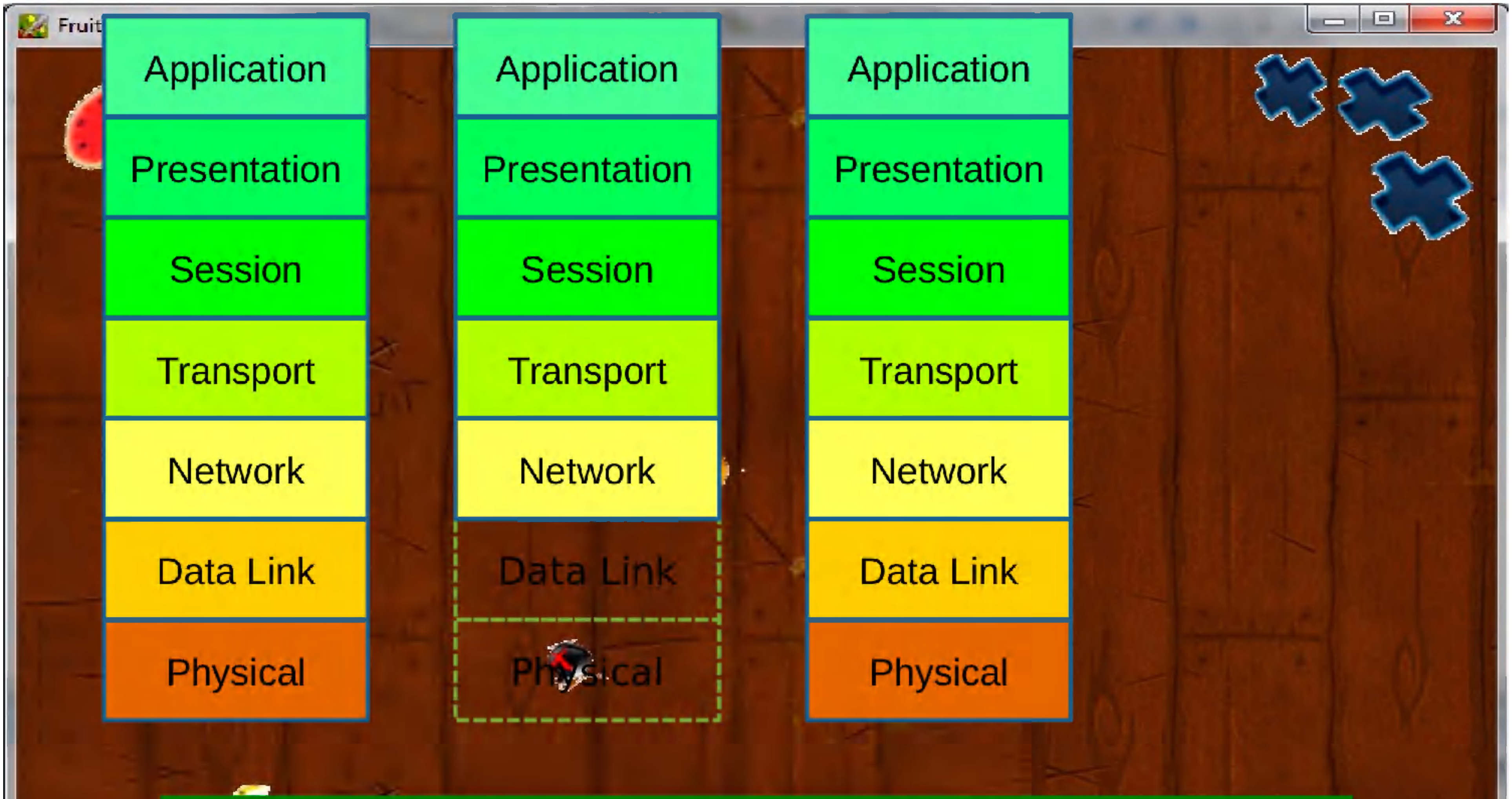
Physical

# Reality Ninja (U//FOUO)



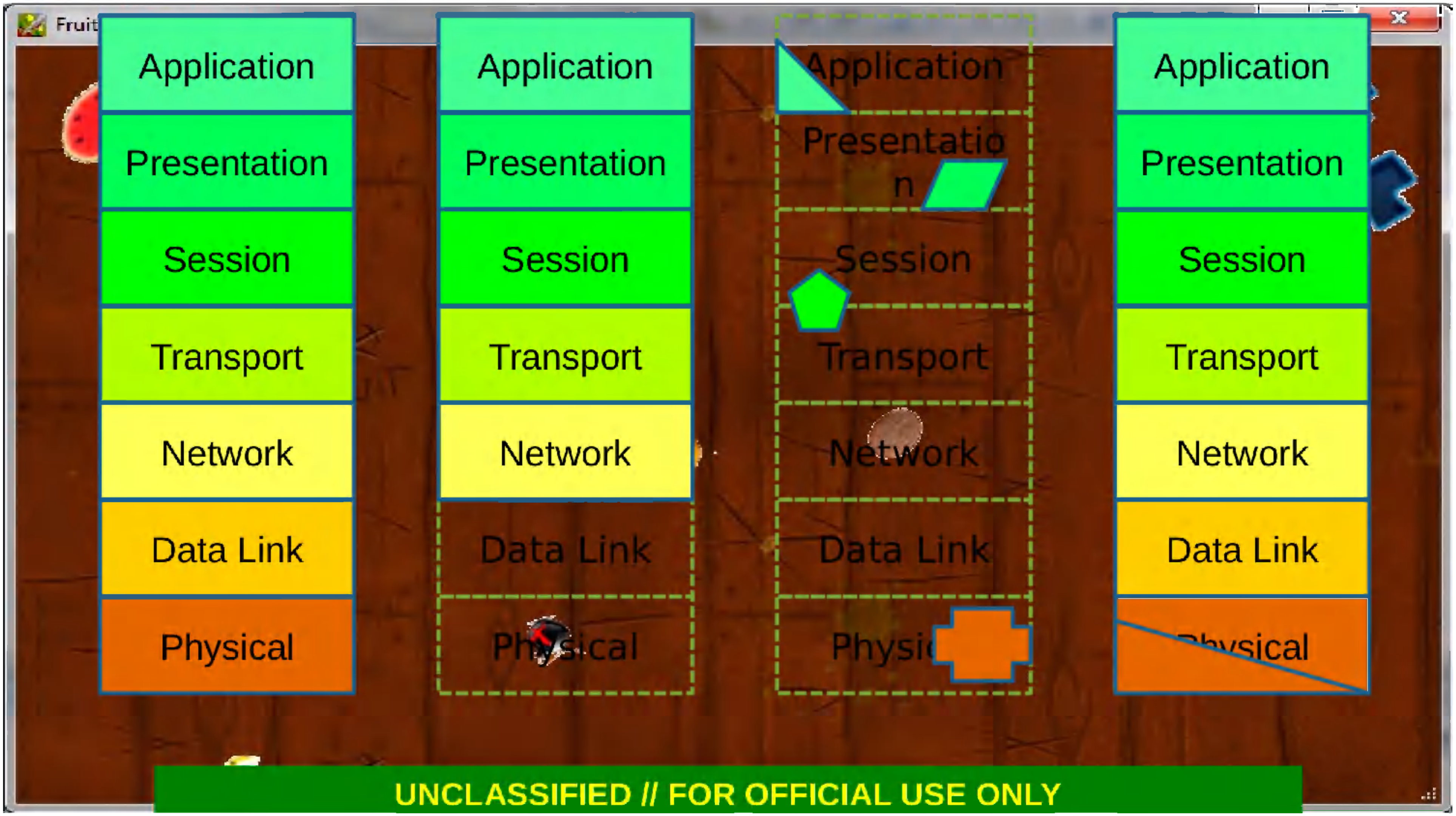
| Reality | Network Emulators |
|---|---|
| Application | Application |
| Presentation | Presentation |
| Session | Session |
| Transport | Transport |
| Network | Network |
| Data Link | Data Link |
| Physical | Physical |

# Reality Ninja (U//FOUO)



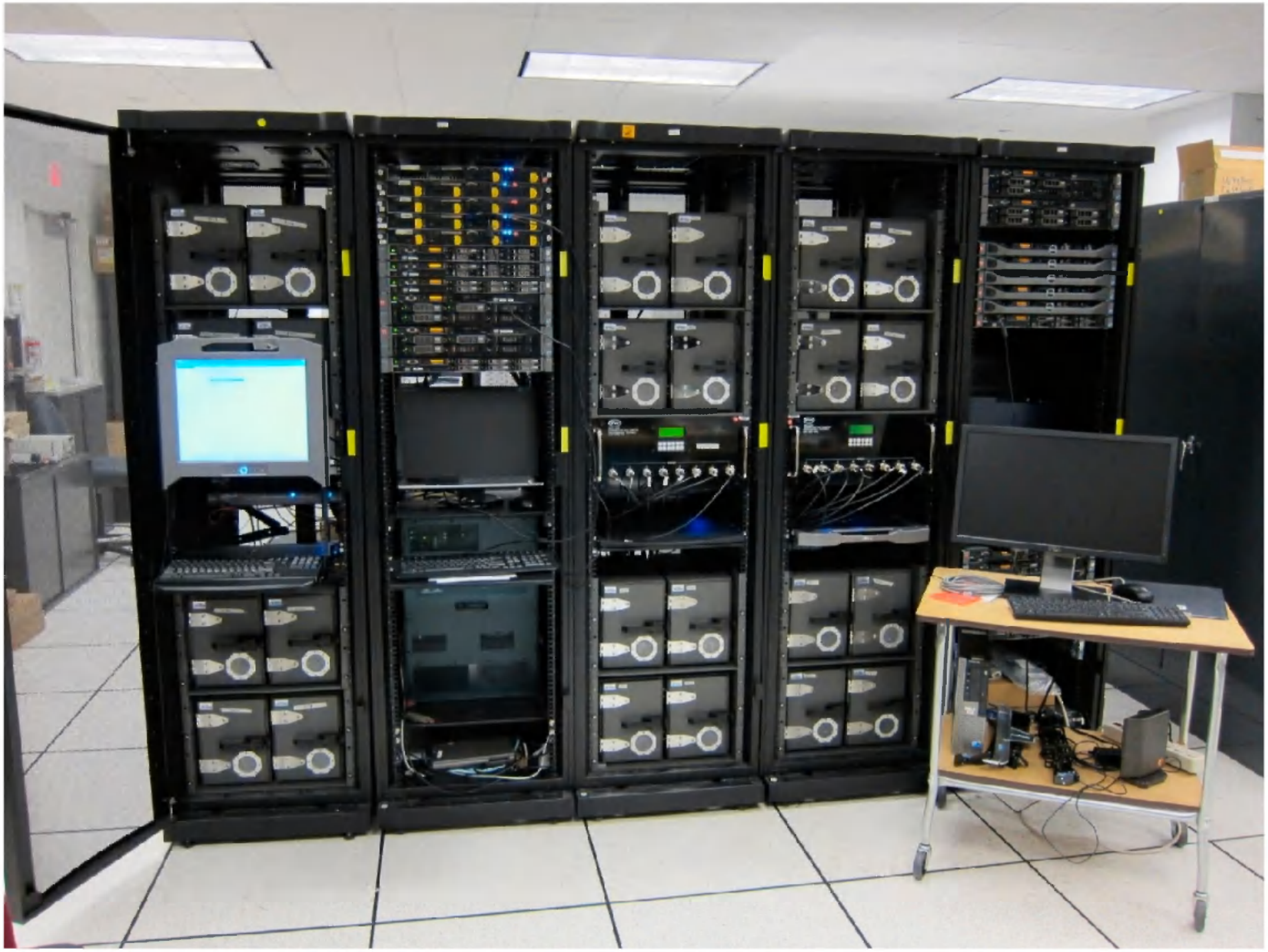
| Reality | Network Emulators | Simulation |
|---|---|---|
| Application | Application | Application |
| Presentation | Presentation | Presentation |
| Session | Session | Session |
| Transport | Transport | Transport |
| Network | Network | Network |
| Data Link | Data Link | Data Link |
| Physical | Physical | Physical |

# Reality Ninja (U//FOUO)

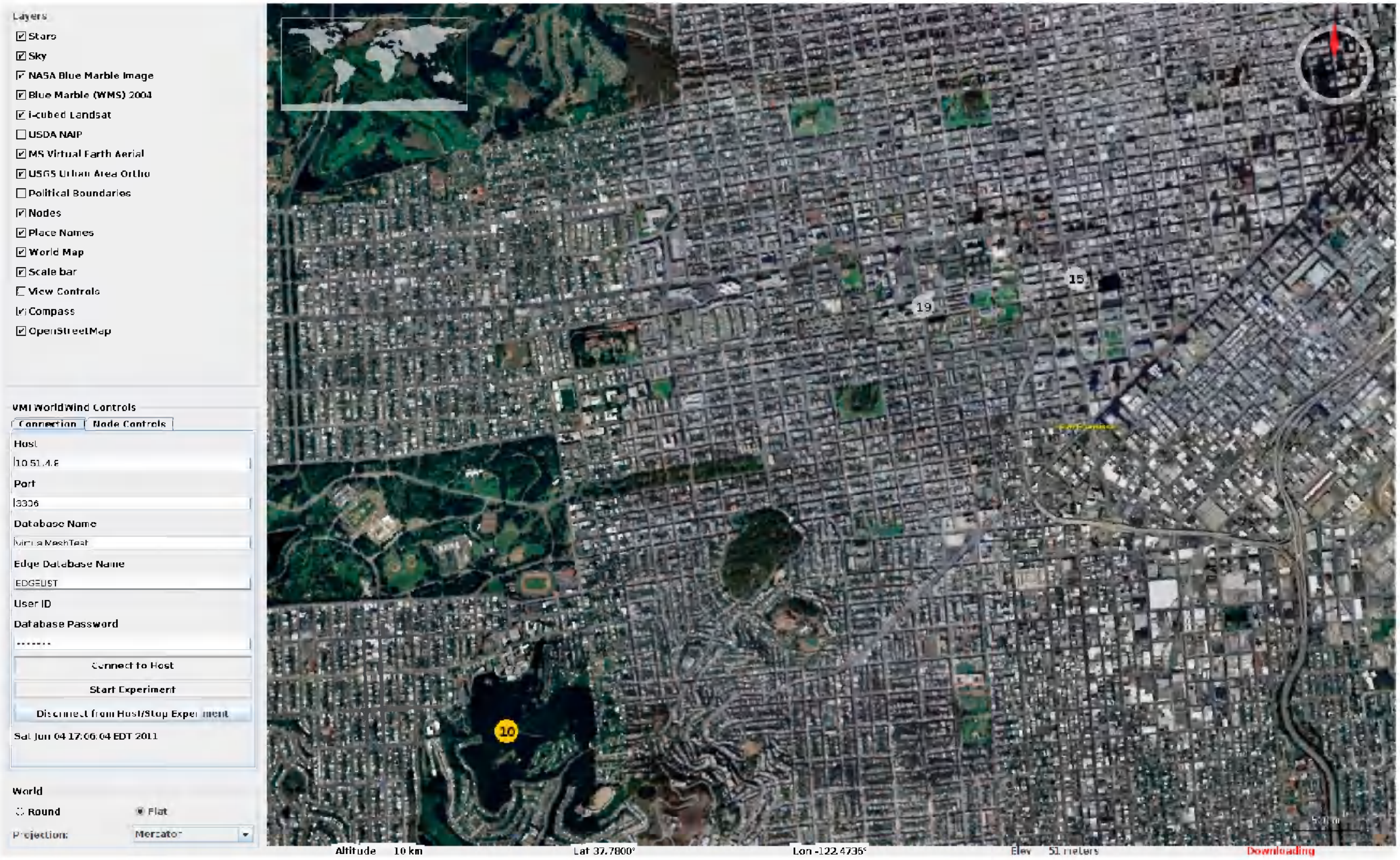


| Reality | Network Emulators | Simulation | MeshTest |
|---|---|---|---|
| Application | Application | Application | Application |
| Presentation | Presentation | Presentation | Presentation |
| Session | Session | Session | Session |
| Transport | Transport | Transport | Transport |
| Network | Network | Network | Network |
| Data Link | Data Link | Data Link | Data Link |
| Physical | Physical | Physical | Physical |

# 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: 10.51.4.8

Port: 3306

Database Name: VirtualMeshTest

Edge Database Name: EDGELIST

User ID

Database Password: •••••••

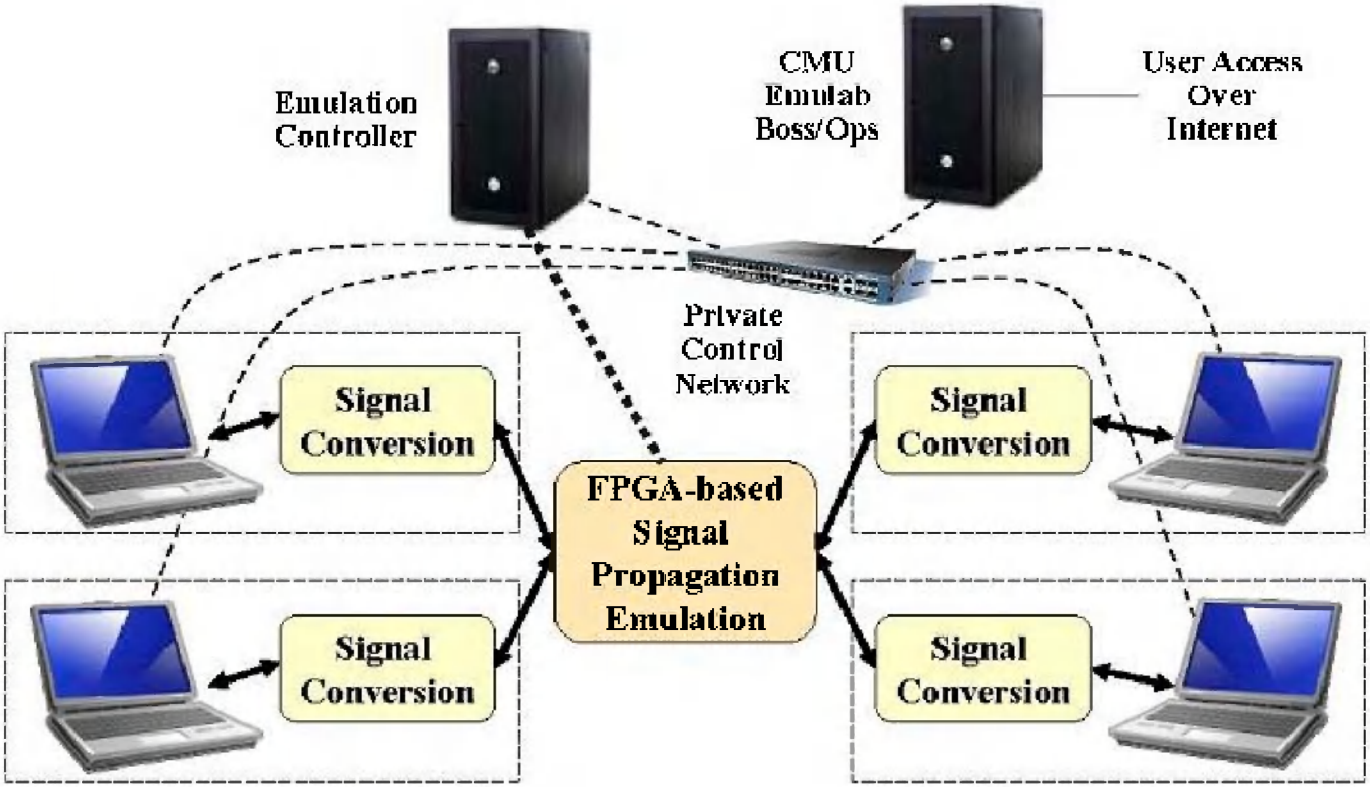
Sat Jun 04 17:06:04 EDT 2011

World: ○ Round ● Flat

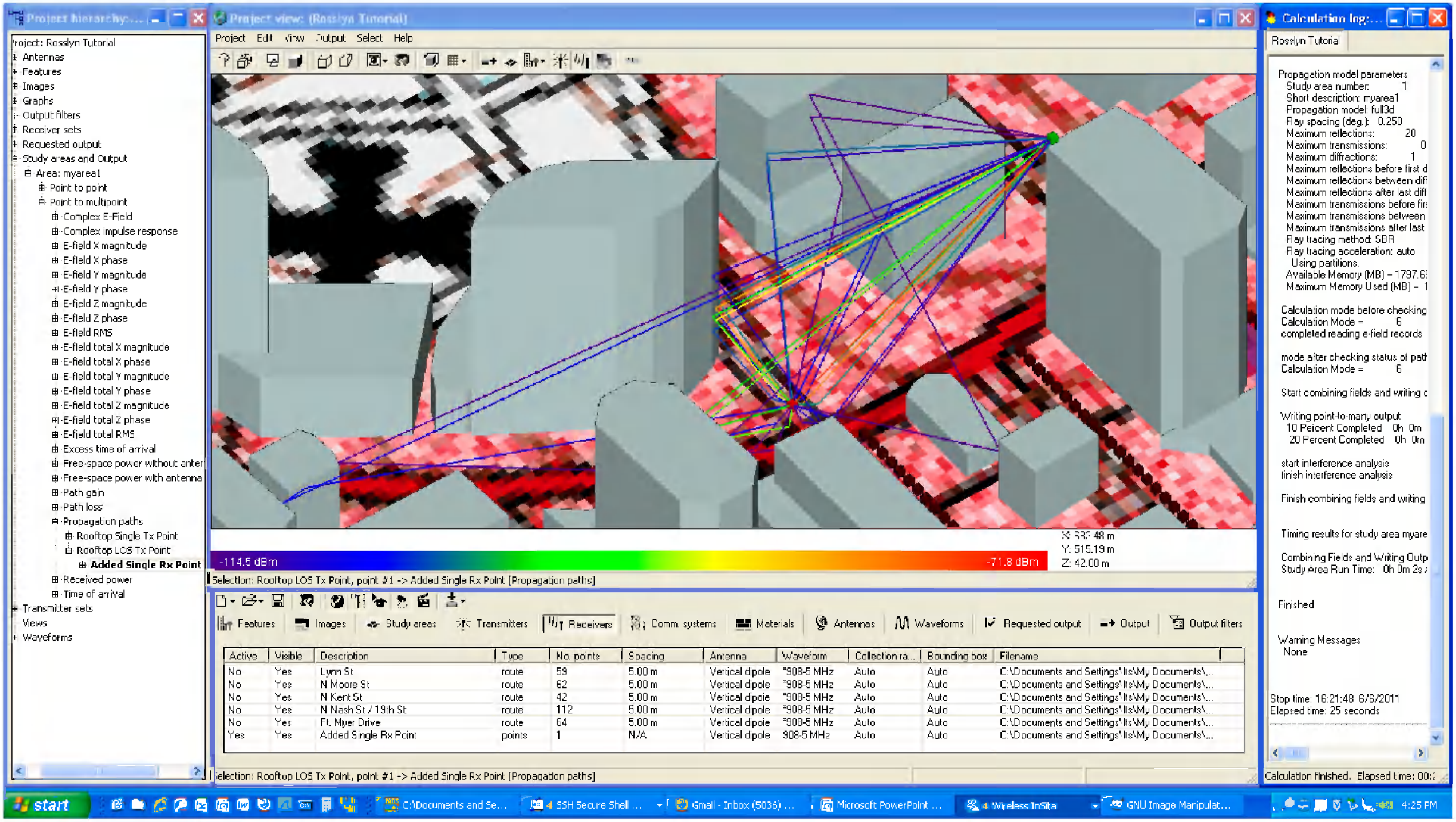
Projection: Mercator

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

# CMU Wireless Emulator (U//FOUO)



# Detailed Channel Modeling (U//FOUO)



```
'roject: 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 anter
        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
```

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

| 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\ lts\My Documents\... |
| No | Yes | N Moore St | route | 62 | 5.00 m | Vertical dipole | *908-5 MHz | Auto | Auto | C:\Documents and Settings\ lts\My Documents\... |
| No | Yes | N Kent St | route | 42 | 5.00 m | Vertical dipole | *908-5 MHz | Auto | Auto | C:\Documents and Settings\ lts\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\ lts\My Documents\... |
| No | Yes | Ft. Myer Drive | route | 64 | 5.00 m | Vertical dipole | *908-5 MHz | Auto | Auto | C:\Documents and Settings\ lts\My Documents\... |
| Yes | Yes | Added Single Rx Point | points | 1 | N/A | Vertical dipole | 908-5 MHz | Auto | Auto | C:\Documents and Settings\ lts\My Documents\... |

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

```
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 d
  Maximum reflections between diff
  Maximum reflections after last diff
  Maximum transmissions before fir
  Maximum transmissions between
  Maximum transmissions after last
  Ray tracing method: SBR
  Ray tracing acceleration: auto
    Using partitions.
  Available Memory (MB) = 1797.6
  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 myare

 Combining Fields and Writing Outp
 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:

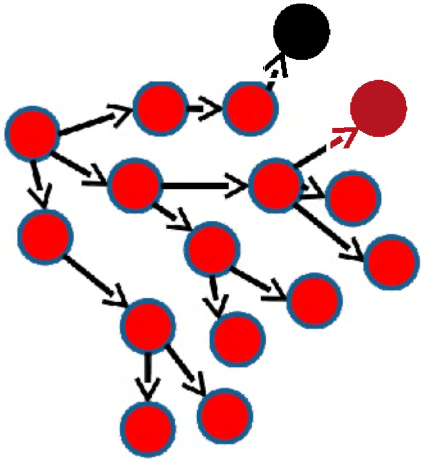
- Routing and Reliability Issues
- Security Issues

# 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:

  dtn://dtnbone.umd.edu.dtn/

  dtn://nodea.dtn/

  ebr://group5.dtn/

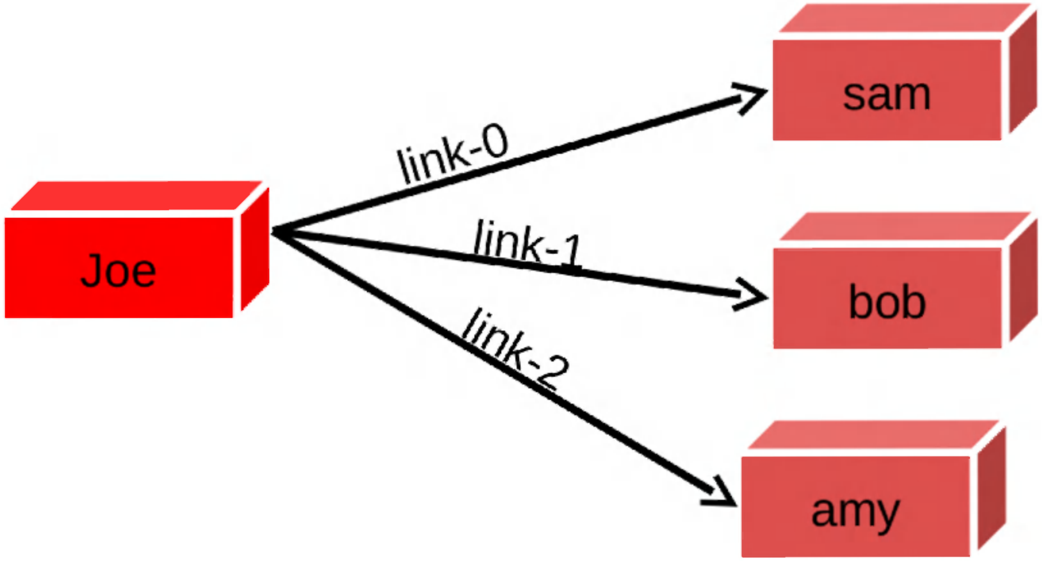
- Convergence Layer connections to neighbors are called “Links”
  - For example a TCP connection to a neighbor is a link

- Each link knows the EID of the neighbor associated with it

# Static Routing Tables (U)

One-hop "Direct Delivery"

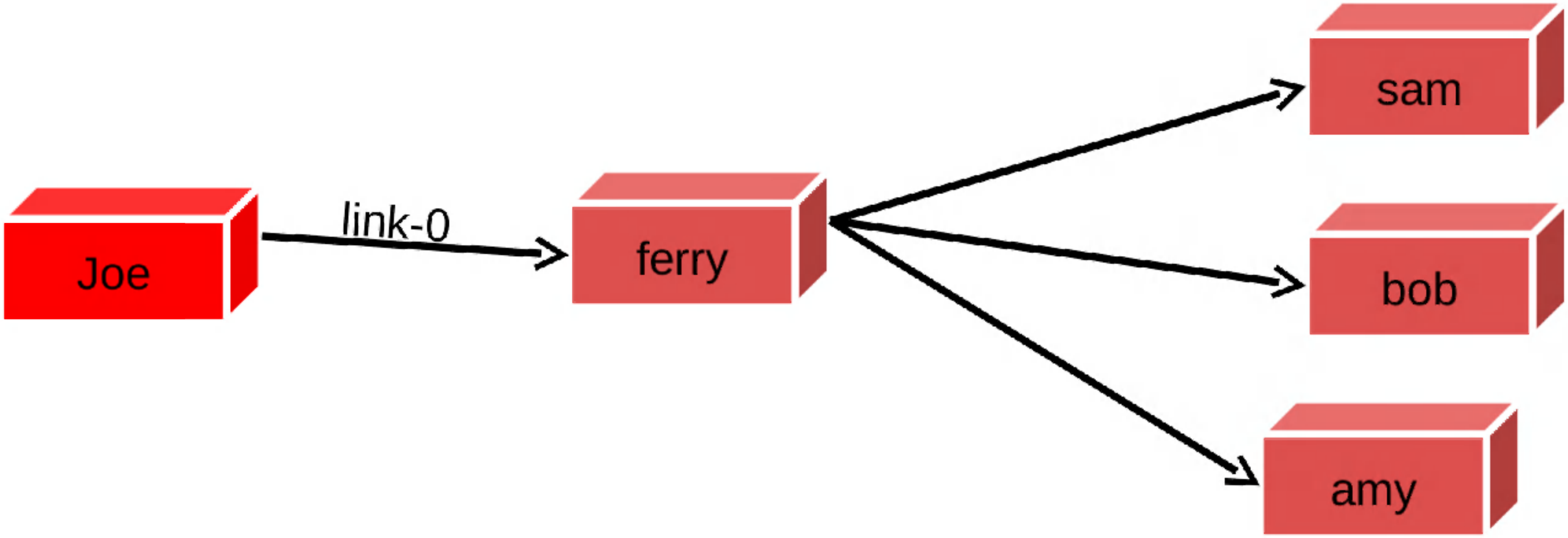
| Destination | Next hop | Action |
|---|---|---|
| dtn://sam.dtn/ | link-0 | FWD |
| dtn://bob.dtn/ | link-1 | FWD |
| dtn://amy.dtn/ | link-2 | FWD |



# Static Routing Tables (U)

Two-hop “Bundle Ferry”

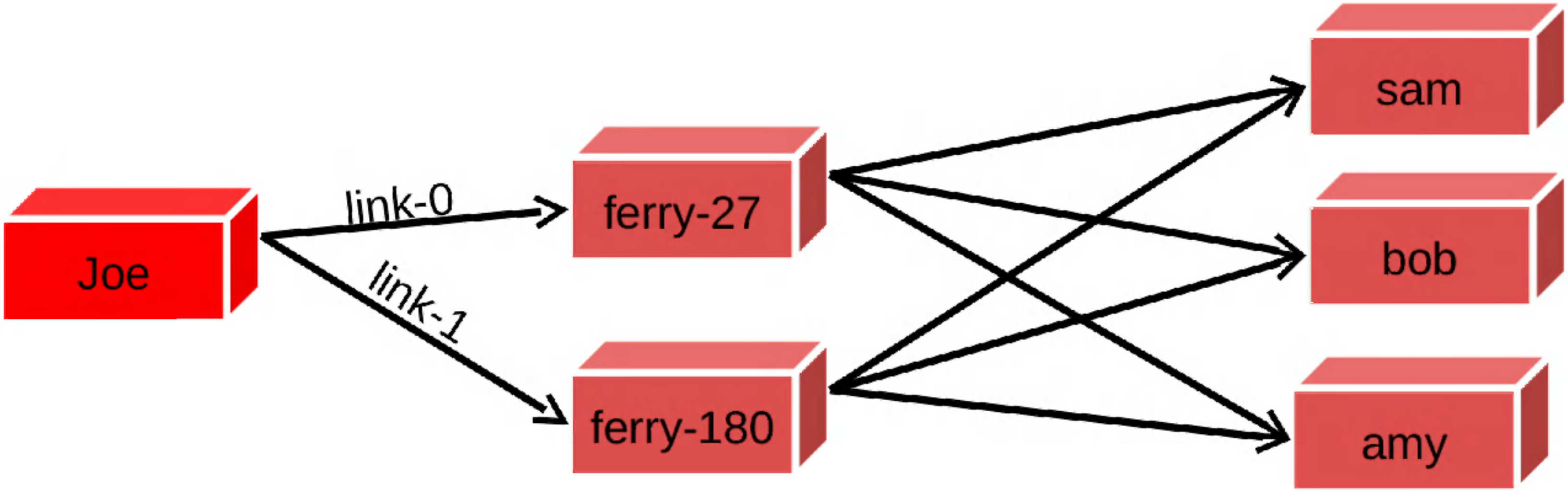
| Destination | Next hop | Action |
|---|---|---|
| dtn://sam.dtn/ | dtn://ferry.dtn/ | FWD |
| dtn://bob.dtn/ | dtn://ferry.dtn/ | FWD |
| dtn://amy.dtn/ | dtn://ferry.dtn/ | FWD |
| dtn://ferry.dtn/ | link-0 | FWD |



# Static Routing Tables (U)

Two-hop “Bundle Ferry” with wildcards

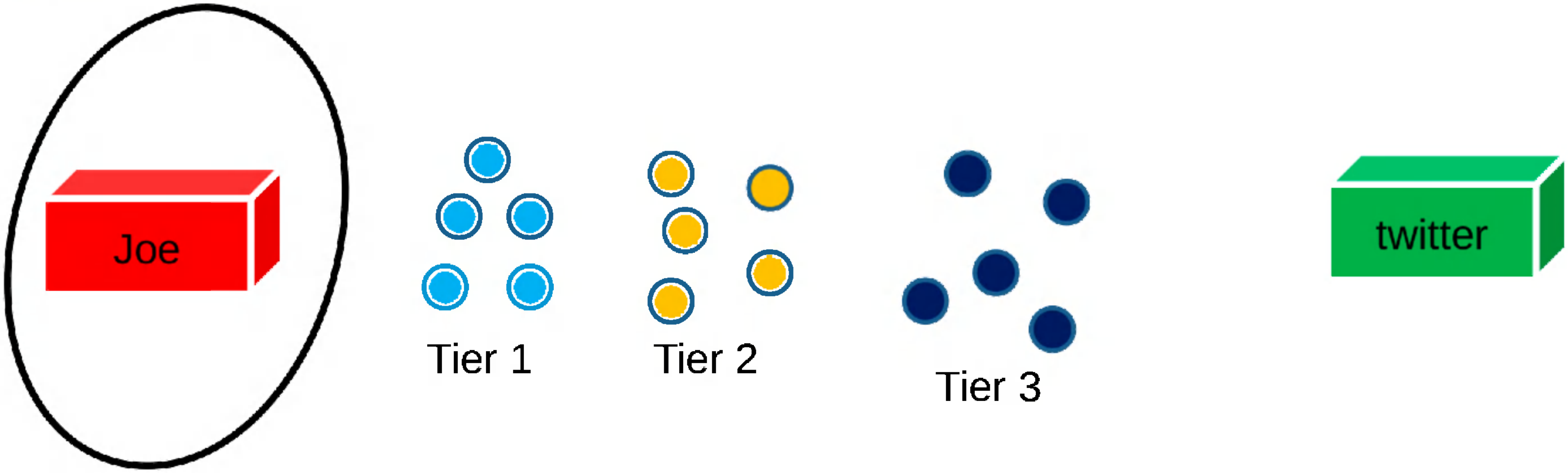
| Destination | Next hop | Action |
|---|---|---|
| dtn://sam.dtn/ | dtn://ferry-*.dtn/ | FWD |
| dtn://bob.dtn/ | dtn://ferry-*.dtn/ | FWD |
| dtn://amy.dtn/ | dtn://ferry-*.dtn/ | FWD |
| dtn://ferry-27.dtn/ | link-0 | FWD |
| dtn://ferry-180.dtn/ | link-1 | FWD |



# Static Routing Tables (U)

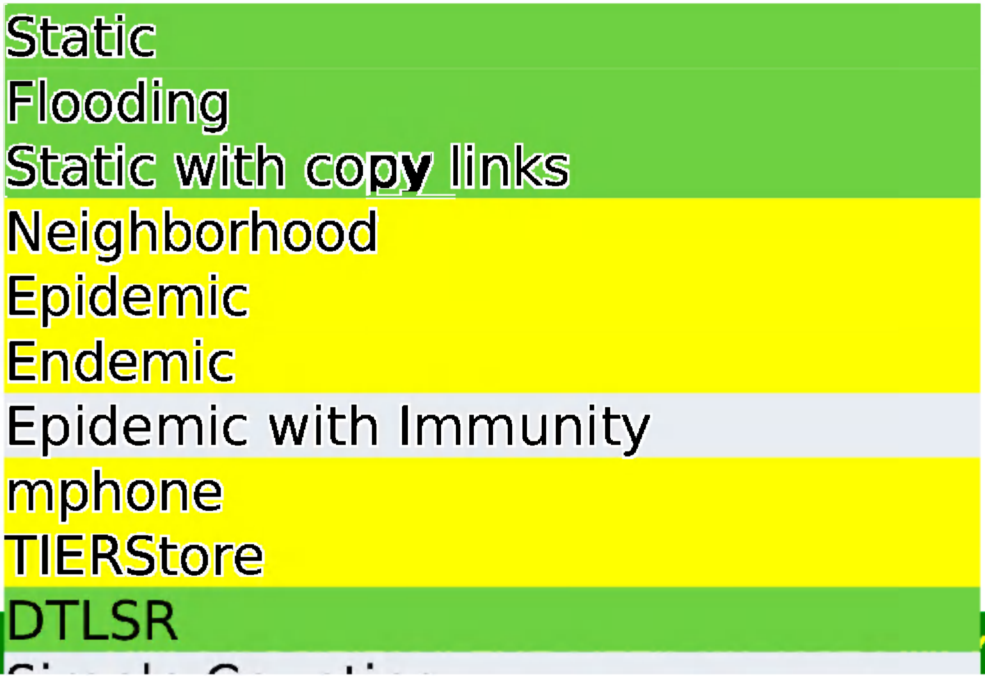
Multi-hop “Tiered routing”

| 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 |



# DTN Routing Bonanza (U)

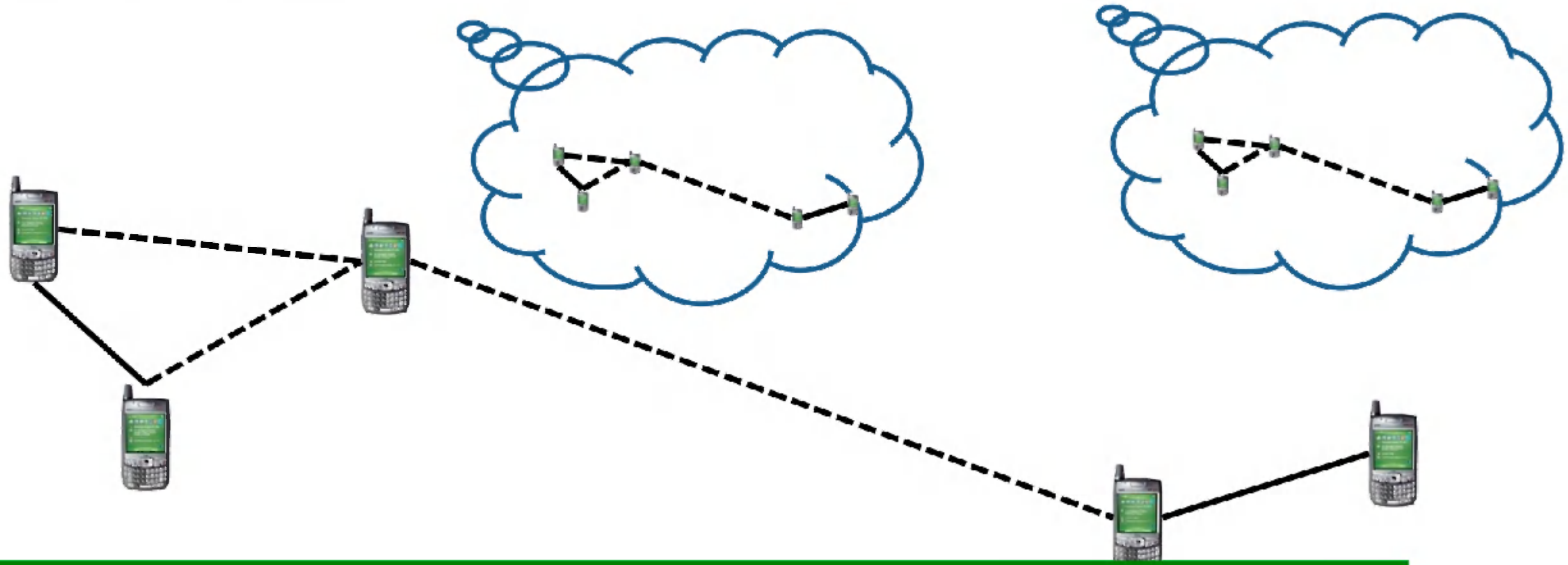
- (U//FOUO) People propose routing protocols for many different environments and purposes.
  - Sometimes with novel applications, sometimes with no real need
- (U) Has inspired the phrase “Yet Another Routing Protocol”



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

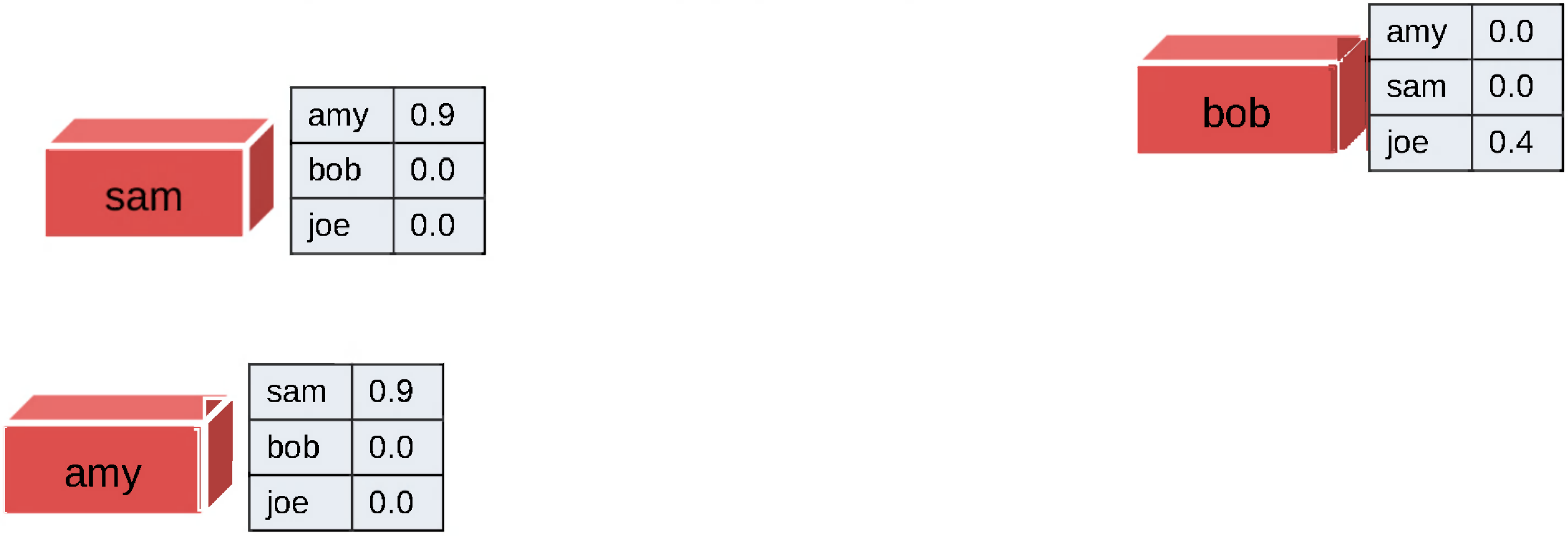
# DTLSR (U)

- (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)



| | |
|---|---|
| amy | 0.0 |
| sam | 0.0 |
| joe | 0.4 |

| | |
|---|---|
| amy | 0.9 |
| bob | 0.0 |
| joe | 0.0 |

| | |
|---|---|
| sam | 0.9 |
| bob | 0.0 |
| joe | 0.0 |

# “Intelligent” Routing: PRoPHET (U)

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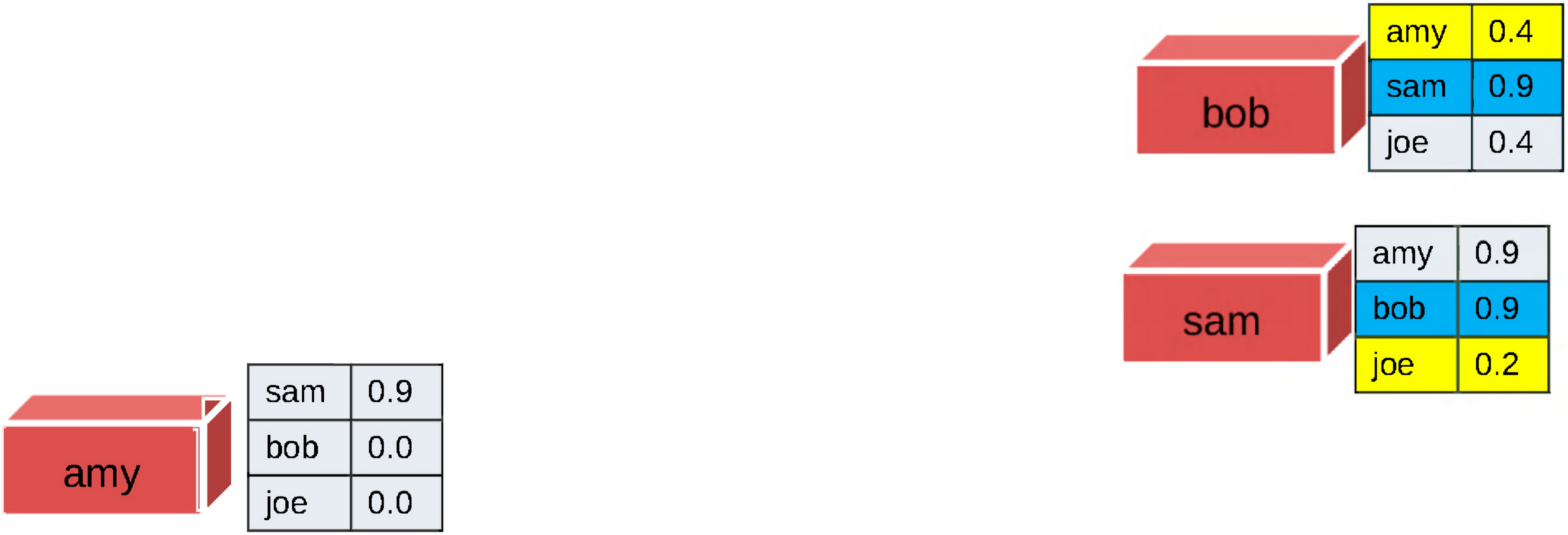


bob

| | |
|---|---|
| amy | 0.4 |
| sam | 0.9 |
| joe | 0.4 |

sam

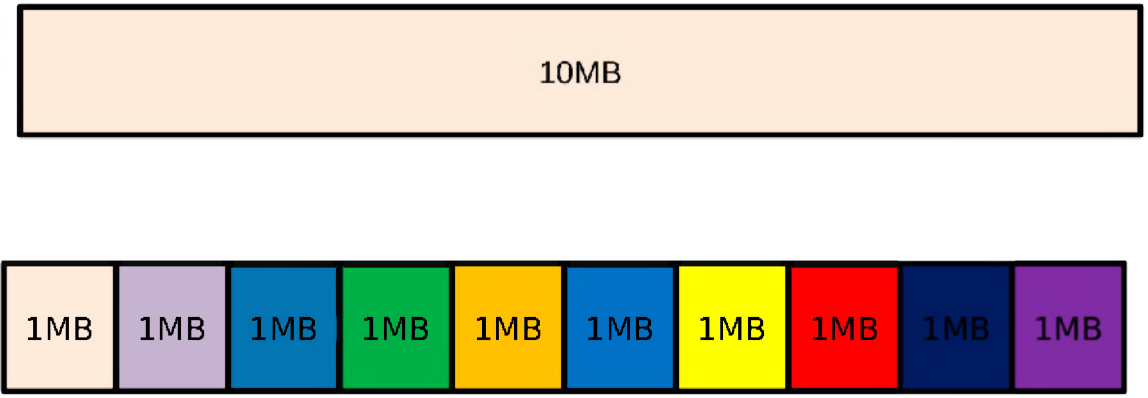
| | |
|---|---|
| amy | 0.9 |
| bob | 0.9 |
| joe | 0.2 |

amy

| | |
|---|---|
| sam | 0.9 |
| bob | 0.0 |
| joe | 0.0 |

# Network-Coding in DTNs (U)

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

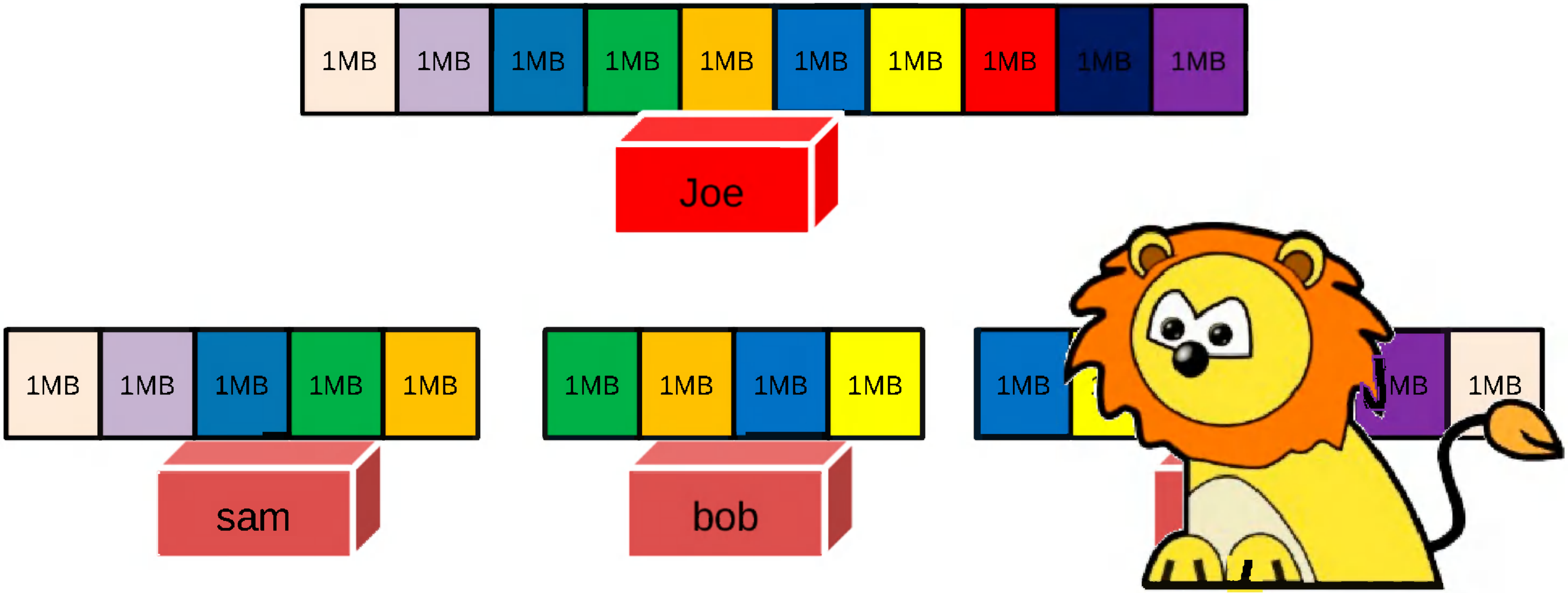


10MB

1MB 1MB 1MB 1MB 1MB 1MB 1MB 1MB 1MB 1MB

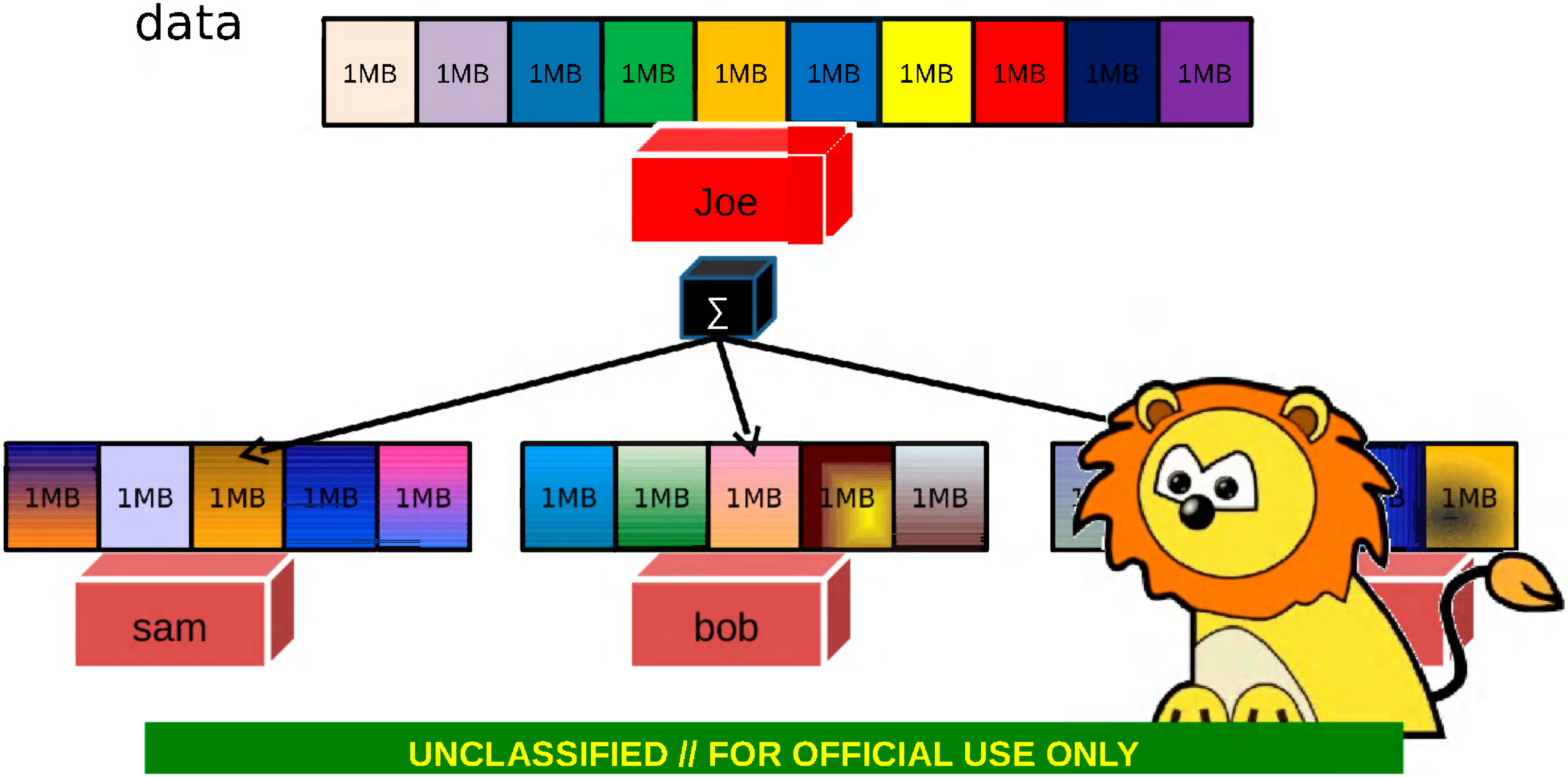
# Network-Coding in DTNs (U)

- 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 polices 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)

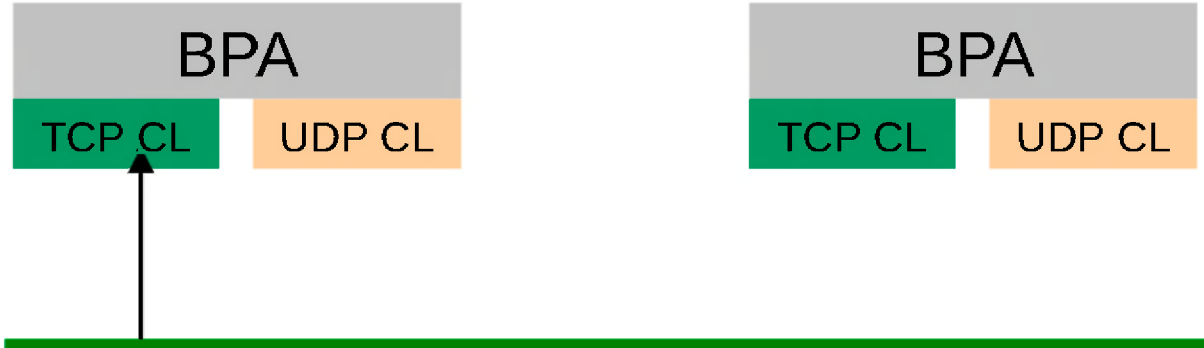
- (U//FOUO) Payload data encrypted with AES in Galois Counter Mode (GCM)
- (U) Provides data integrity
- (U) AES key is encrypted with the destination’s RSA public key

# 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



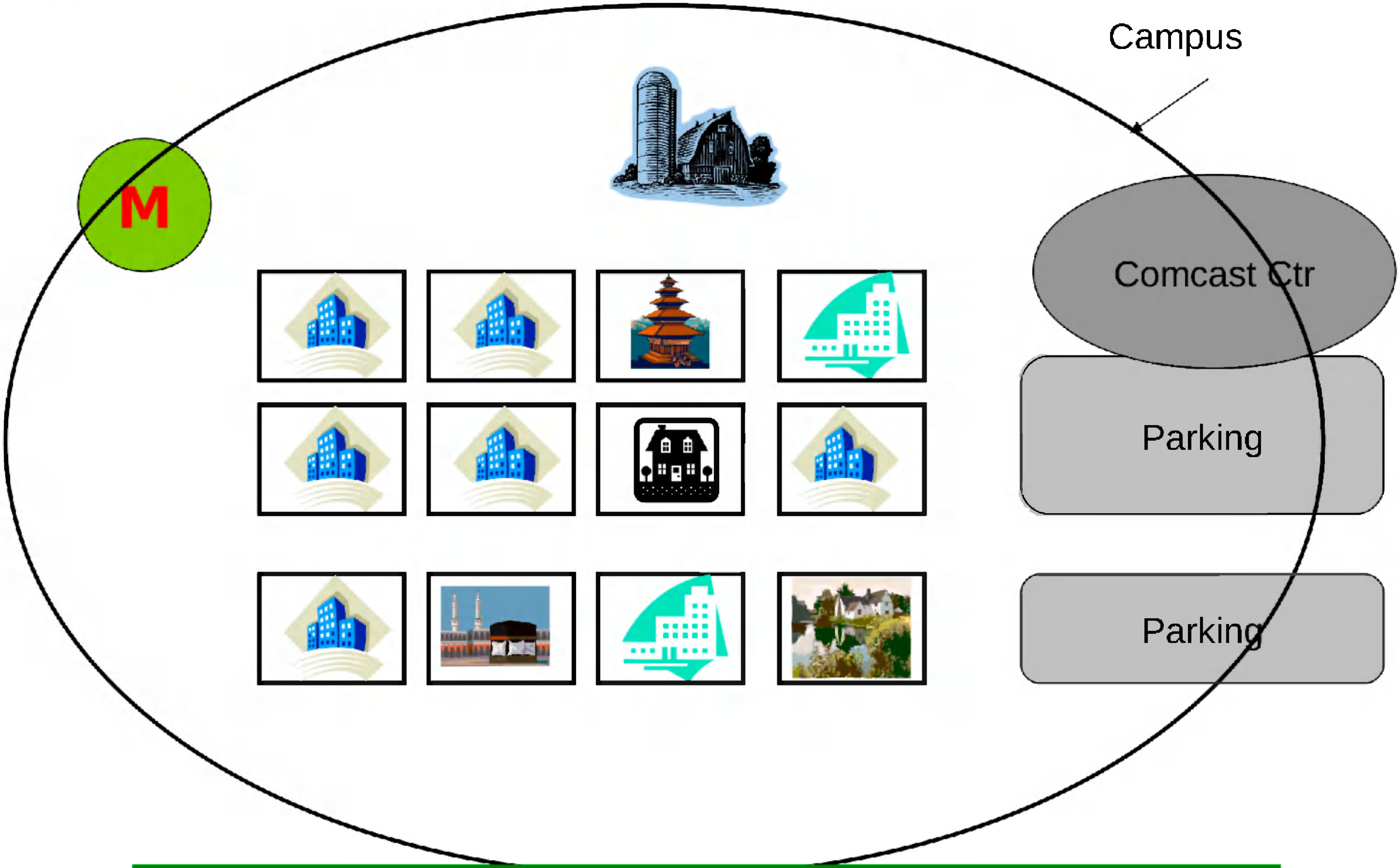
# Link-Layer Security (U)

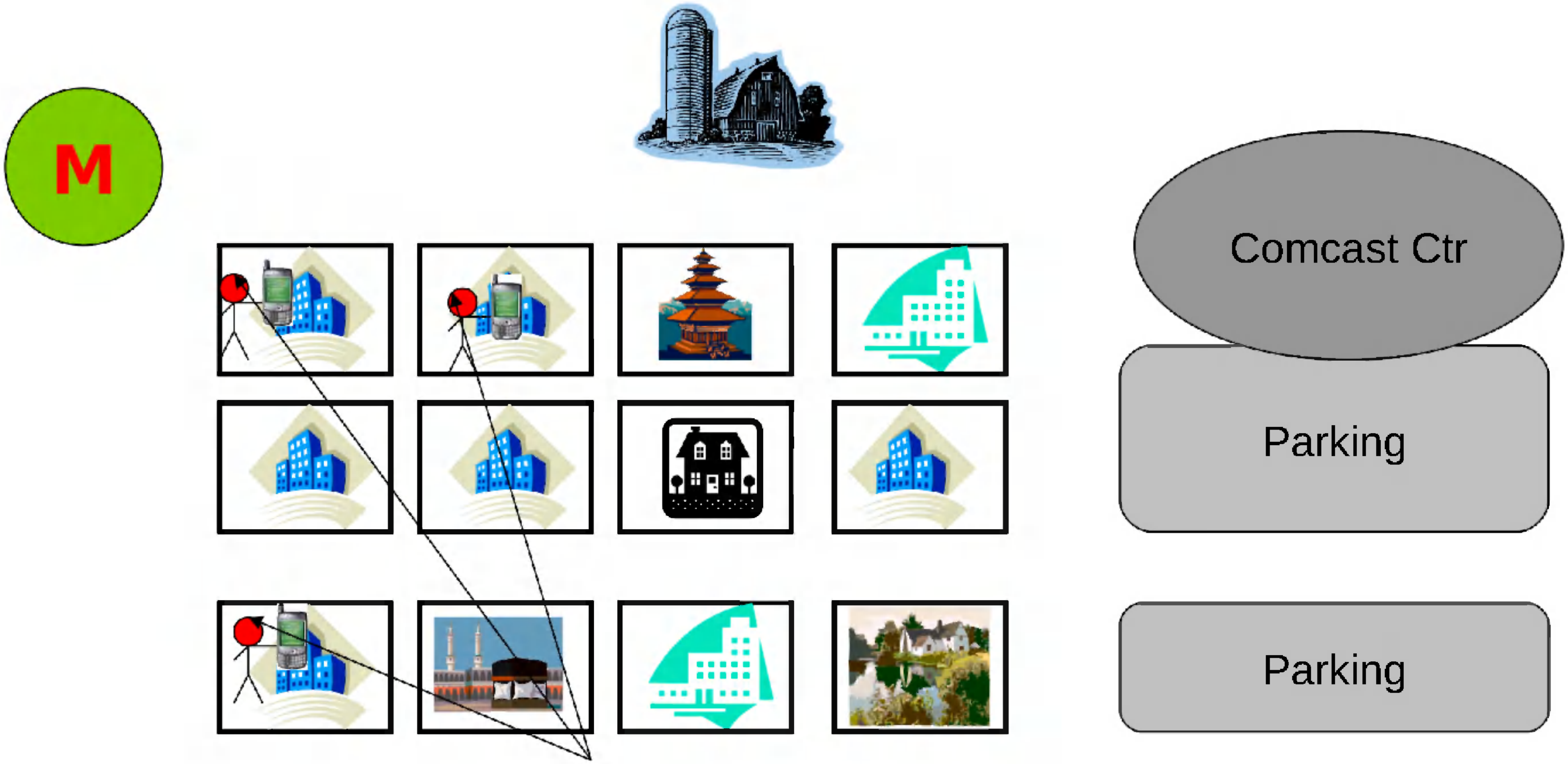
- (U) Constraints
  - Lightweight
  - Low setup latency
  - Limited bandwidth consumption
  - Minimal provisioning/maintenance
  - Compatible with short session durations

# Covert Discovery (S//REL)

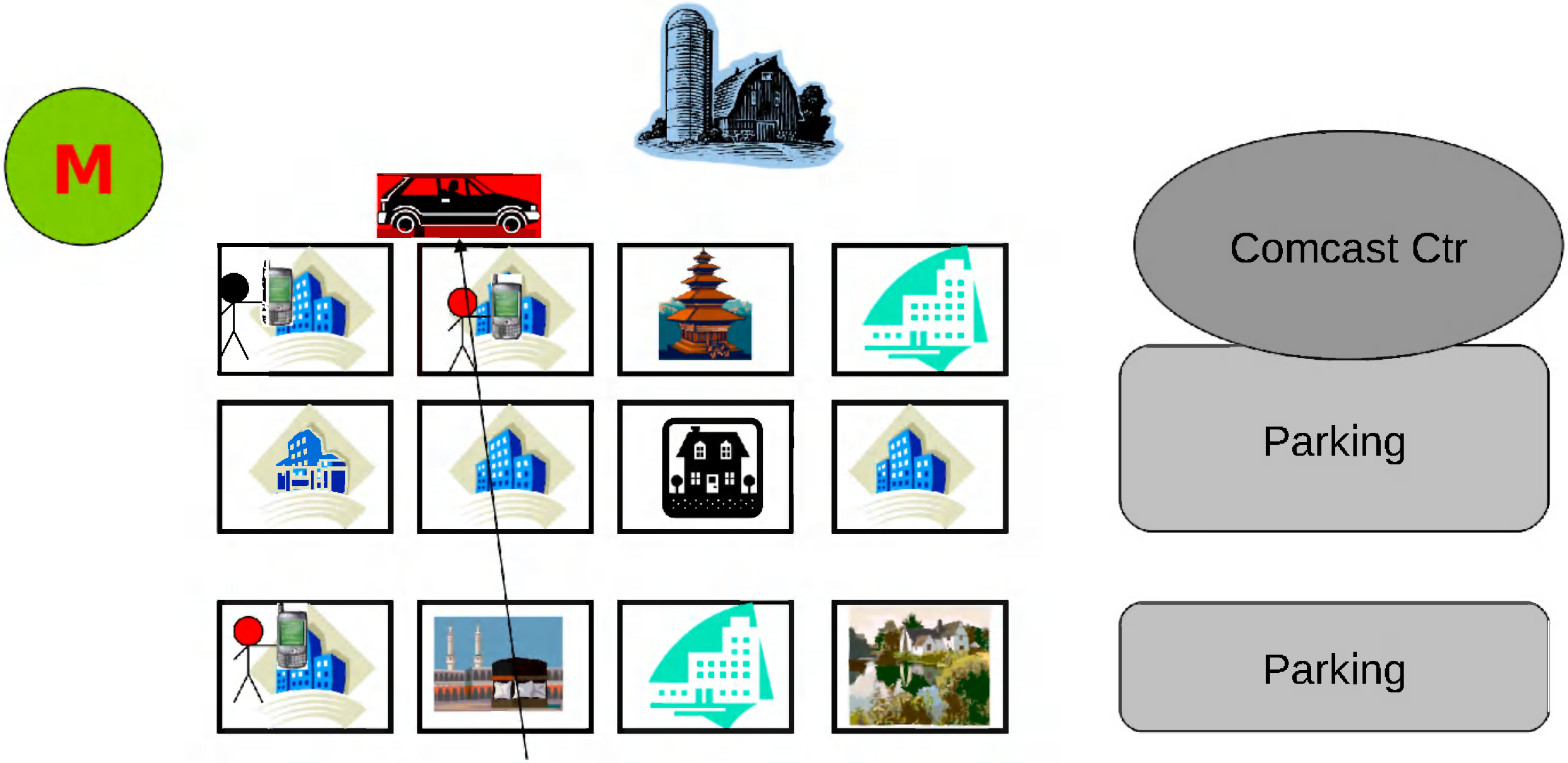
- (TS//SI//REL) Have set up external triggers for establishing DTN links
- (S//REL) Similar work being done outside to reduce power consumption
- (U) Example: Bluetooth beacons triggering a wifi connection
- (S//REL) Another option: use our own radios for some hops

# Surveillance-oriented Demo (U)

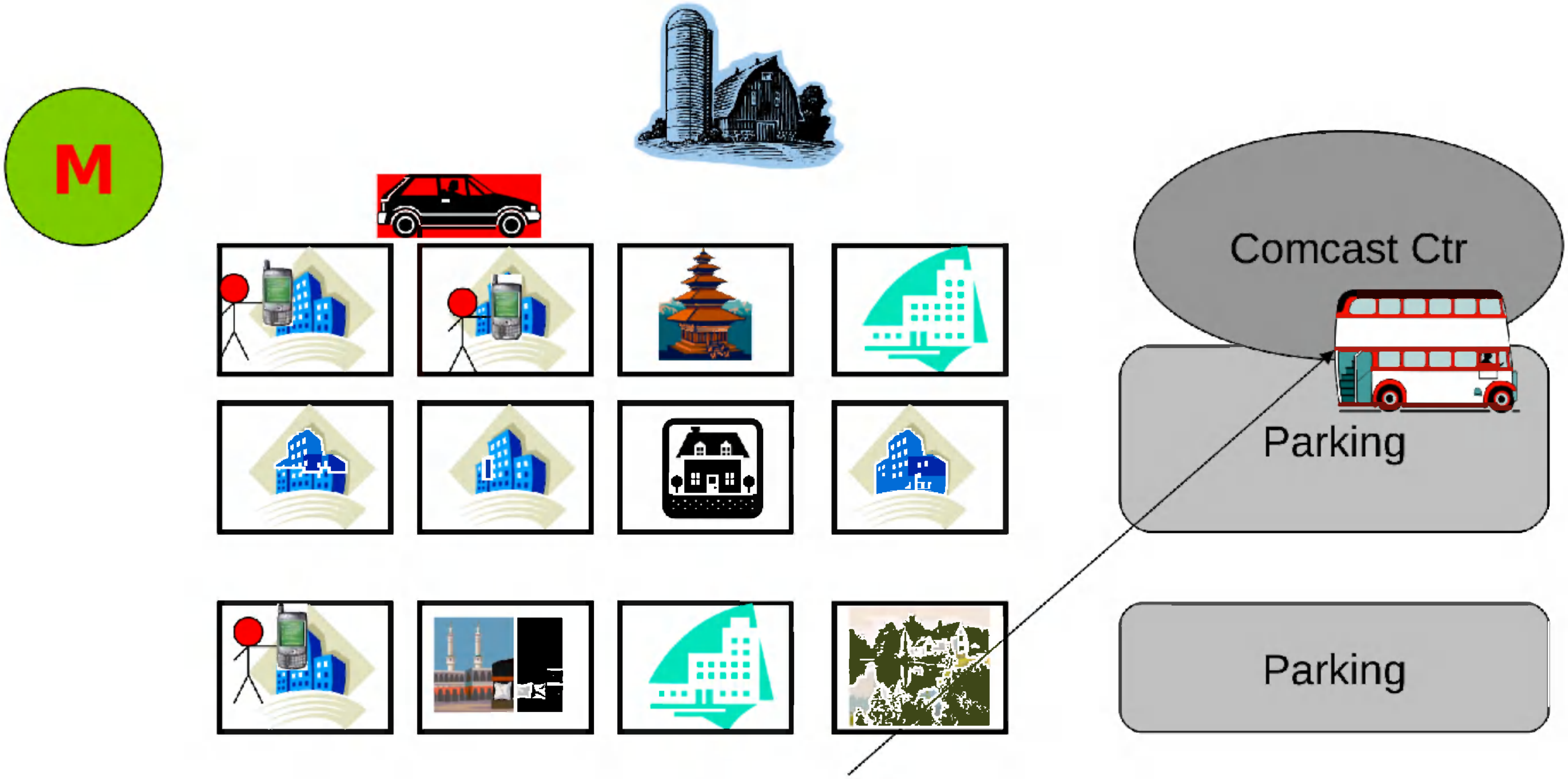

Campus
M
Comcast Ctr
Parking
Parking



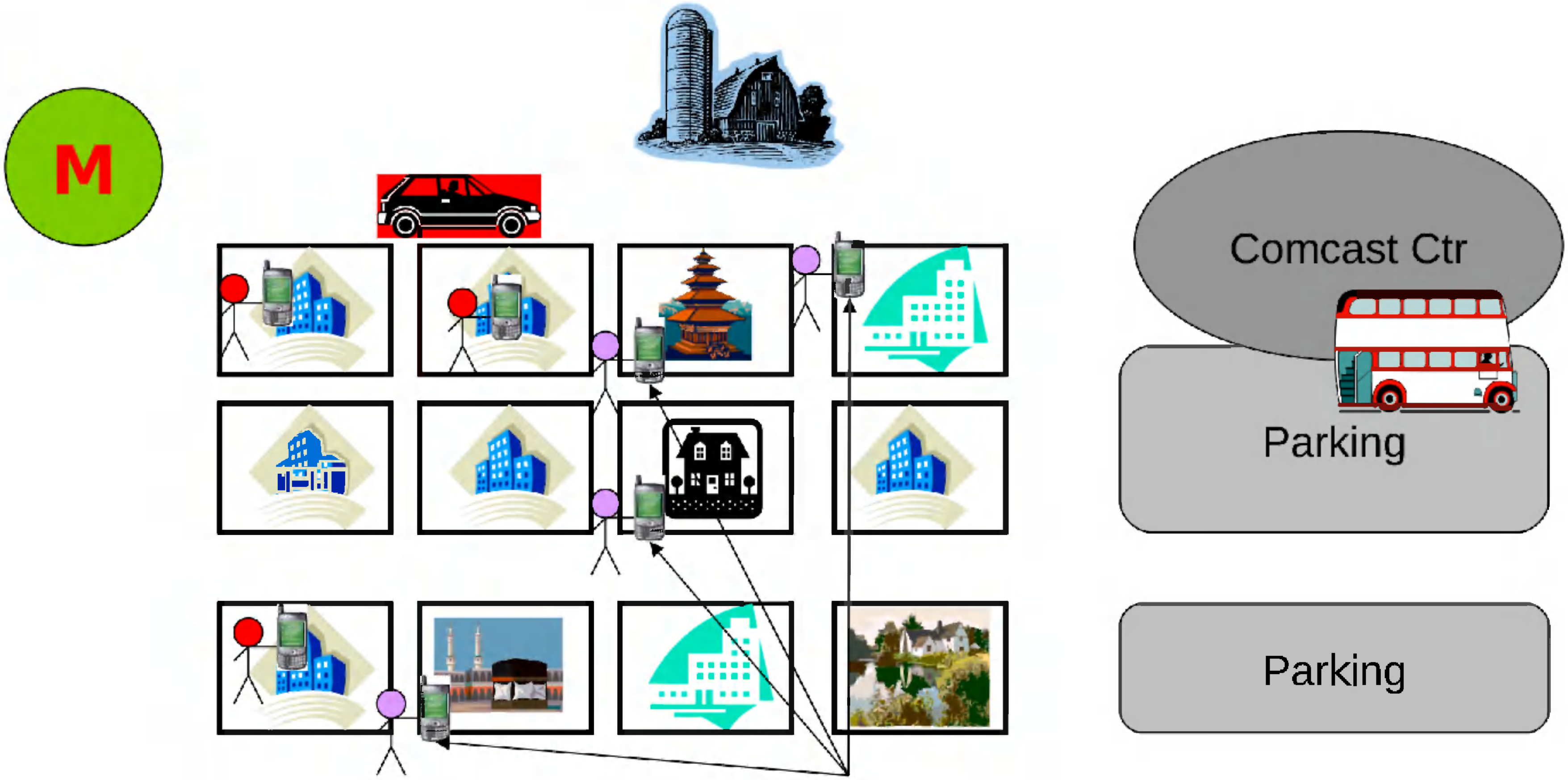
Data sources at “secret” locations on campus. Queue up or generate data.



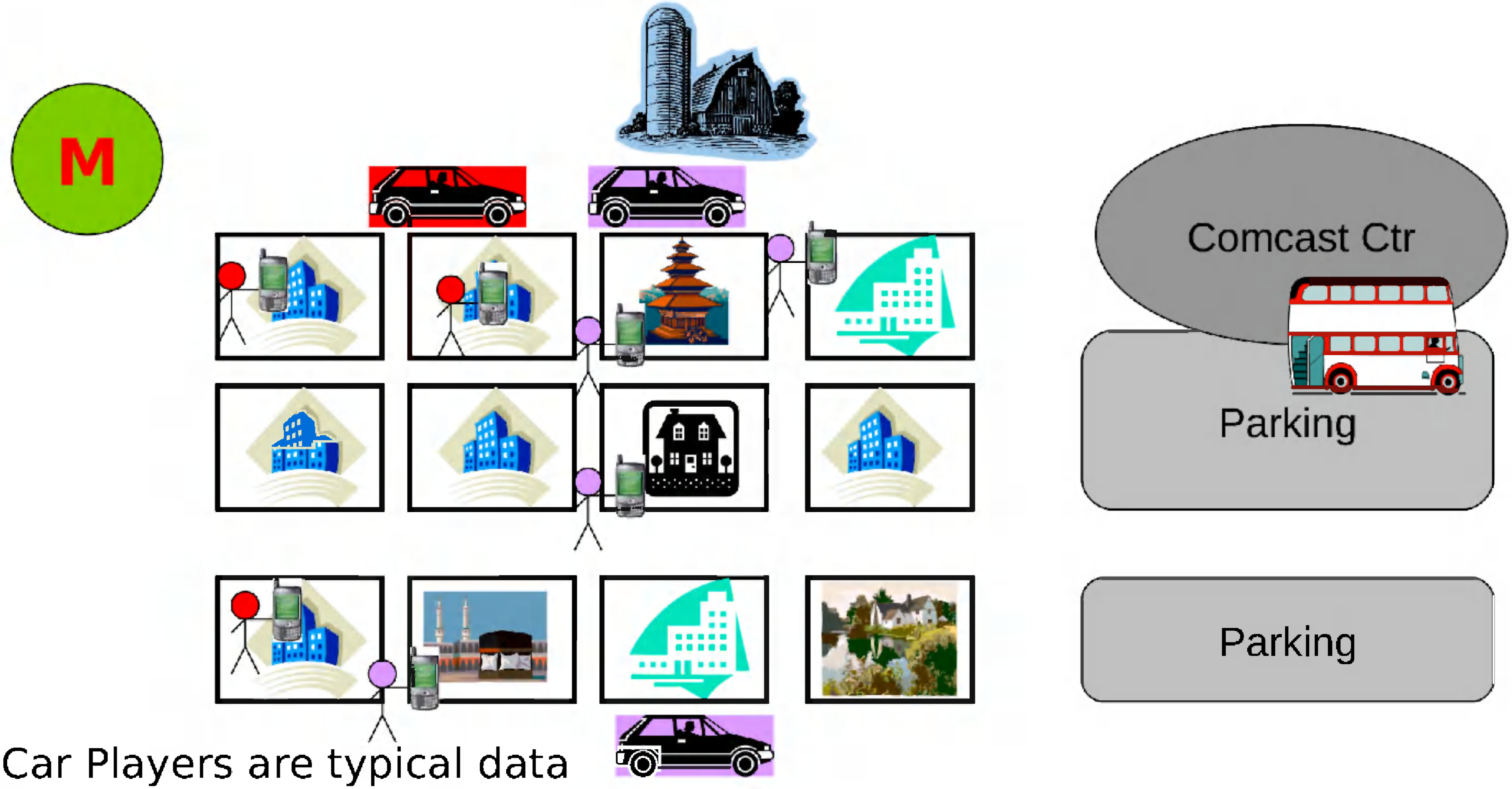
Mobile data generator in a car sending segments of audio



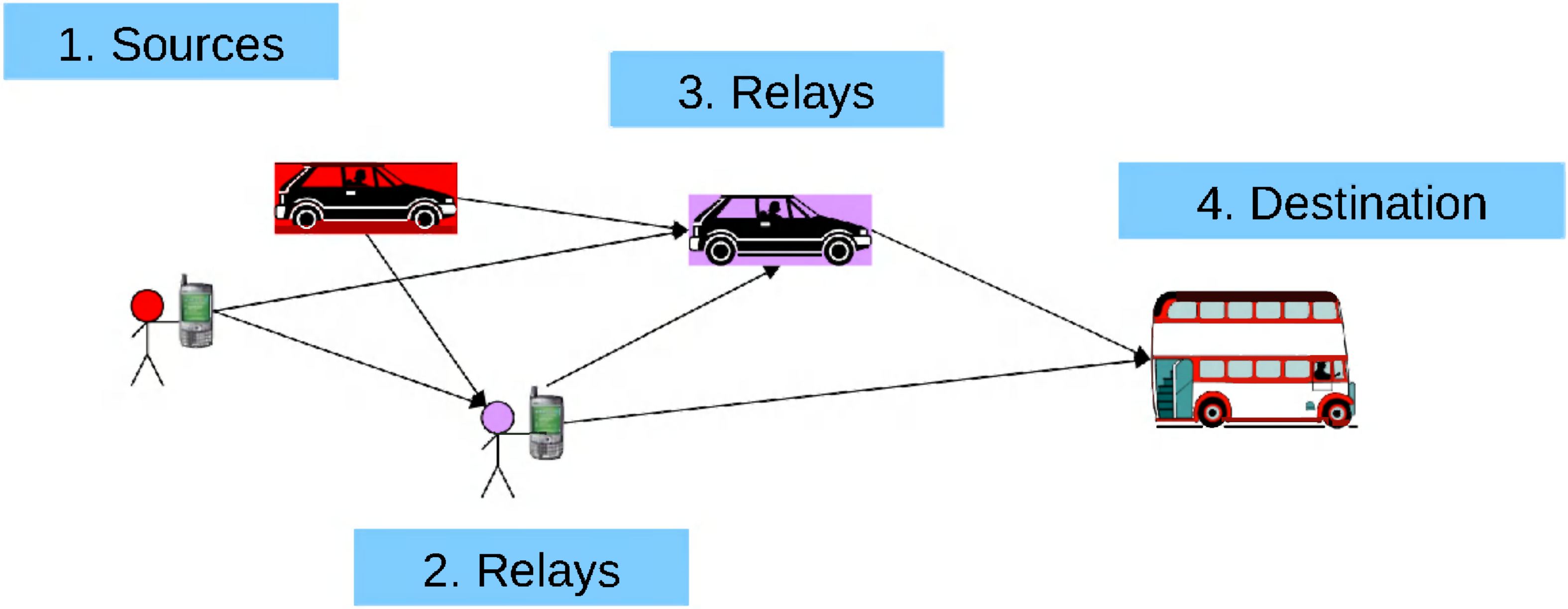
Destination node in parking lot by the Comcast Center



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?