Low-cost Communication for Rural Internet Kiosks Using Mechanical Backhaul

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Outline

- **The big picture: Goals, principles, and techniques**
- Architecture
  - Naming and addressing
  - Routing and locationing
  - Application support
- Pilot deployment
- Conclusions

Bridging the digital divide…

- Rural areas in developing countries can greatly benefit from timely access to information services

- Farmers

  - Crop inputs and treatments

  - Market prices

- Health workers

  - Diagnosis, treatment

- Citizens

  - Government services

  - Grassroots media

Reducing cost of access

- Share the cost of *technology*

- Share the cost of *knowing* how to use the technology

- *Information kiosks*

- Government of India wants to help set up 100,000 kiosks all over India by March 2008

Kiosk connectivity

- Dial-up: Low penetration, slow (56 kbps), and flaky

- Cellular broadband: Low penetration because of high Cap-Ex

- Very Small Aperture Terminals: Expensive

- Long range WiFi / WiMax

  - Extensive planning required

  - Expensive up-front cost (for 18m tower)

- Short range WiFi meshes

  - Equipment security issues

  - Not incrementally deployable

Mechanical backhaul*
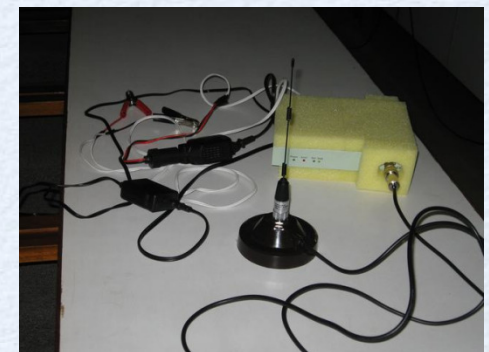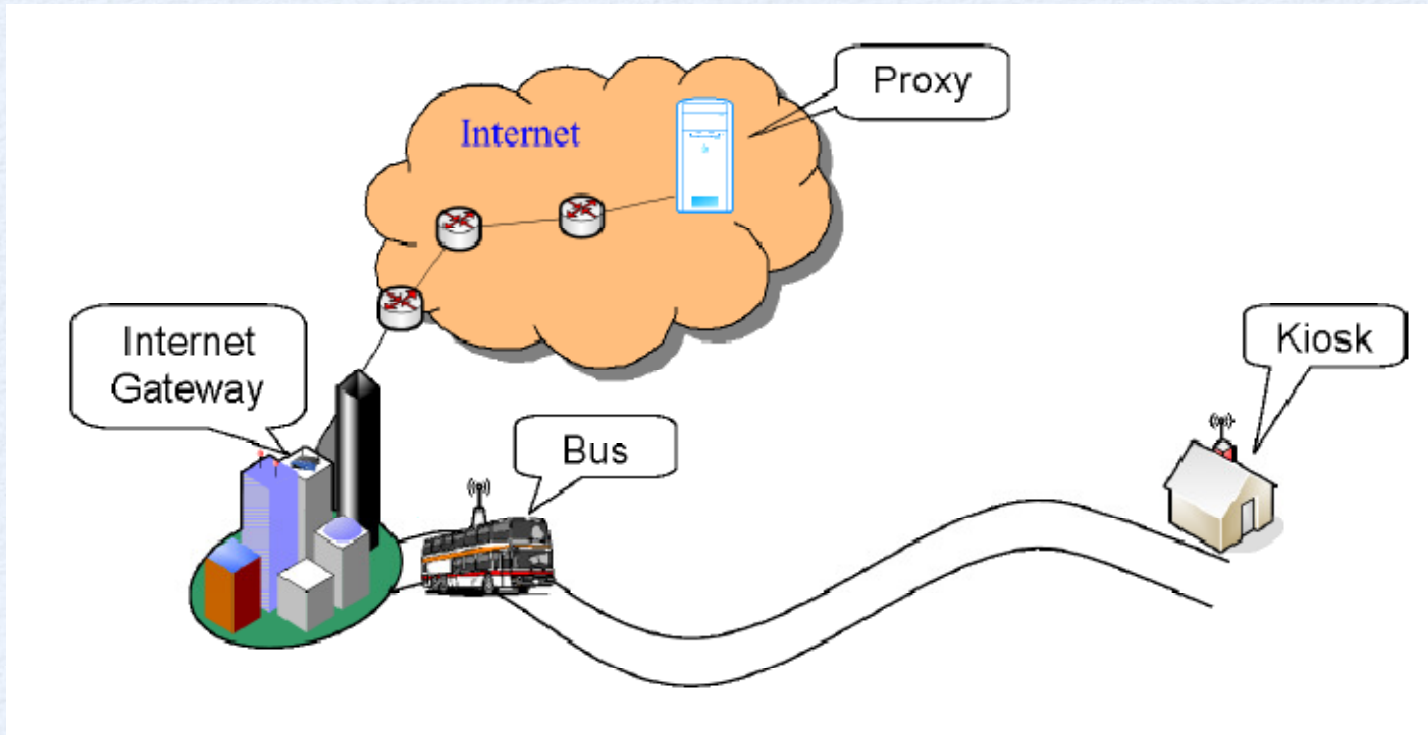
A vehicle carries an 802.11g (54 Mbps) enabled single board computer (SBC) with 40 GB hard-disk

Advantages

- Low cost of connectivity per kiosk (< $250 Cap.ex)
    - Cost of mobile SBC gets shared across kiosks
    - $1/person/year – no trench, no tower!
- Increased penetration
    - Even in interior areas where there are no telephone lines
- High bandwidth data transfer in both directions
- Rapidly and incrementally deployable
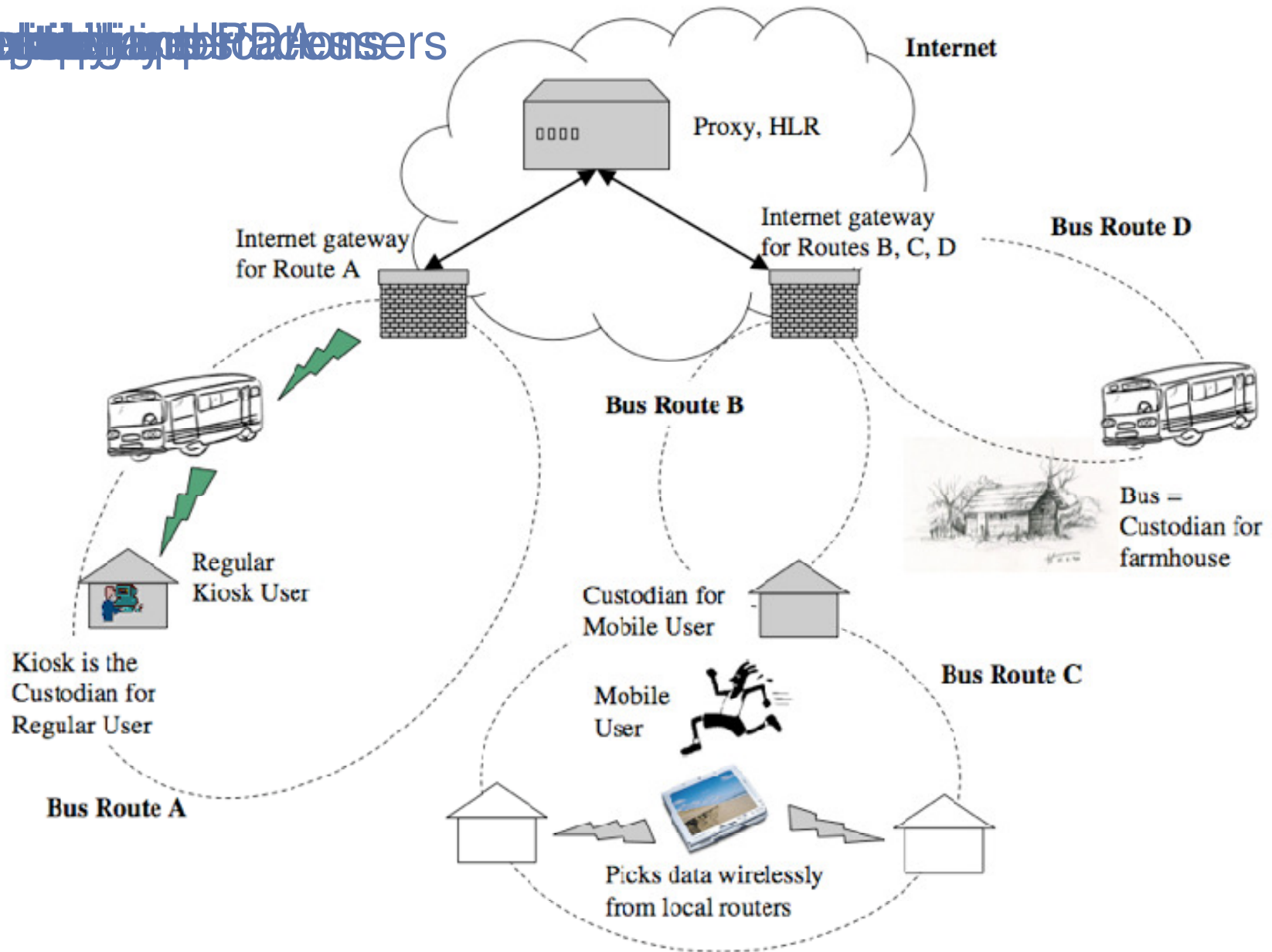
Disadvantages

- Data transfer is delayed

  - Depends on frequency of visits of vehicles

  - Can be up to 2 – 3 days

- But many useful applications are delay tolerant

- Suitable for smaller non-governmental organizations to set up kiosks
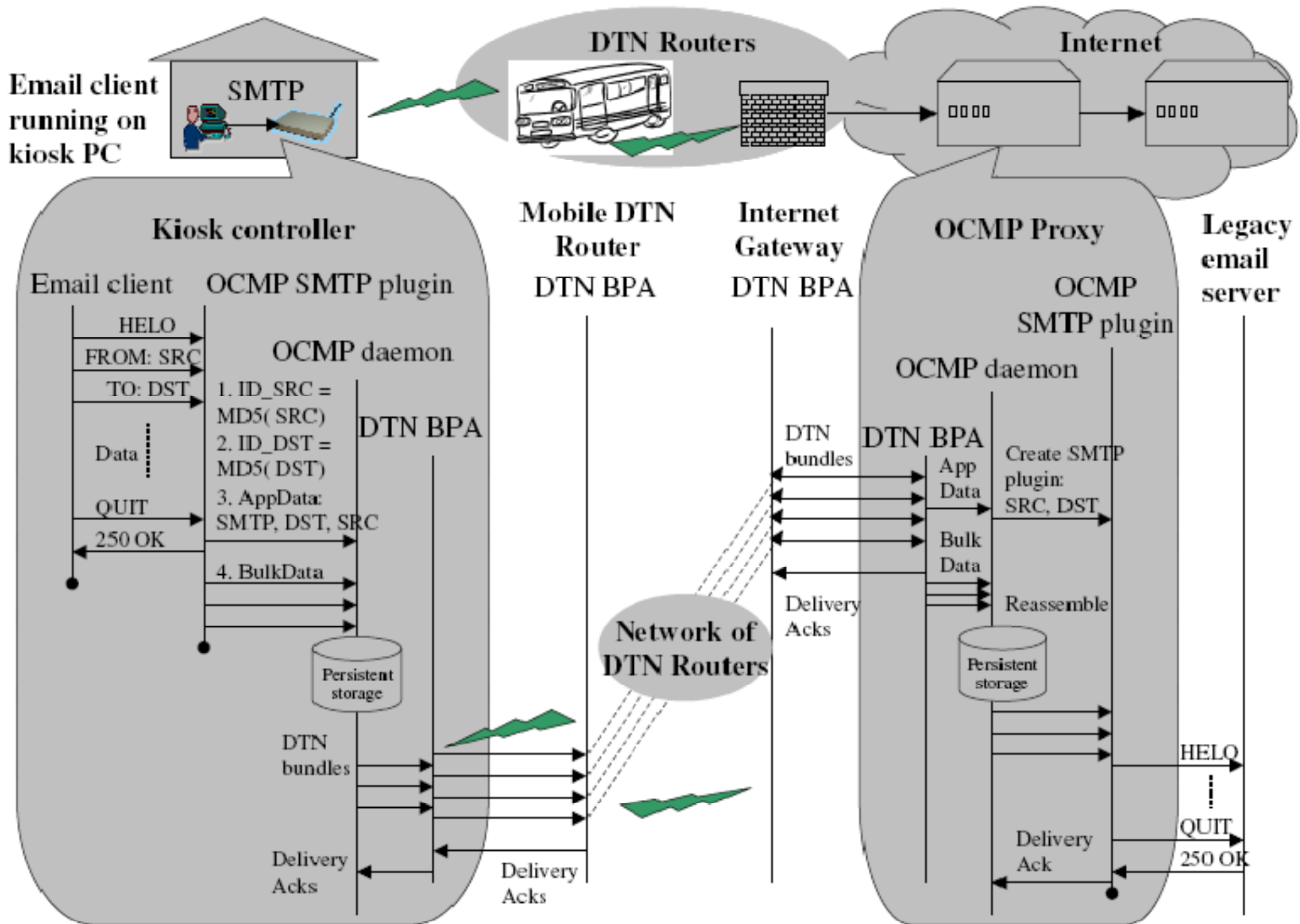
Simple backhaul
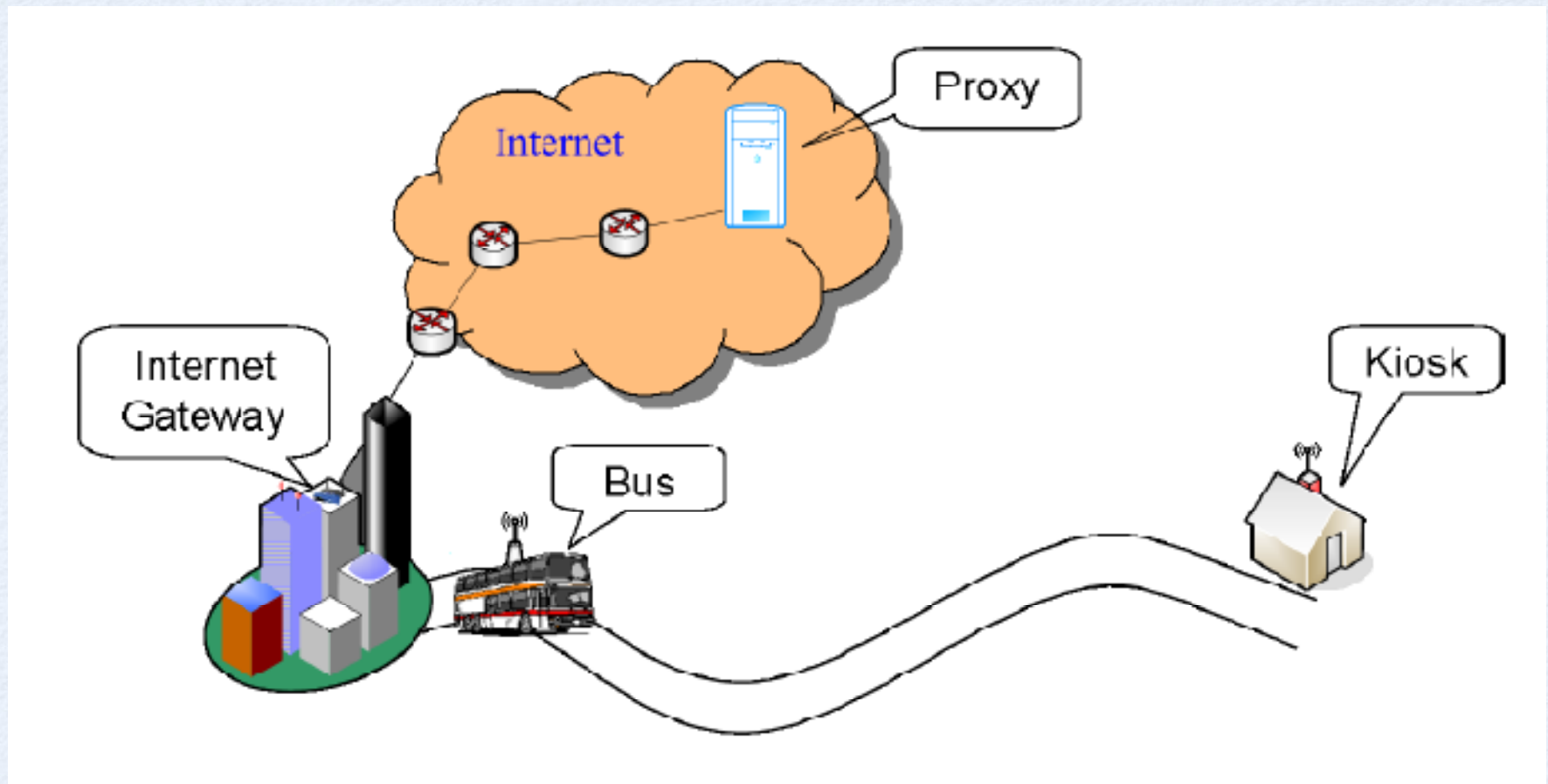
Generalized backhaul

- Multiple types of users

Related work

- Both ends of the connection are not simultaneously present

    - Cannot use standard TCP/IP, DNS, SSL

- Multiple hops of disconnection

    - Cannot use MIP, HIP, I3, PCMP, etc

- Need routing control, naming and addressing

    - DTN better than e-mail

    - Store and forward self-describing data (bundles)

Email client running on kiosk PC

SMTP

DTN Routers

Internet

Kiosk controller

Mobile DTN Router
DTN BPA

Internet Gateway
DTN BPA

OCMP Proxy

Legacy email server

Email client

OCMP SMTP plugin

HELO
FROM: SRC
TO: DST

OCMP daemon

1. ID_SRC = MD5(SRC)

Data

DTN BPA

2. ID_DST = MD5(DST)

QUIT
250 OK

3. AppData: SMTP, DST, SRC

4. BulkData

Persistent storage

DTN bundles

Delivery Acks

Network of DTN Routers

Delivery Acks

DTN bundles

DTN BPA

DTN bundles

Delivery Acks

App Data

Bulk Data

OCMP SMTP plugin

Create SMTP plugin: SRC, DST

OCMP daemon

Reassemble

Persistent storage

Delivery Ack

HELO

QUIT
250 OK

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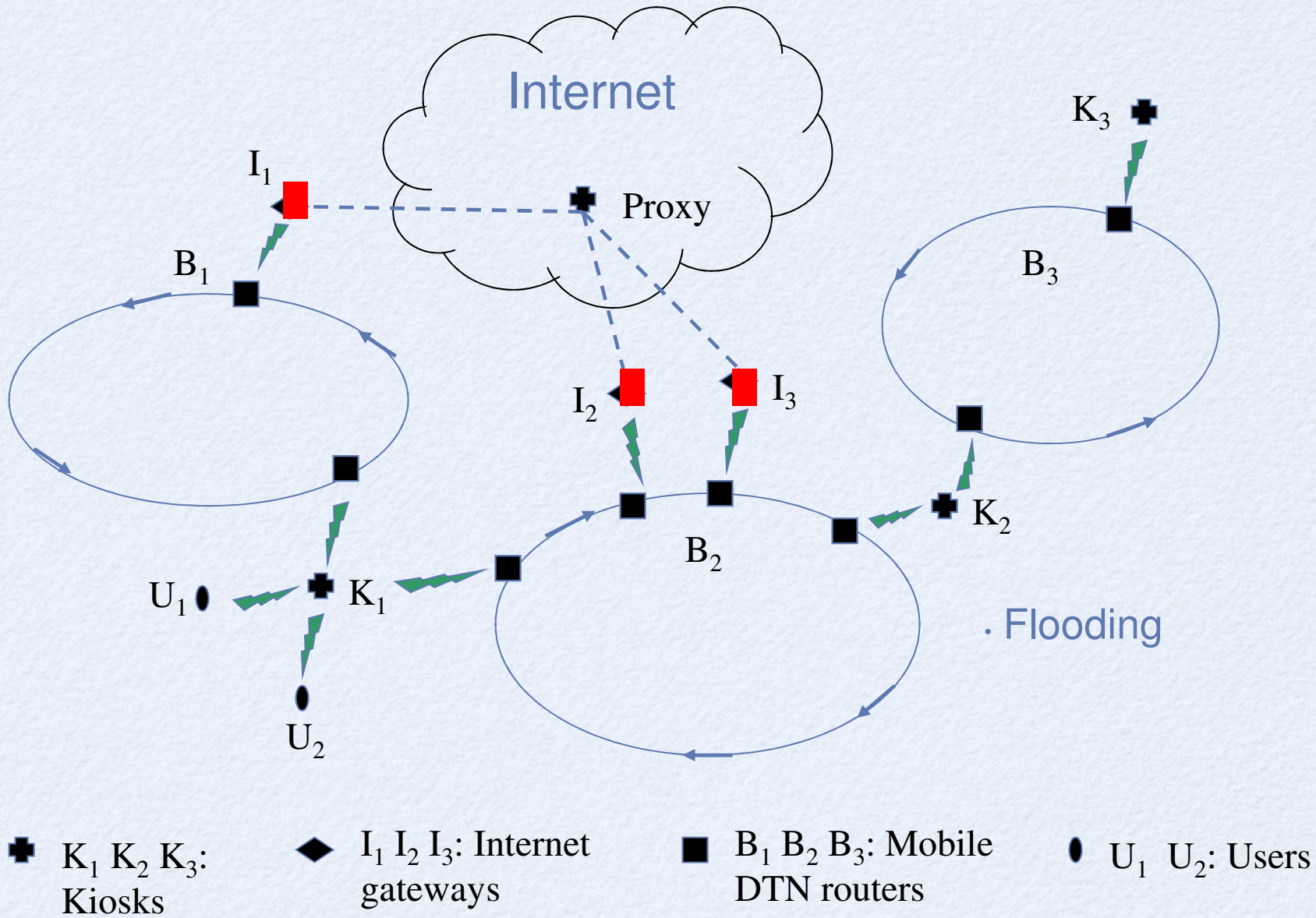- Pilot deployment
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Naming and addressing

- Flat namespace for identifying users and nodes
  - MD5 hash of human-readable GUID
  - Also used as HIBC public-key for security
- Name based forwarding
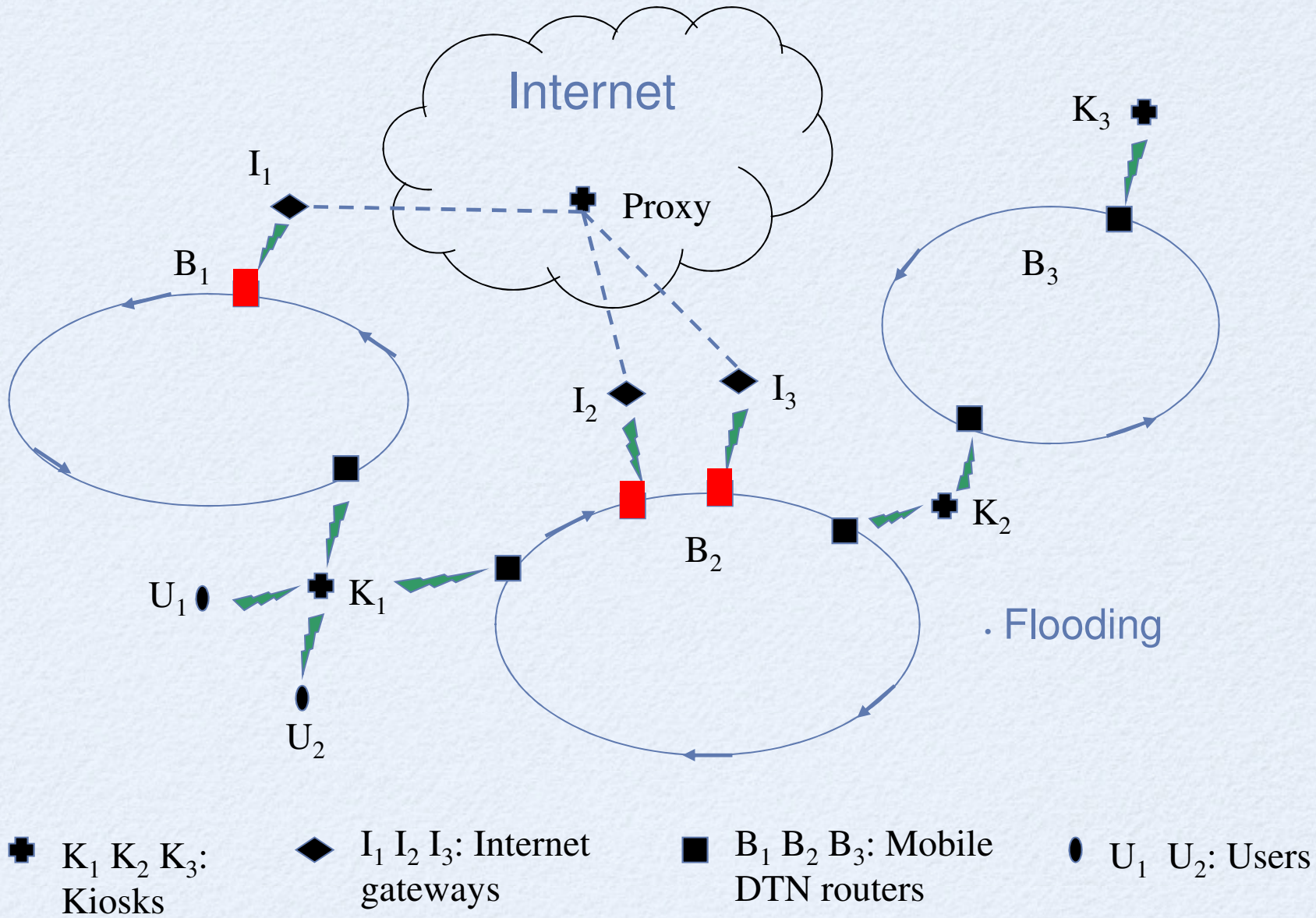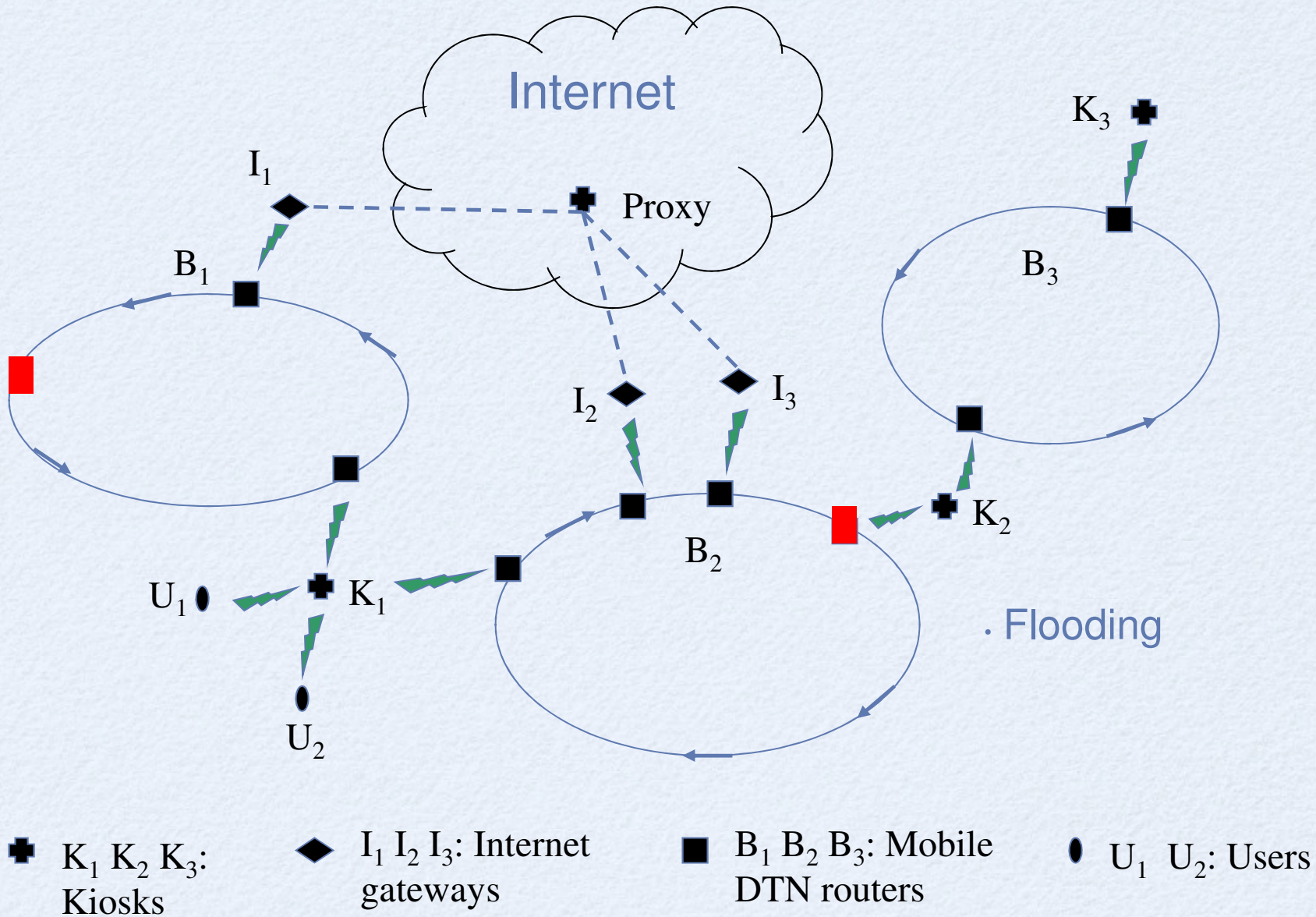 - Most general approach to build different routing schemes
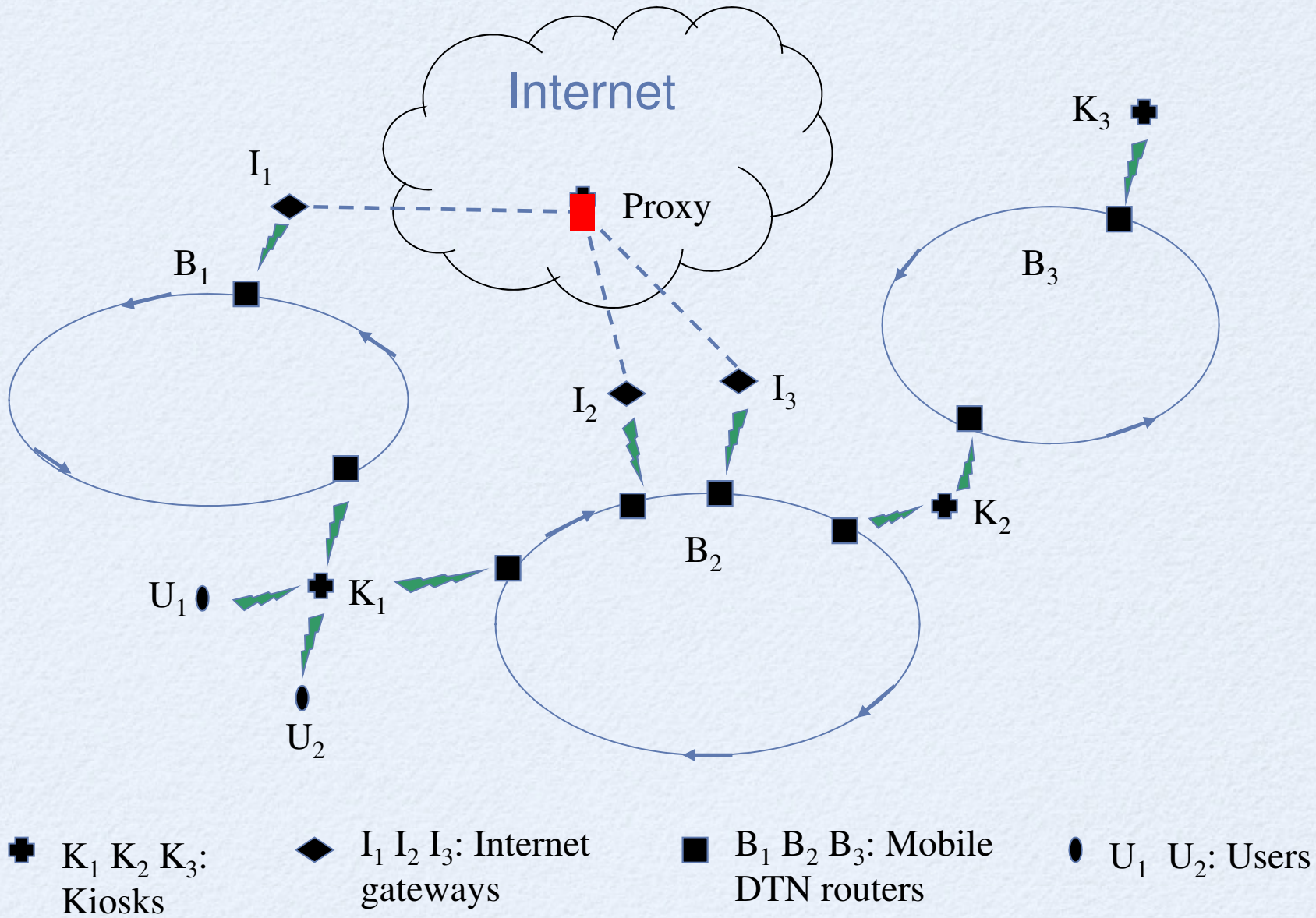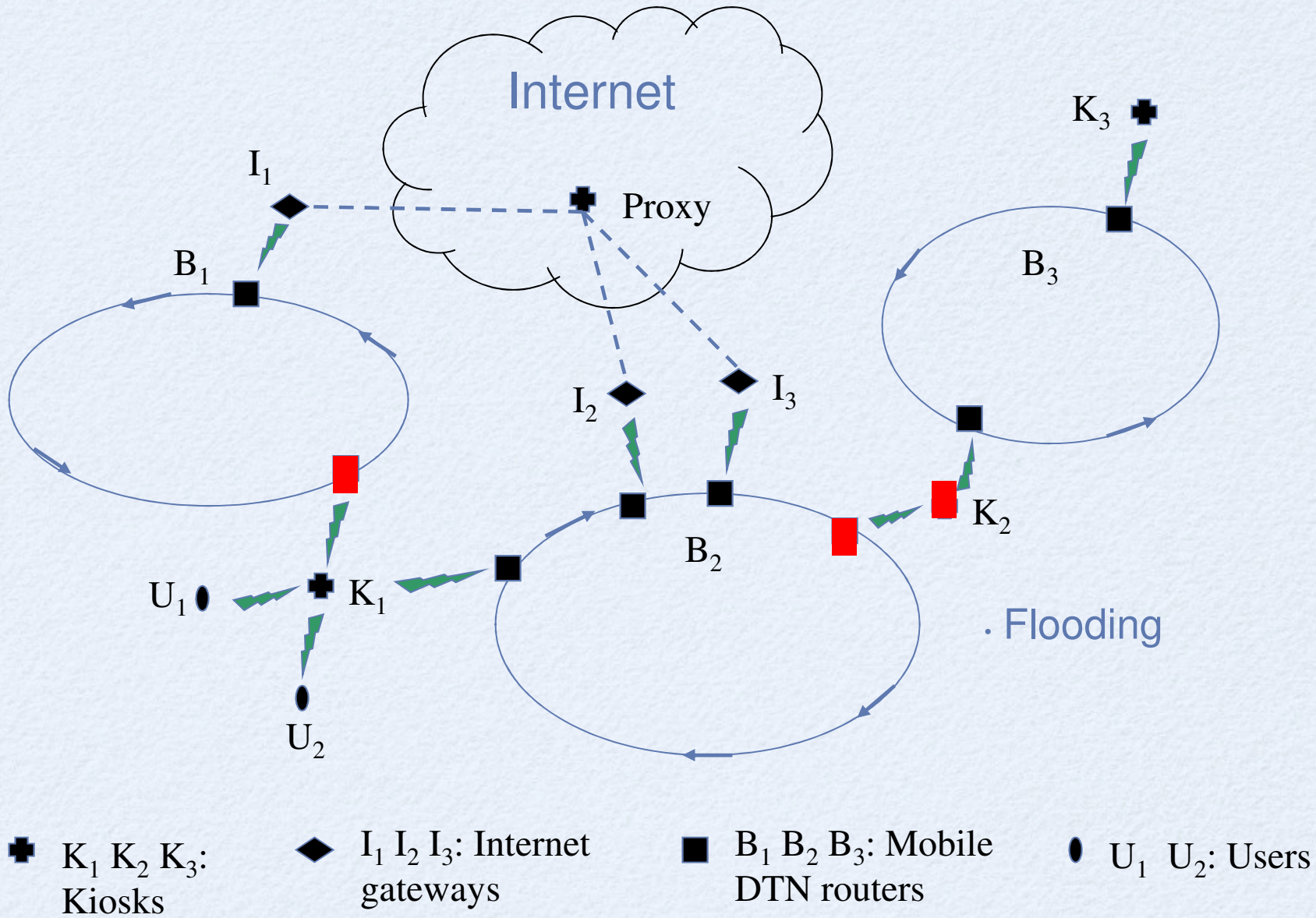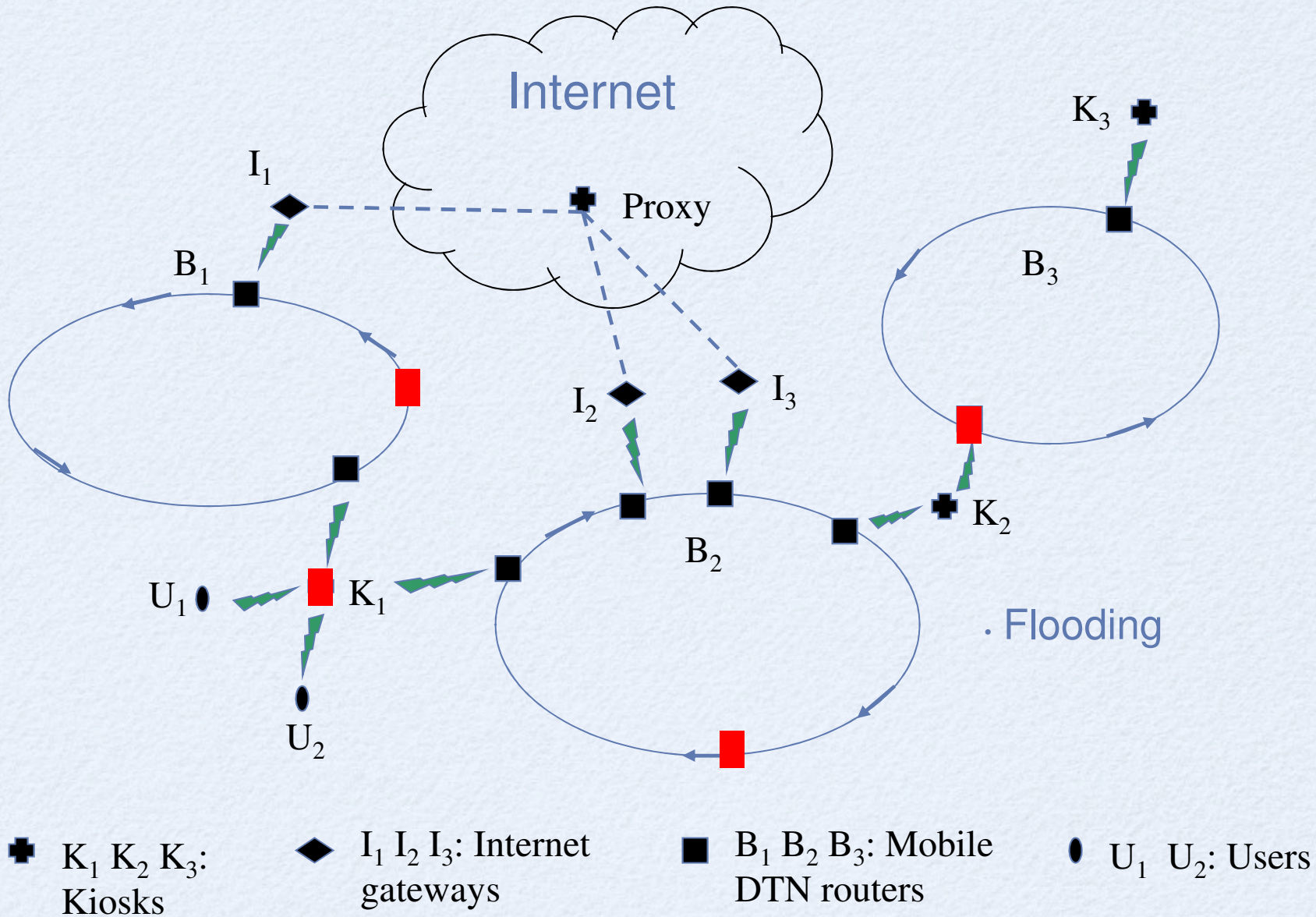
Routing

Routing

Routing

Internet

Proxy

I_1

B_1

I_2 I_3

B_2

K_3

B_3

K_2

U_1 K_1

U_2

· Flooding

K_1 K_2 K_3: Kiosks

I_1 I_2 I_3: Internet gateways

B_1 B_2 B_3: Mobile DTN routers

U_1 U_2: Users

Routing

Routing

Internet

I₁

Proxy

B₁

K₃

B₃

I₂   I₃

B₂

U₁   K₁

U₂

K₂

. Flooding

K₁ K₂ K₃: Kiosks   I₁ I₂ I₃: Internet gateways   B₁ B₂ B₃: Mobile DTN routers   U₁ U₂: Users

Routing

Routing

Internet

Proxy

K_3

I_1

B_1

B_3

I_2

I_3

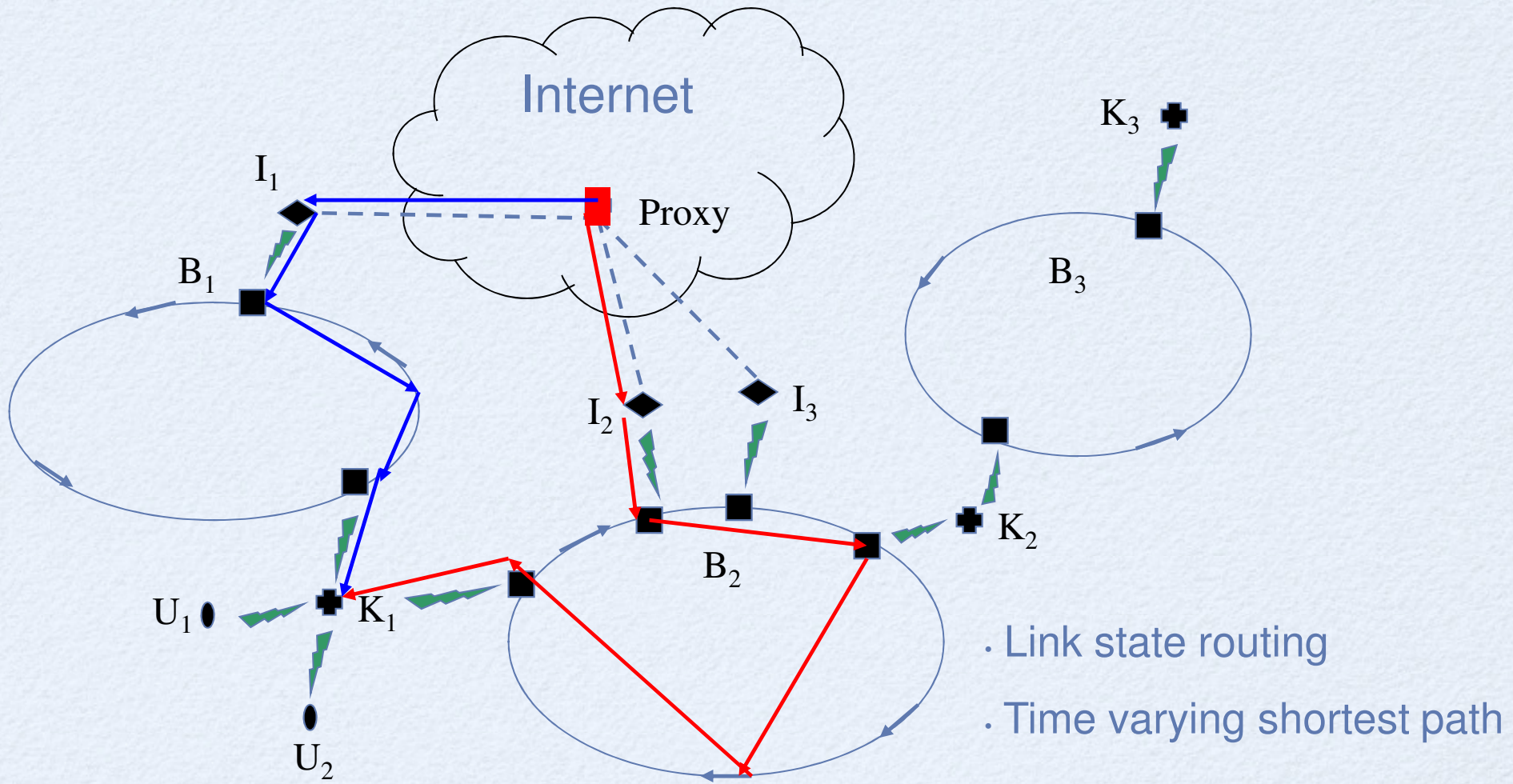B_2

K_2

U_1

K_1
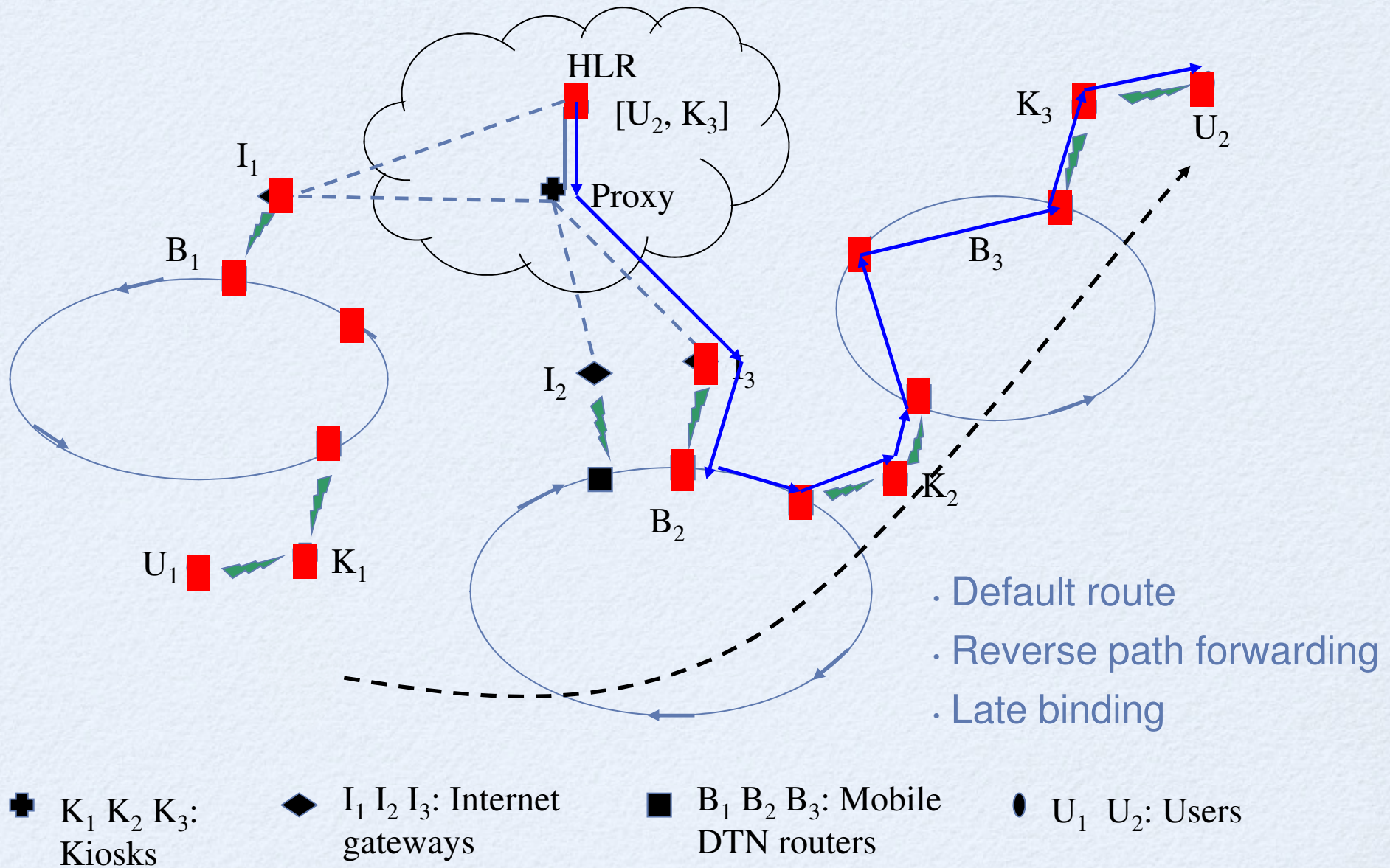
U_2

- Link state routing
- Time varying shortest path

$K_1 K_2 K_3$: Kiosks

$I_1 I_2 I_3$: Internet gateways

$B_1 B_2 B_3$: Mobile DTN routers

$U_1 \ U_2$: Users
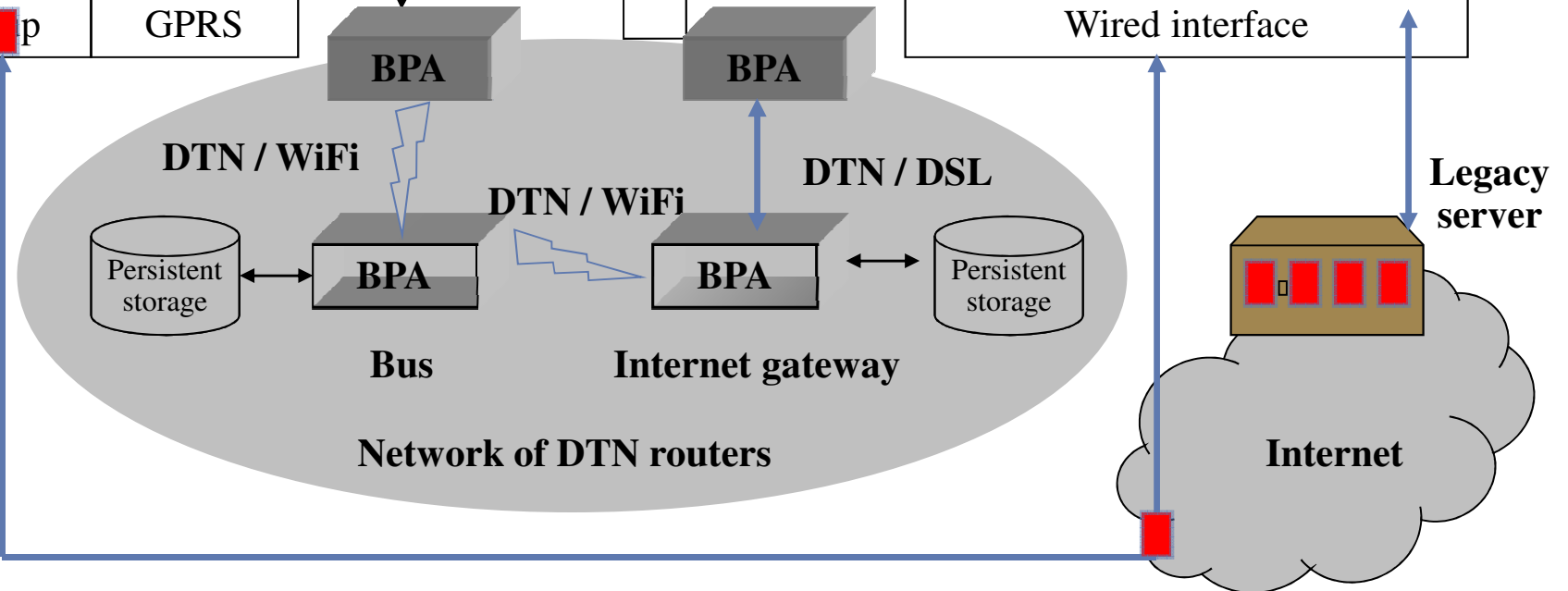
Routing and locationing
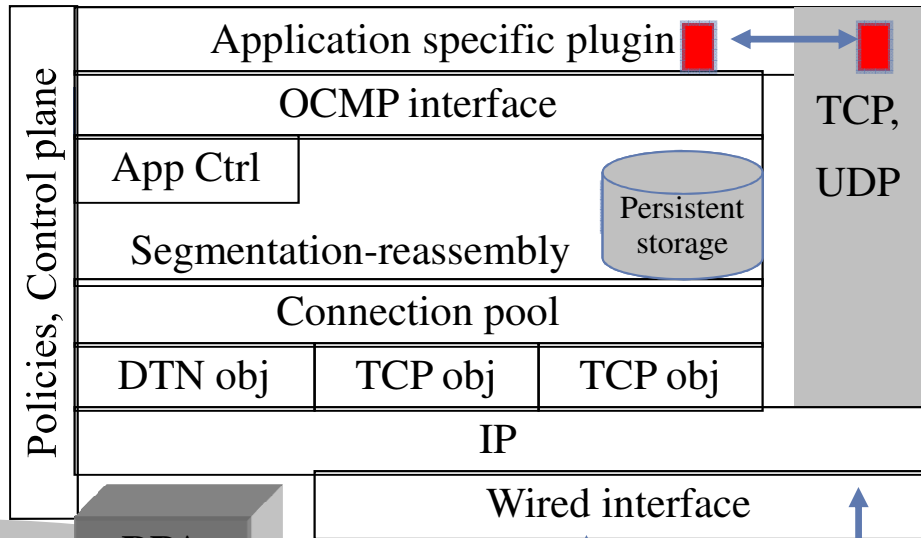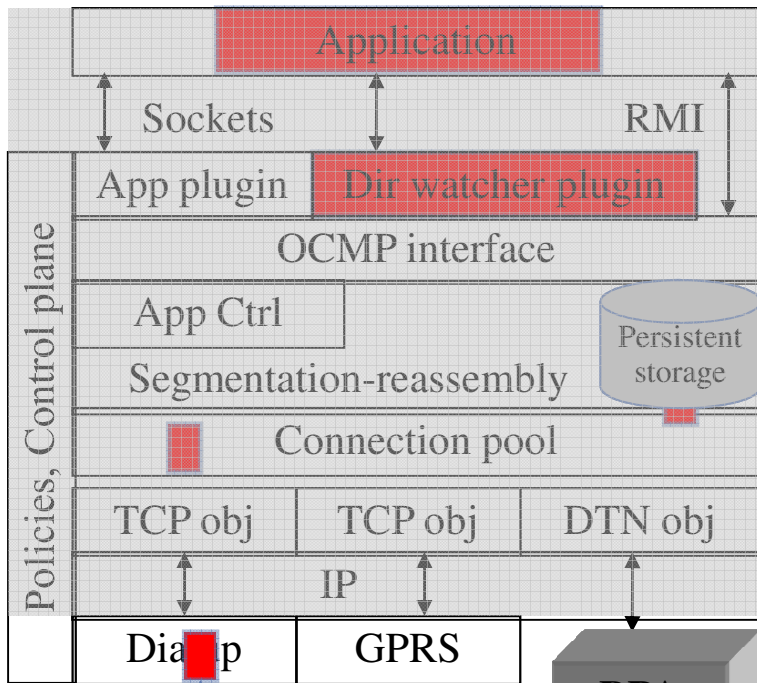
Application support

- Goals

    - Simple API – shield app. from aspects of disconnection

    - Session persistence

    - Intelligent use of multiple networks

    - Interaction with legacy servers

- Solution

    - OCMP (Opportunistic Connection Management Protocol)

    - J2ME based application layer on DTN or TCP

    - Policy framework for per-bundle selection of interface

    - Session migration

Kiosk controller

Proxy

Application

Sockets   RMI

App plugin   Dir watcher plugin

OCMP interface

App Ctrl

Segmentation-reassembly

Persistent storage

Connection pool

TCP obj	TCP obj	DTN obj

IP

Dialup	GPRS

Policies, Control plane

Application specific plugin

OCMP interface

App Ctrl

Segmentation-reassembly

Persistent storage

Connection pool

DTN obj	TCP obj	TCP obj

IP

Wired interface

Policies, Control plane

TCP, UDP

BPA

BPA

DTN / WiFi

DTN / WiFi

DTN / DSL

Persistent storage

BPA

BPA

Persistent storage

Bus

Internet gateway

Network of DTN routers

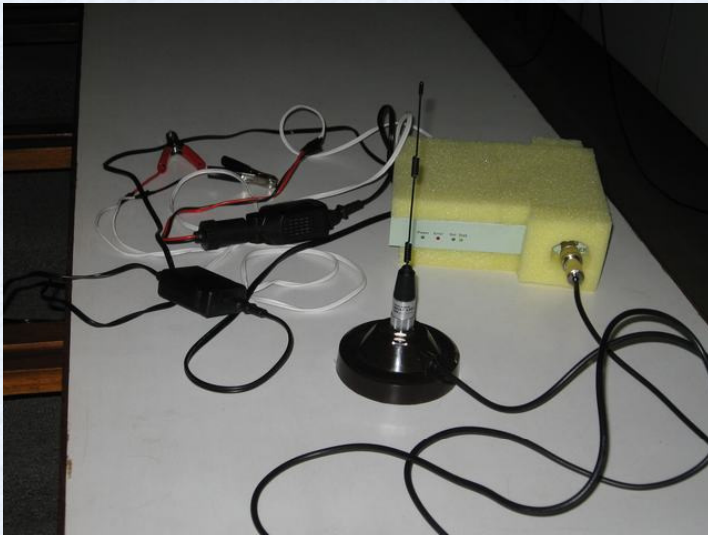**Legacy server**

Internet

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- **Pilot deployment**
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Kiosk setup (Anandpuram, AP, India)

Vehicle and gateway setup

Conclusions

- Mechanical backhaul is an attractive solution to provide connectivity to rural Internet kiosks

    - Under $1/person/year

- Generalized backhaul is a complex problem

- Innovative and practical solutions for naming, addressing, routing, security, and application development

- Planning a bigger deployment in Dec 2006
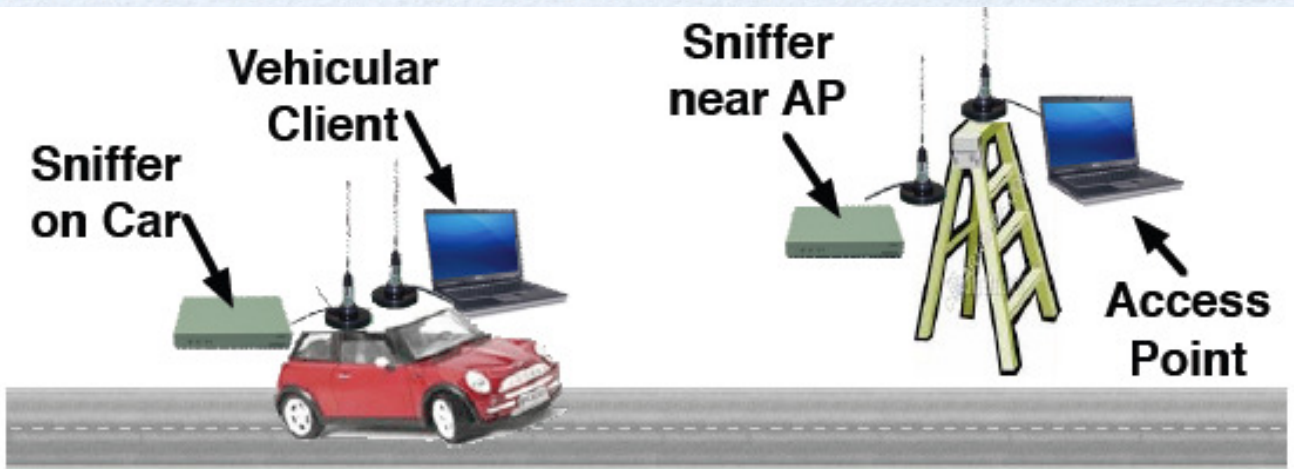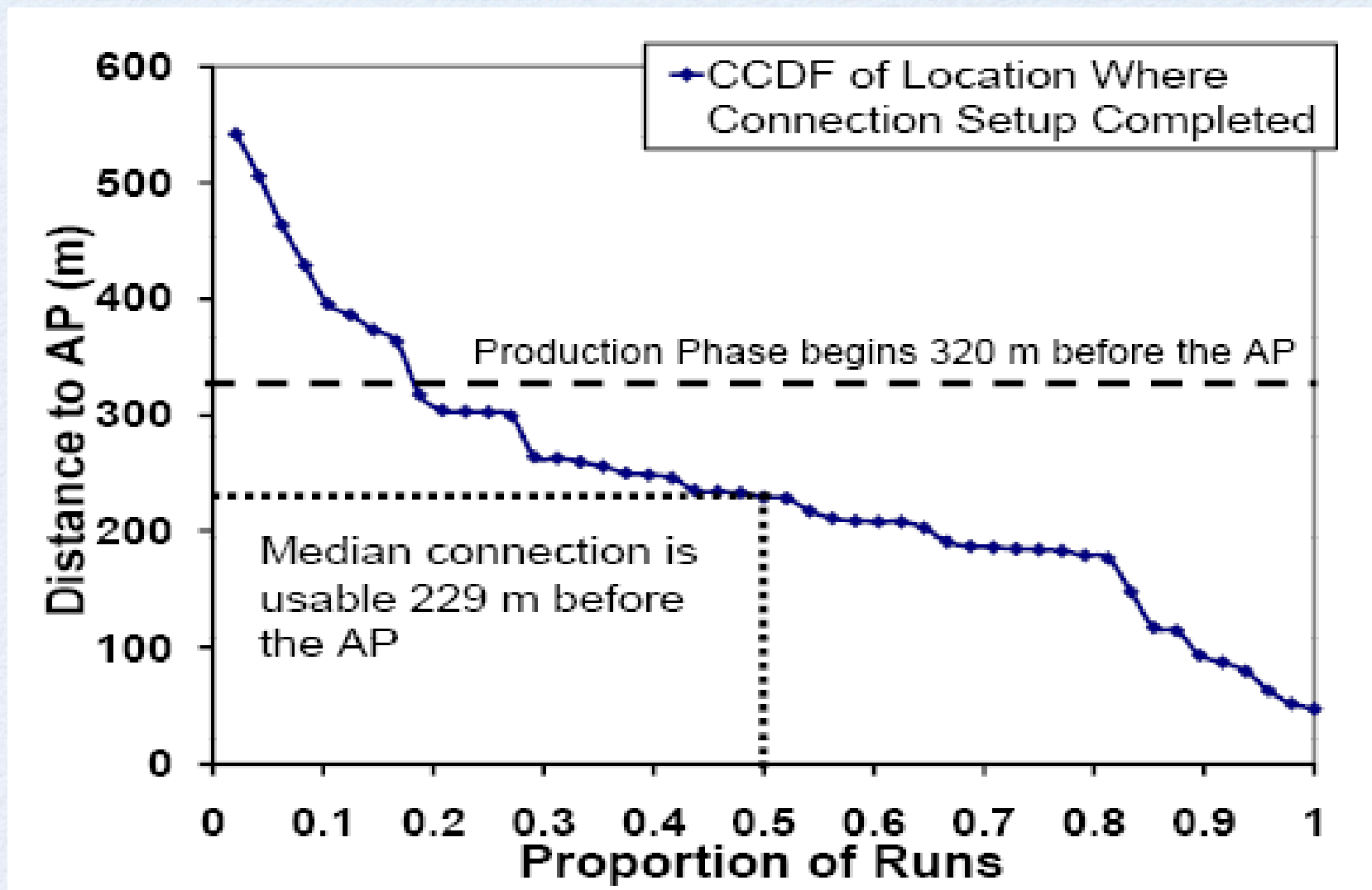
Anandpuram deployment
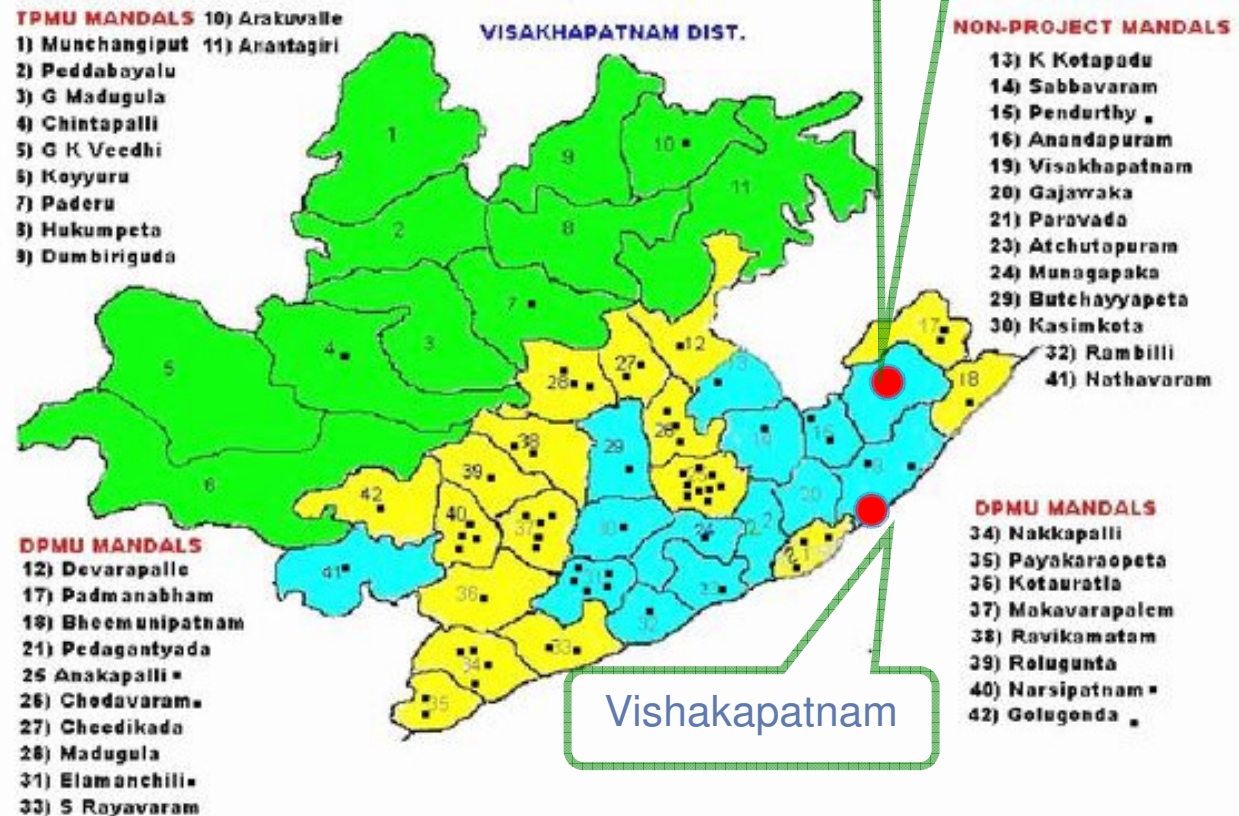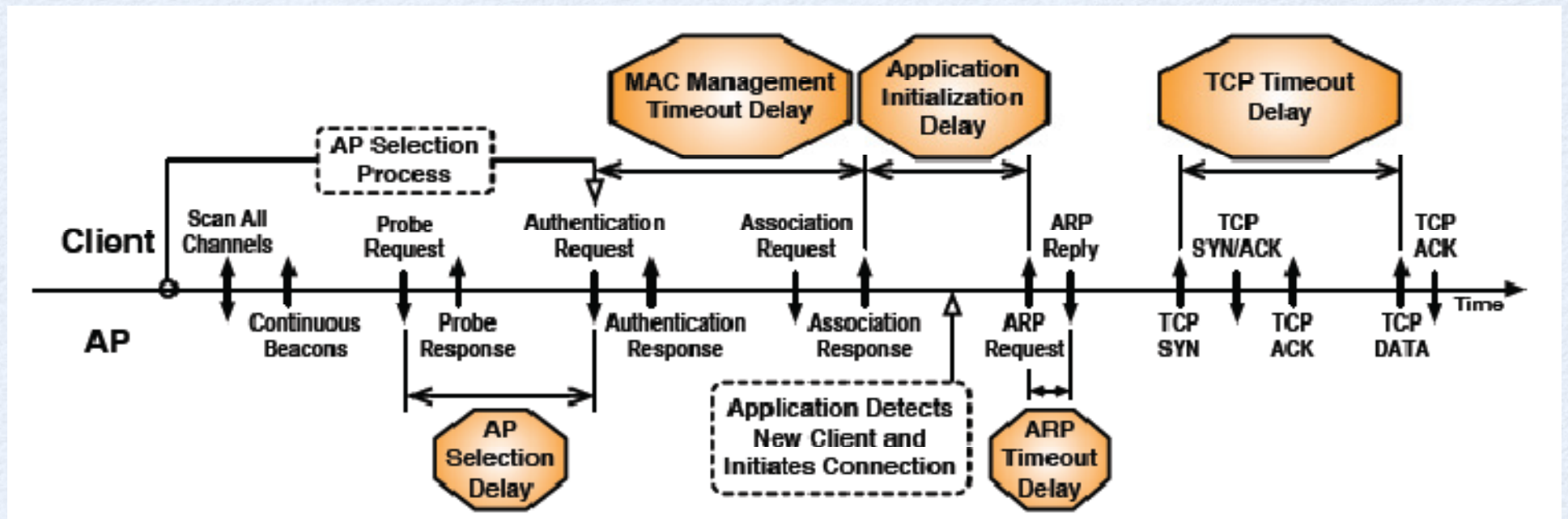
Opportunistic communication

Another experimental setup. Sniffers are different from traffic source/sink
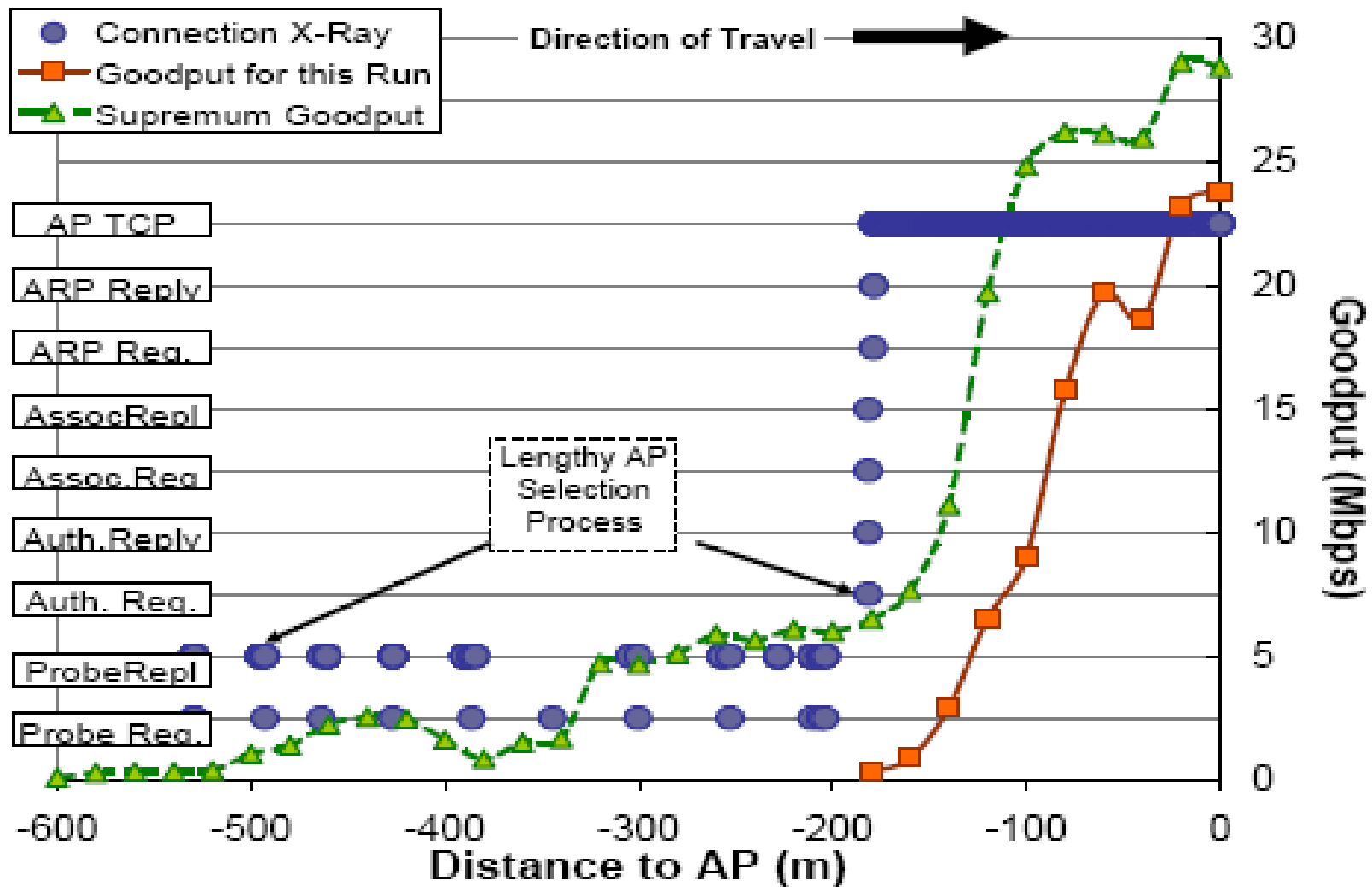
Room for optimization

Very few runs made full use of the production phase
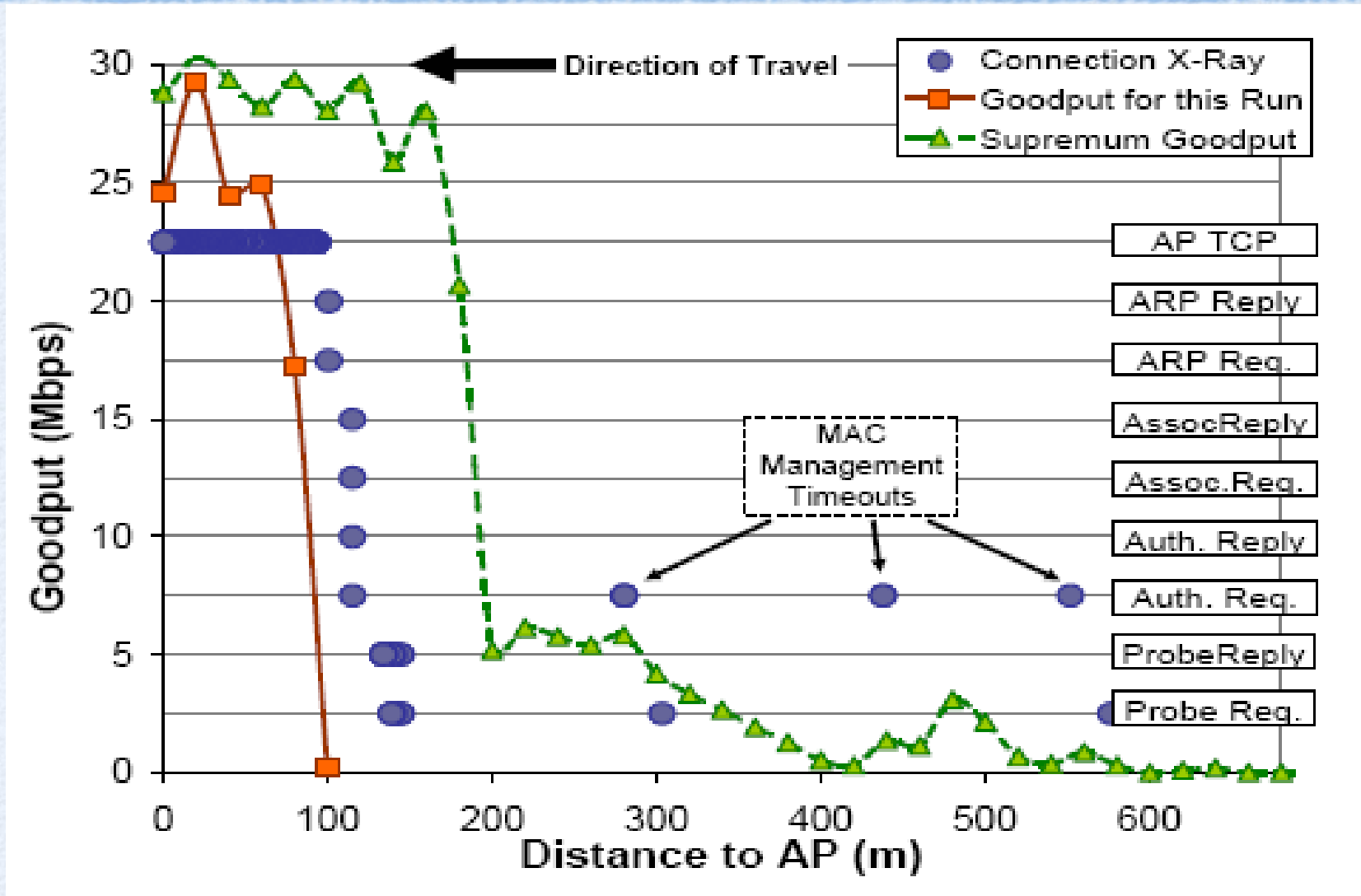
Very chatty association protocol

Delays in connection setup
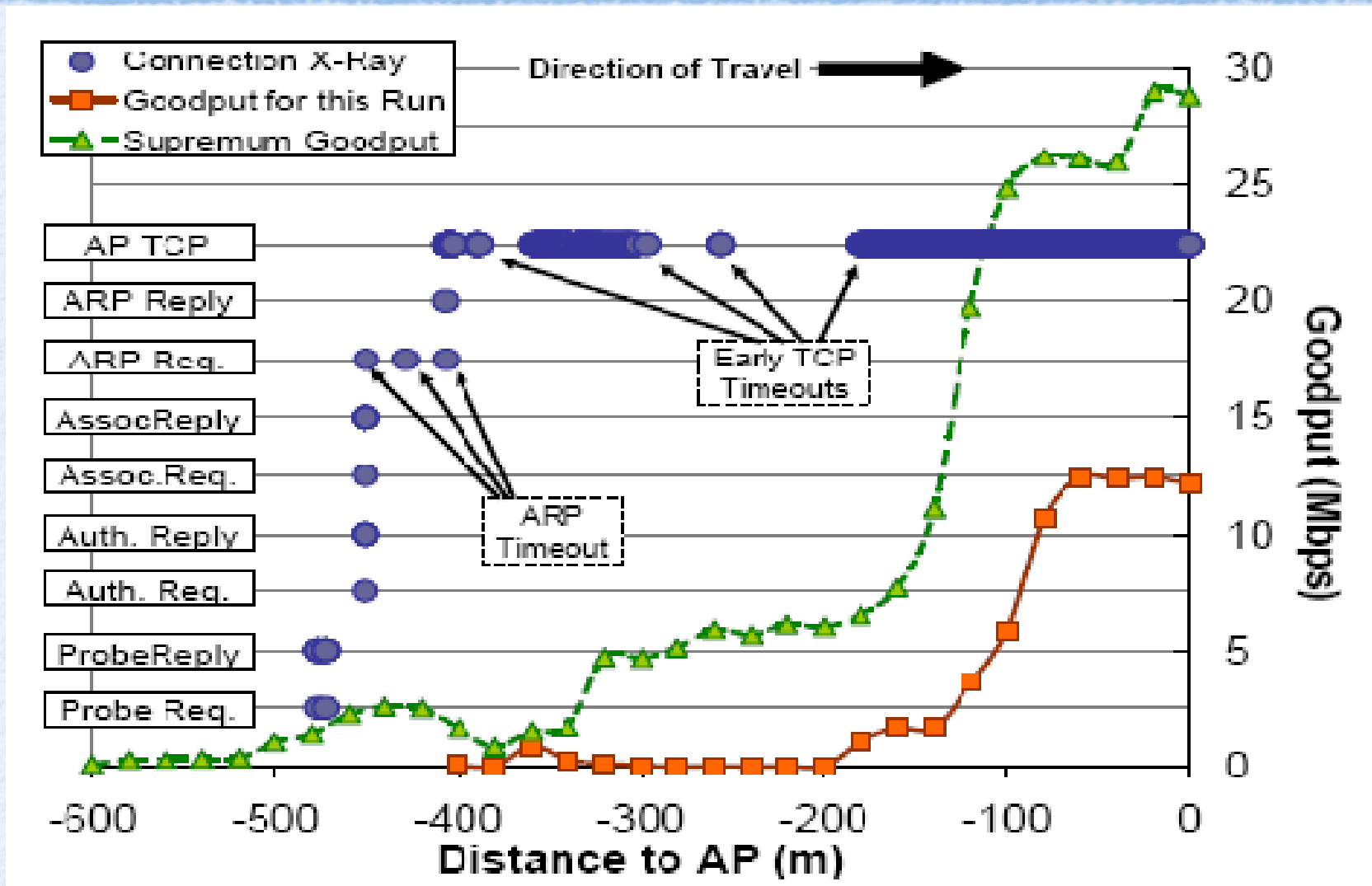
1. Probe request/reply

Entry: Probe replies are often lost at the fringes

2. Authentication

Entry: Authentication requests may not reach the AP

3. ARP request/reply

Entry: ARP requests may get lost

Recommendations

- Avoid fringe areas

    - But how to know that the device is a the fringe?

- More dynamic MAC bit rate selection

    - How to prevent hysteresis

- Transmit signal strength maps

Example

- aAqua project (IIT Bombay, Maharashtra, India)

- Bulletin board system for farmers to consult with experts

    - Market opportunities, fertilizers, pricing

- Most people avoid buying goat milk because it smells. Can you suggest some ways to prevent the smell?

- Please see the attached pic. of a diseased muskmelon fruit, that has developed brown spots.

- We have at our disposal 10-12 tons of aloe-vera plants/leaves for sale. Parties interested in purchasing please catch us at 9848263544

Security

- Problems with PKI

  - Need an extra round-trip to find the recipient public key

  - Key revocation in disconnected scenarios

- Solution

  - Use Identity Based Cryptography

  - GUID or email address can be the public key

  - Private key is generated one-time by a private key generator

  - Key generation for disconnected users

  - Mutual authentication

  - Key revocation

Open problems in location management

- Scalability

  - All location updates need to travel to the HLR

  - Have a distributed system of HLRs and VLRs?

  - How to partition into VLR regions? Cohesion within regions

- Choice of custodian(s)

  - Depends upon user mobility patterns

  - Recall and precision in terms of delay and replication

Issues with link-state routing

- Route update latencies can be large

- Propagation delay in the DTN network is not the only parameter to determine link weights

    - Proxy-gateway link is slow

    - Intelligent scheduling through multiple gateways? Fairness?

- Schedule accuracy

    - Break-downs

    - Vehicle delays
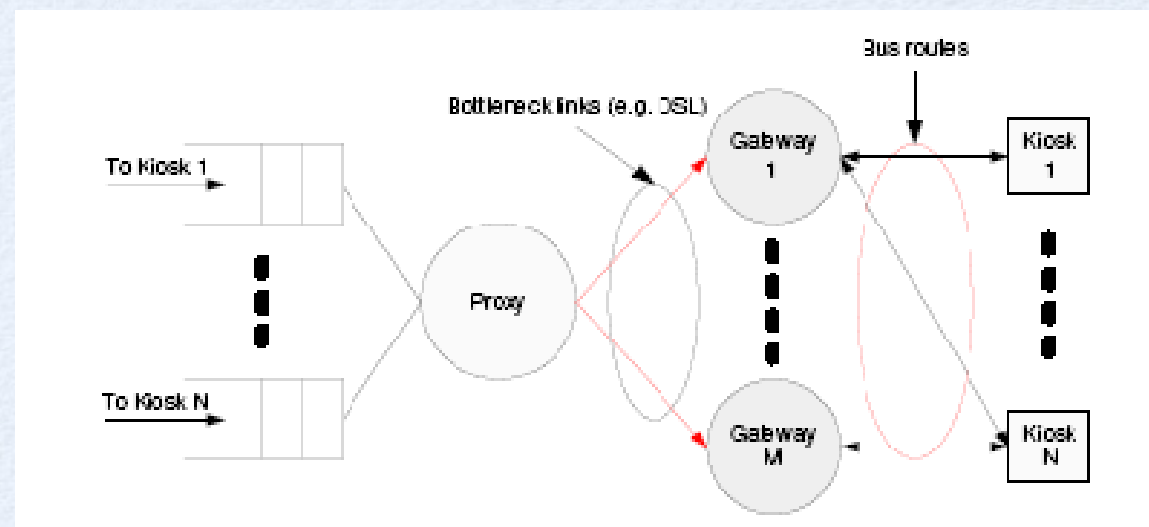
Problems in reliability

- How much to replicate?

- What retransmission timeout to use?

- In the absence of link-state routing, the only data available is observations of round-trip delay distributions

Implementation and status

- Implemented as extension to DTNRG implementation

- Java based application support available on PDAs

- Applications

    - Blogger and Flickr uploads

    - Email

    - Integration with aAqua

- Currently working on

    - Security integration

    - Some hardware quirks

    - Cellphone based control plane