Mobile-IP, Ad-Hoc Networking, and Nomadicity

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Overview

Mobile-IP

- Routing Internet packets to a mobile user

Introduction to ad-hoc networking

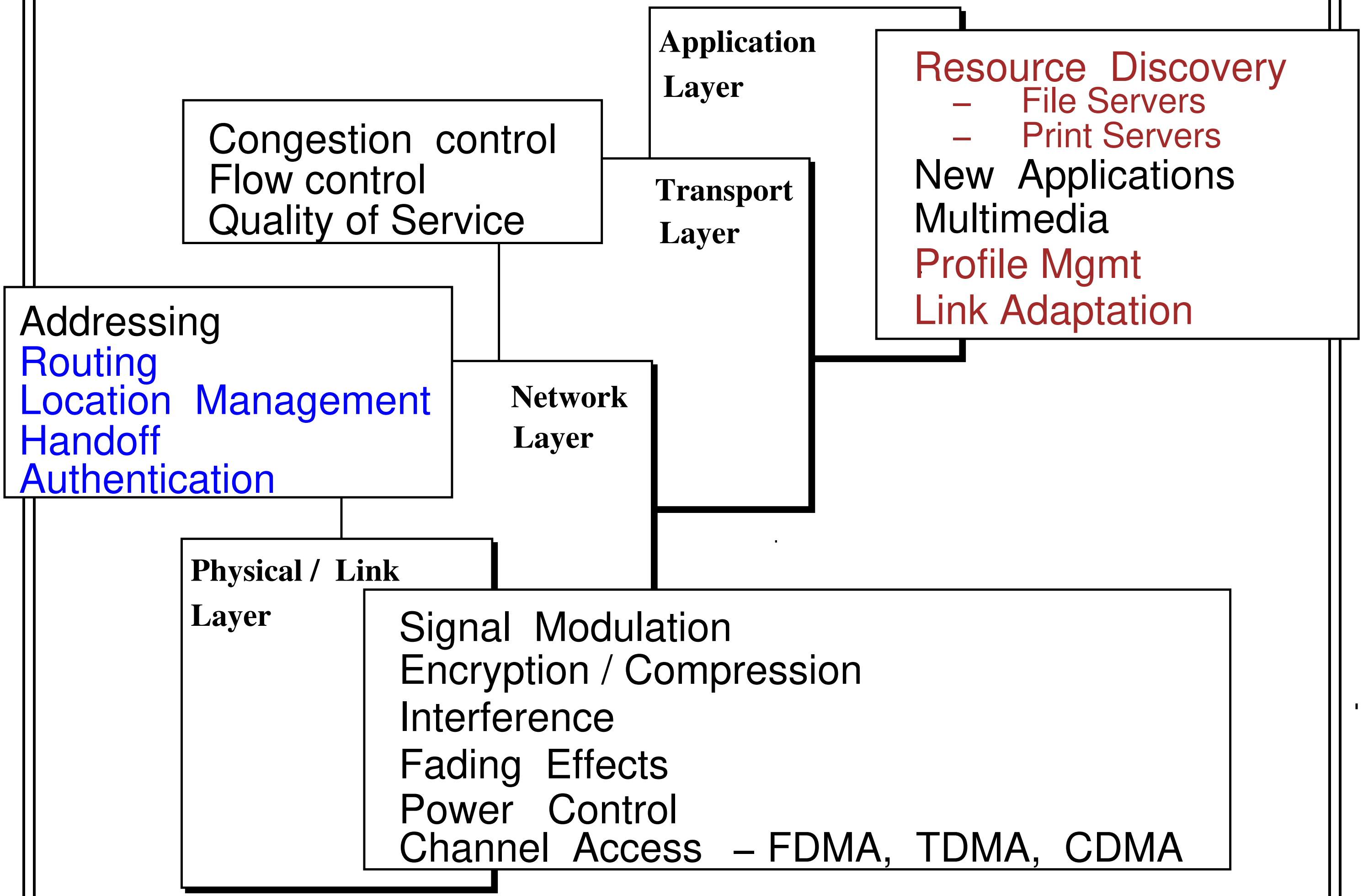
- Internet networking without the Internet

Service Location Protocol

- Finding services by name

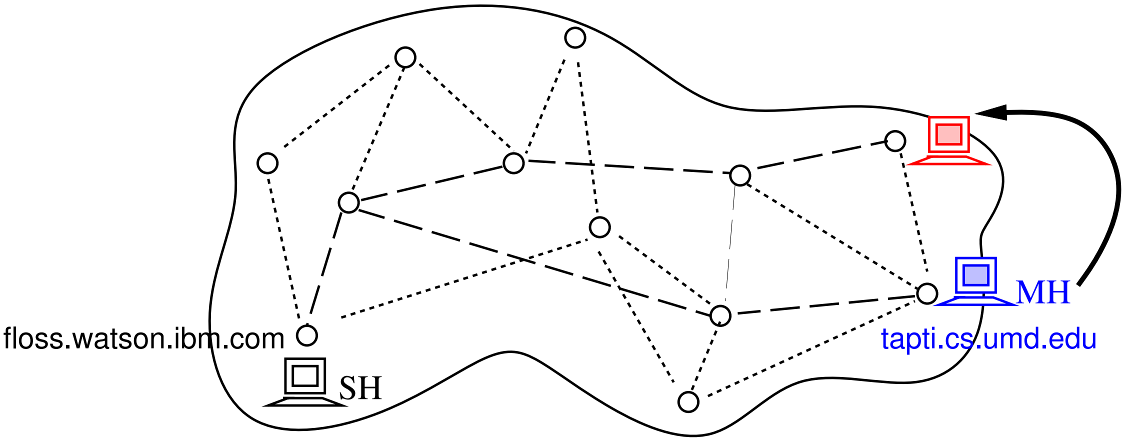
Nomadicity

- What's left to do for nomadic users (answer: almost everything)



Mobile-IP does not solve all of the problems posed by nomadic computing!

Connections between Internet computers



Connection := <129.34.16.43, sh_port #, 128.8.128.45, mh_port #>

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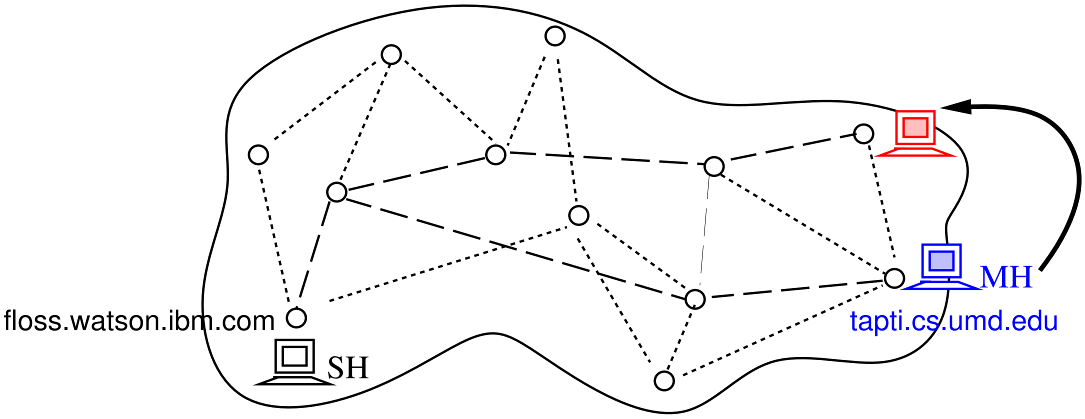
TCP connections are defined by source and destination IP addresses and port numbers.

Thus, to maintain a connection, one's IP address must stay the same (unless TCP is to be modified Internet-wide).

Mobility Problem : The Internet Viewpoint



Connection := <129.34.16.43, sh_port #, 128.8.128.45, mh_port #>

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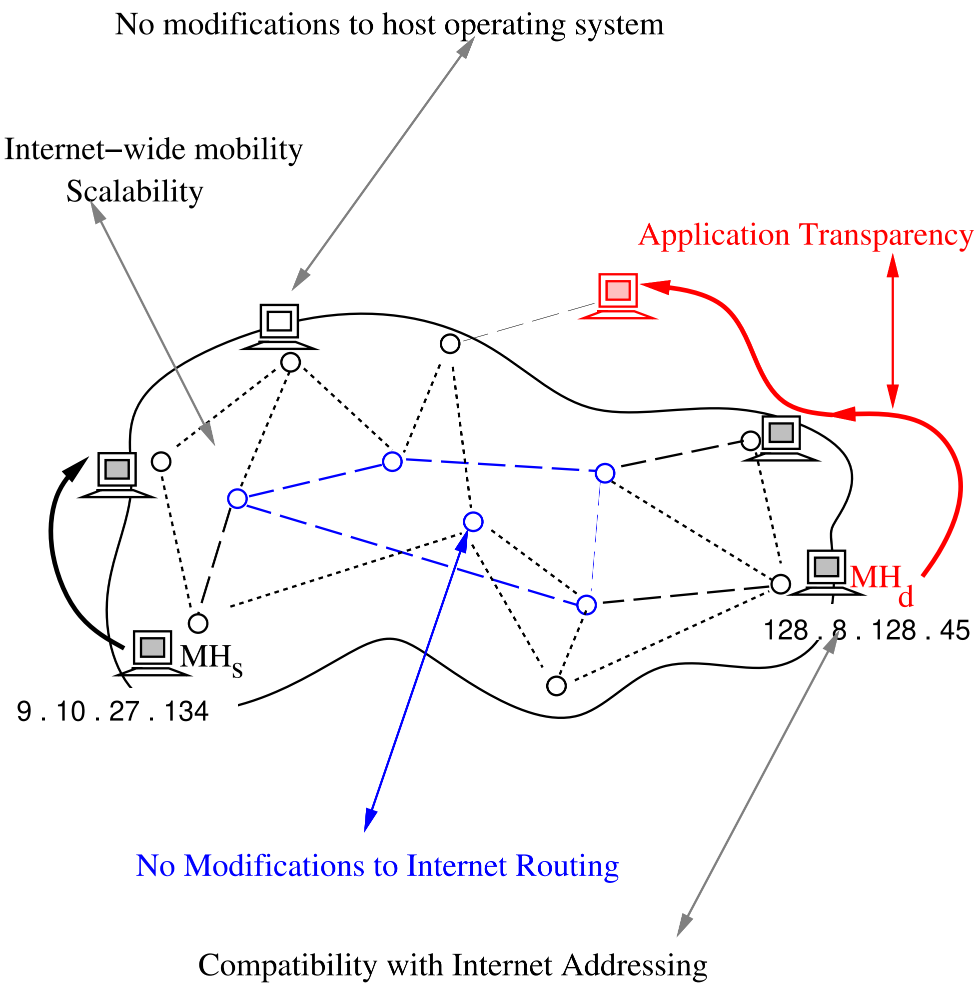
- Change host address → Connection breaks
- Retain host address → Routing fails

Host address must be preserved regardless of its location

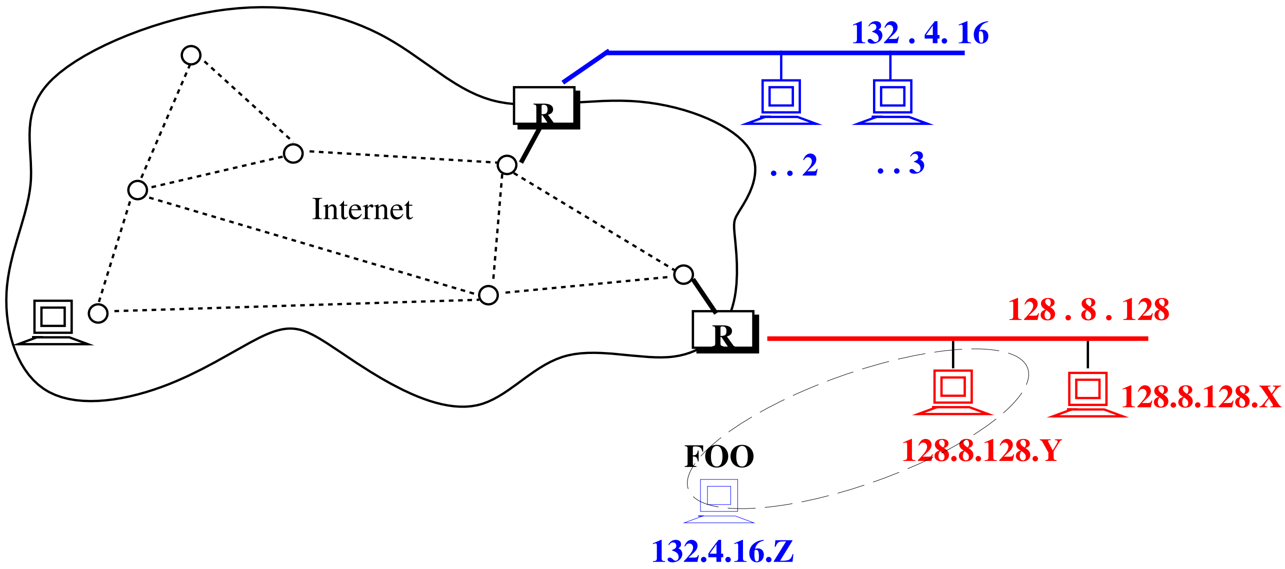
Characteristics of allowable solutions



Compatibility (in all respects) with existing Internet computers and applications

Solution: two-tier IP addressing

	Topologically Significant Part	Static Part
FOO	128 8 128 Y	132 4 16 Z



Mobile computer keeps its static IP address, but borrows the service of a "care-of address" on whatever IP subnet it happens to be visiting. This care-of address may (in many configurations) be used by many visiting mobile nodes.

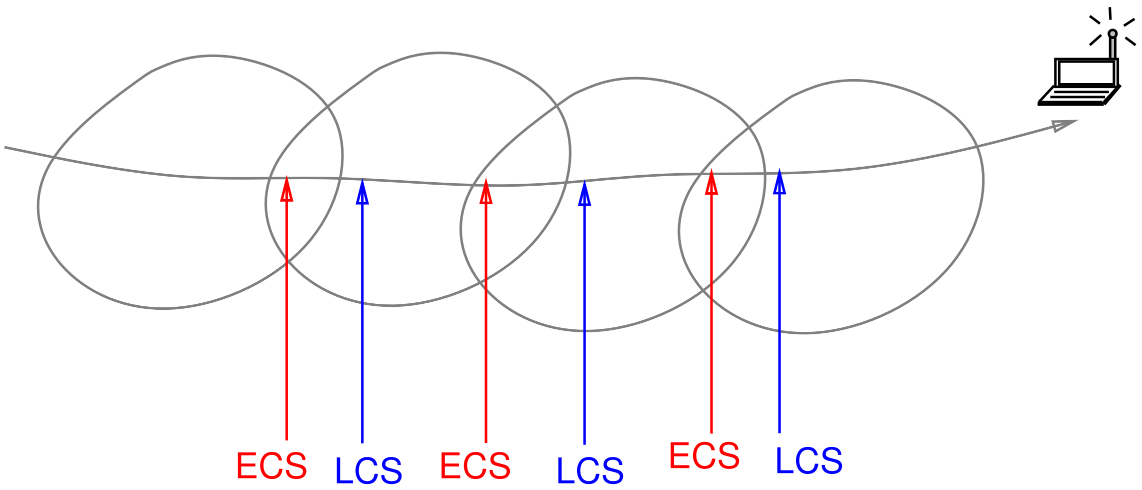
Service Advertisement

A *mobility agent* is either a foreign agent or a home agent

- Mobility agents send *agent advertisements*
- Mobile nodes can *solicit* for agents
- Foreign agents:
  - advertise care-of Addresses
  - can be too busy for more clients
  - describe offered services (encapsulation and compression)
  - can require registration via an advertised care-of address

For purposes of discussion, we will assume the presence of a foreign agent

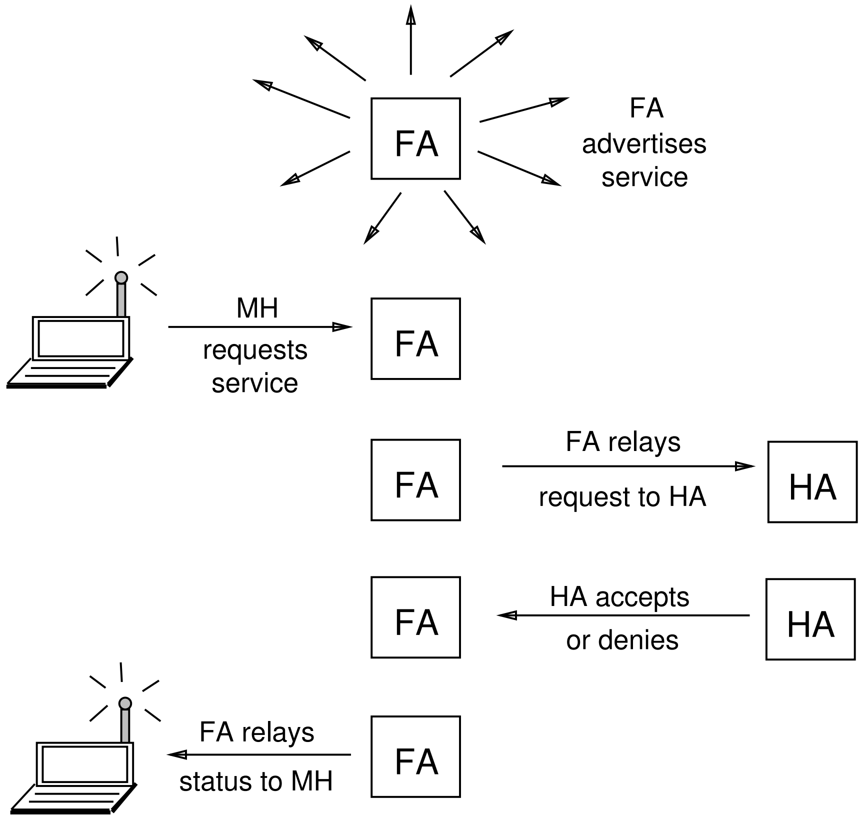
Algorithms for Motion Detection



- Lazy Cell Switching (LCS) (switch on BLUE)
- Eager Cell Switching (ECS) (switch on RED)
- Prefix Comparison (switch on RED) (requires more subnets)
- Link-Layer notification (can include signal-strength, etc.)

Performance depends upon pattern of user mobility, frequency of advertisement, and whether mobile node can respond to multiple IP addresses

Registration Request and Reply

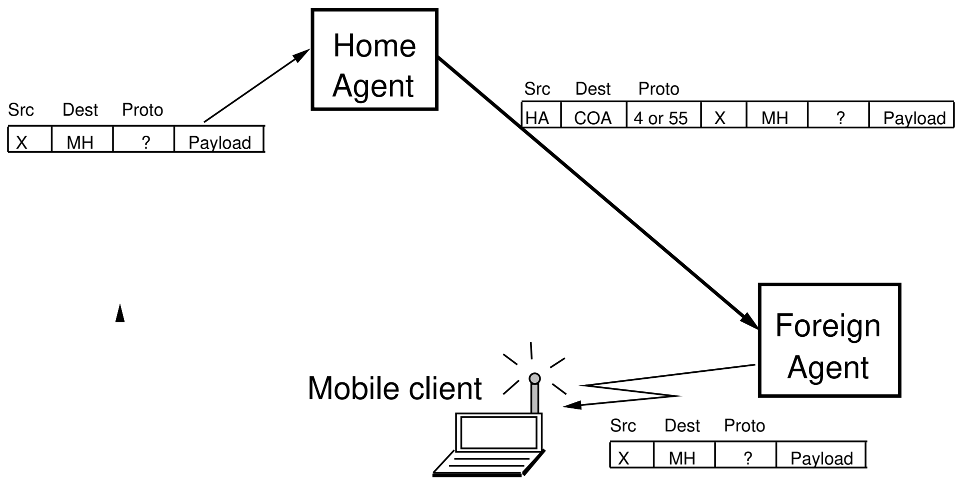


A *binding* is the tuple (mobile, care-of address, lifetime)

Registration is a form of *remote redirect*; authentication is *required*

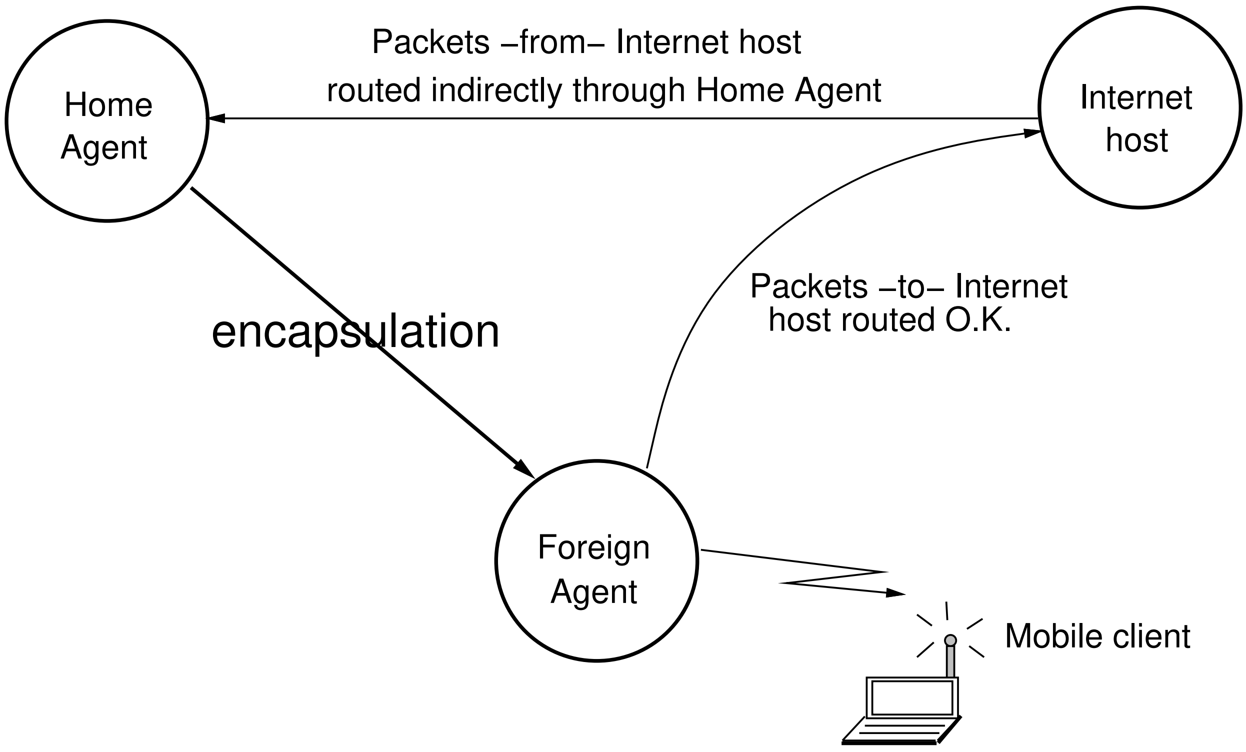
A mobile node can discover its home agent's address

Encapsulation/Decapsulation



- A *tunnel* is needed to allow delivery to the mobile node
- IP within IP and *minimal encapsulation*
- If fragmentation is necessary, IP within IP *must* be used

Triangle (Non-Optimal) Routing



Triangle routing is undesirable:

- Home Agent bottleneck
- Increased network utilization
- Increased sensitivity to network partition

Route Optimization

Current solution requires modified correspondent with security associations with home agents

Idea: Allow correspondent hosts to know the care-of address of the mobile node – i.e, to get a *binding update.*

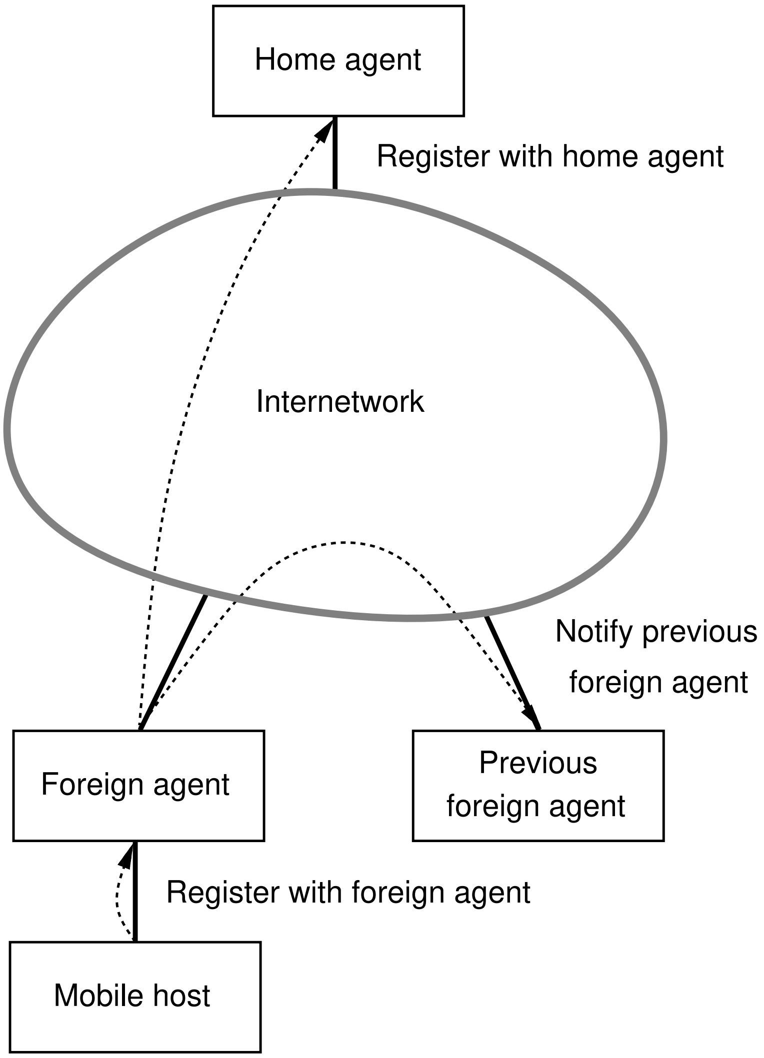
Location cache, part of route table

Four UDP messages types:

- Binding Warning
- Binding Request
- Binding Update
- Binding Acknowledge

When a mobility agent sees that a correspondent host has a stale location cache, it issues a *Binding Warning*. The correspondent then makes a *Binding Request*, which elicits a *Binding Update*. The update may be acknowledged with a *Binding Acknowledge*.

Smooth Handoffs



Smooth handoffs use binding updates, too

- Mobile asks the new foreign agent to *relay* its binding update to its previous foreign agent

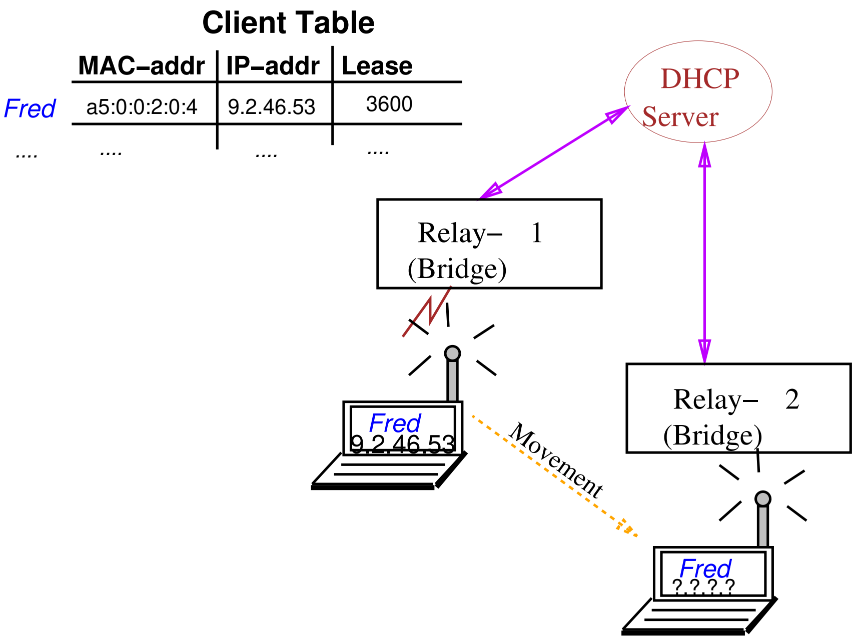
DHCP

Dynamic Host Configuration Protocol – for IP addresses and more:

- Subnet mask
- Domain Name Server (DNS)
- Default Router
- Miscellaneous (IP and TCP parameters, timezone, timeserver)

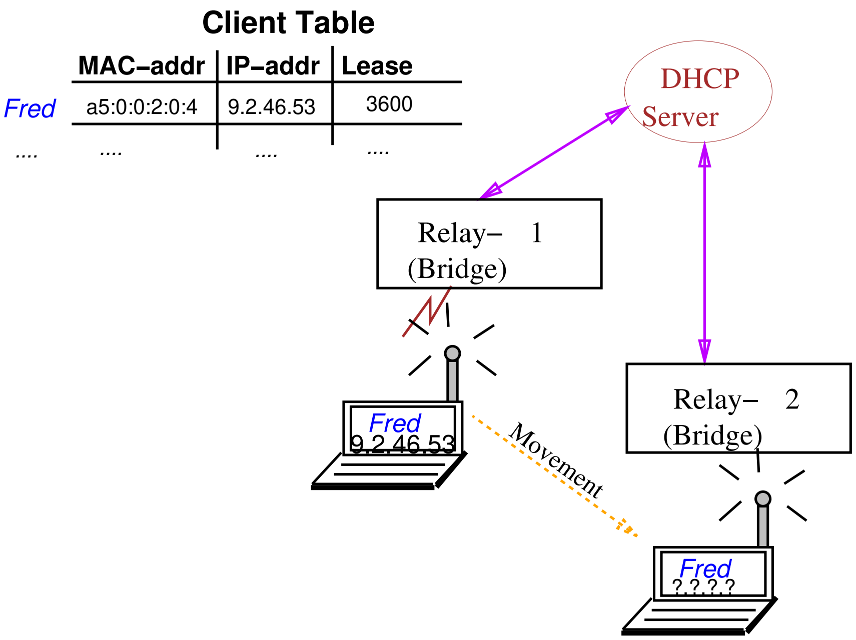
- Location changes imply some IP address change
- Dynamic Internet address schemes require new DNS feature
- DHCP will require significant new administrative skills
- Security vs. eliminating preconfiguration

DHCP for Portability



- Portable computer accesses LAN via bridge
- Sends DHCP_DISCOVER to get appropriate Internet address
- Reinitializes Internet operation
- Begins network transactions
  - Connections break upon movement
  - Finding portable computer may be difficult

DHCP for Mobility



- Mobile computer accesses LAN via bridge
- Sends DHCP_DISCOVER to get local care-of address
- Registers with Home Agent
- Continues all network transactions
  - Only a few datagrams dropped upon movement
  - Finding portable computer is simple as always

IP version 6

Reasons for creation:

- Exponential route table expansion
- Rapid address space exhaustion

Important changes in IPv6 over IPv4:

- 128 bit addresses
- Improved option handling
- Authentication services assumed universal
- Address autoconfiguration
- Source route reversal not required
- *flow id* field
- Address space for Novell, Appletalk, OSI, ...
- Fragmentation only at endpoints
- No checksum
- Some level of multi-homing guaranteed

Since IPv6 is in an early stage of its life, we can still place requirements on IPv6 nodes needed to support mobility.

Mobility for IP version 6

- Mobile node may notify its correspondents when it moves
- Correspondents put care-of address in routing headers
- Home agent encapsulates packets if it gets them (e.g., from correspondents not having current care-of address)
- Binding updates are carried in a Destination Option
- Acknowledgments (usually only sent by a home agent) in another Destination Option, with status codes
- Mobile nodes can create their care-of address using link-local address and automatic address configuration.
- Mobile nodes should be able to receive packets at multiple addresses

Work done with Dave Johnson, CMU

Establishing the Link

Automatic Address Configuration (RFC 1971)

- Provides means for creating a unique globally routable address
- Specifies algorithms for 'duplicate address detection'
- Stateless and idempotent

Neighbor Discovery (RFC 1970)

- Defines router advertisements, host advertisements, solicitations
- Replaces and improves upon ARP
- Proxy advertisement specified
- Defines a *Neighbor Unreachability Detection* algorithm

These processes (and Mobile IP) are independent of any particular layer 2 requirements

Mobile IPv6 Care-of Addresses

Mobile node acquires its own care-of address with IPv6 dynamic *address autoconfiguration*

- *Stateful* address autoconfiguration (DHCPv6)
  - Address acquired from server, with deprecation and invalidation lifetime
- *Stateless* address autoconfiguration
  - Local subnet prefix advertised by Neighbor Discovery
  - Combine advertised prefix with own hardware address

Advertised subnet prefix	IEEE 802 MAC address

All packets tunneled directly to the mobile node at the care-of address

Multi-Homing

- *Multi-homed* means able to send and receive IP datagrams at multiple IP addresses (e.g, routers).
- Can be used to avoid dropped packets
- Overlapping wireless cells desirable
- Mobile nodes have their own care-of addresses for each cell
- The rare case: multiple home addresses

Sending Binding Updates

Each mobile node maintains a *Binding Update* list:

- All nodes to which it has sent a Binding Update, for which the lifetime has not expired

The mobile node sends a Binding Update to nodes on its list when it acquires a new care-of address:

- Can be included in any existing packet (eg: TCP ack)
- Or, in a packet by itself
- Requires inclusion of an IPv6 *Authentication Header*

IPv6 Movement Detection

IPv6 *Neighbor Unreachability Detection*

- While sending packets to a neighbor, sender needs confirmation of "forward progress"
- Normally, monitor return traffic (example: TCP acks)
- If necessary, can send explicit probes

Mobile node uses this to confirm its connection *to* the local router for current care-of address

- This only confirms it while actually sending packets
- But, this is the only time the outbound direction is needed

Mobile node confirms its connection *from* the local router by listening for any packets from it (e.g. Router Advertisement)

IPv6 requirements for Mobility

All IPv6 nodes need to support:

- Routing headers (they're supposed to anyway!)
- Mobility Cache (perhaps part of Destination Cache)
- Binding Update processing

IPv6 Mobile nodes:

- Detect motion
- Construct care-of addresses
- Decapsulate
- Send Binding Updates to home agents and correspondent nodes

Requirements for Home Agents (Routers)

- Encapsulation
- Binding Update, Binding Acknowledgment
- Proxy Neighbor Advertisements for departed Mobile Hosts
- Stable storage?

Note: home agents used only rarely

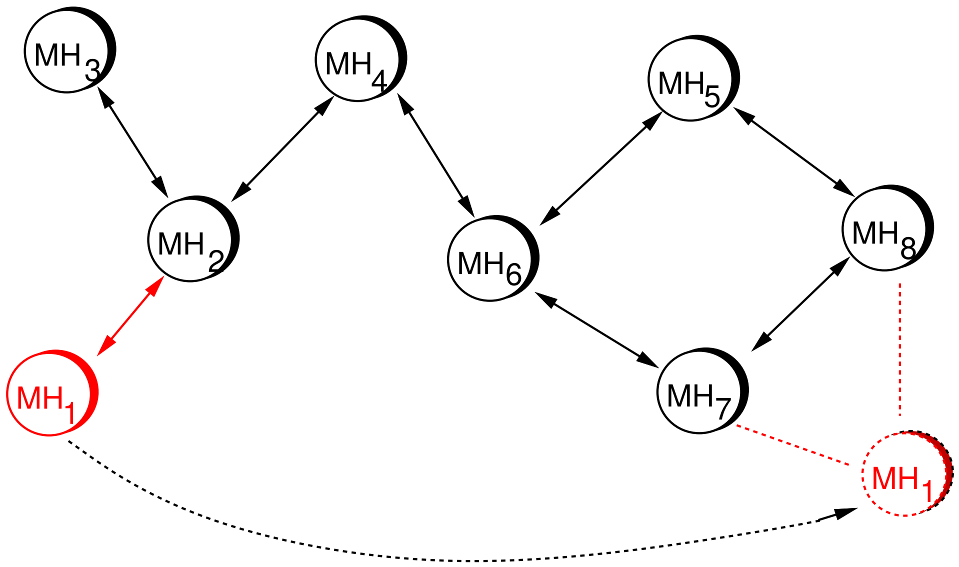
IP version 6 mobility - Conclusion

Support for mobility is *far* simpler

- Address autoconfiguration for care-of addresses
- Neighbor Discovery replaces IPv4 solicitation/advertisement, works well for maintaining even wireless links
- No extra packets are needed – a *destination option* carries a binding update to anyone needing it (including the home agent)
- Binding updates are issued to any nodes that need them whenever the mobile node detects that it has moved to a new subnet
- Destination options and Routing headers offer much improved performance compared to the analogous IPv4 features
- Universal availability of security services avoids problems with *remote redirects*
- No need for foreign agents any more

Since IPv6 isn't yet fully deployed, we expect all correspondent nodes to support the few operations required for mobility

Ad-hoc Networking Overview



Allow an arbitrary collection of mobile nodes to create a network on demand, without support from any infrastructure, base stations (or administrative support)

(emergency, military, community, conferencing applications)

Goal: Cooperative, interpersonal networking

Ad-hoc Networking Overview, continued

- Model of operation (*Instant Infrastructure*)
- No “system administration” allowed
- Internet Routing
- Mobile wireless nodes are motivating the work
- IETF working group to standardize a protocol with focussed objectives
- Existing infrastructure elements (perhaps using mobile-IP) should be taken into account
  - May require a foreign agent to allow *multi-hop* routes to a mobile node

Proposed model of operation

Features:

- Computers with unrelated IP addresses
- Limited range broadcast media
- Dynamic interconnection
- No "administration" allowed

Questions:

- Symmetric Links *?*
- Should IP routing depend upon link-layer *?*
- Complete connectivity *?*

Left out:

- RSVP, *Quality of Service*
- Considerations regarding sleep mode

Envisioned Applications

File sharing (including electronic mail)

Groupware

Digital Battlefield Communications

Conferencing (for instance, in this room)

Disaster Relief

Any interpersonal communications

What is *networking* good for?

Traditional Routing Methods

Advantages of using routing protocols:

- Self-Starting
- Multi-Hop
- Dynamic topology

Single metric: number of hops to destination (is this good?)

Link-State

- Complete topology stored
- OSPF (RFC 1583)

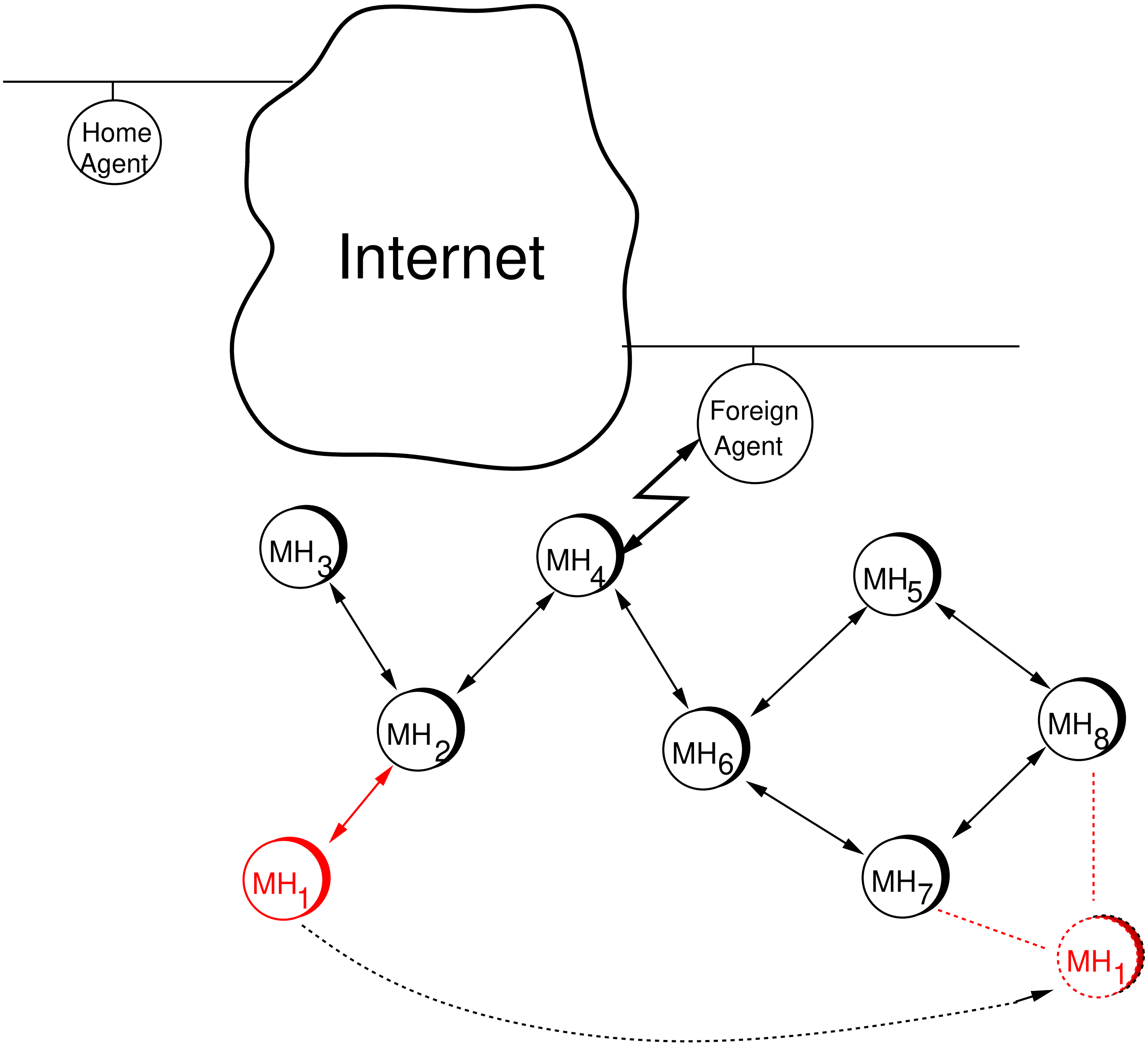
Distance-Vector

- One record per destination
- RIP version 2 (RFC 1723)
- Poisoned-Reverse/Split-Horizon
- Count to ∞ problem

Ad-Hoc Network Research Growth

- WINGs (Glomo: JJ Garcia, UC Santa Cruz path-finding)
- BBN clustered link-state (Glomo)
- DSDV (IBM)
- AODV (refinement of DSDV)
- Dynamic Source Routing (Dave Johnson, CMU)
- WAMIS (Mario Gerla, UCLA)
- Link-Reversal (Scott Corson, University of Maryland)
- Link Quality (SSA) (Rohit Dube, University of Maryland)
- Hierarchical (Ian Akyildiz, Georgia Tech)
- Clustering (Texas A&M)
- Associativity-Based Routing (C.K. Toh - Cambridge)
- Cornell (Zygmunt Haas)
- IETF (working group? IRTF?)

Ad Hoc Networking and Mobile-IP



The foreign agent must appear as part of the ad-hoc cloud

The agent advertisements piggy-back on the ad-hoc routing protocol

In IBM protocols, the mobile-IP stations request *special* routes

Service Location Protocol

- User Agents, Service Agents, Directory Agents
- URLs, Schemes, URNs
- Attributes, Keywords, Where Clauses
- Scope, Naming Authority
- Locality

Introduction

Goal: Provide access to network resources by *name*, not by address

Observations

- The growth of wireless communications is driving mobile networking
- Mobility is driving the need for automatic resource discovery
- Need to access local resources without preconfiguration
- Mobile users should not have to become system administrators
- Web technology has boosted interest in specifying *locators* for specified objects. These locators are called *URL*s, for Uniform Resource Locators. Plus, there has been work on creating objects known as *URN*s, for Uniform Resource Names.
- DHCP provides option 78 to configure a local *Directory Agent* for Service Location.
- The IETF has a Service Location working group in progress.

URLs

URLs are a standardized way to locating and providing access to a large variety of computer resources located on the network.

General form of URLs:

```
<scheme>:<scheme-specific-part>
```

often something like

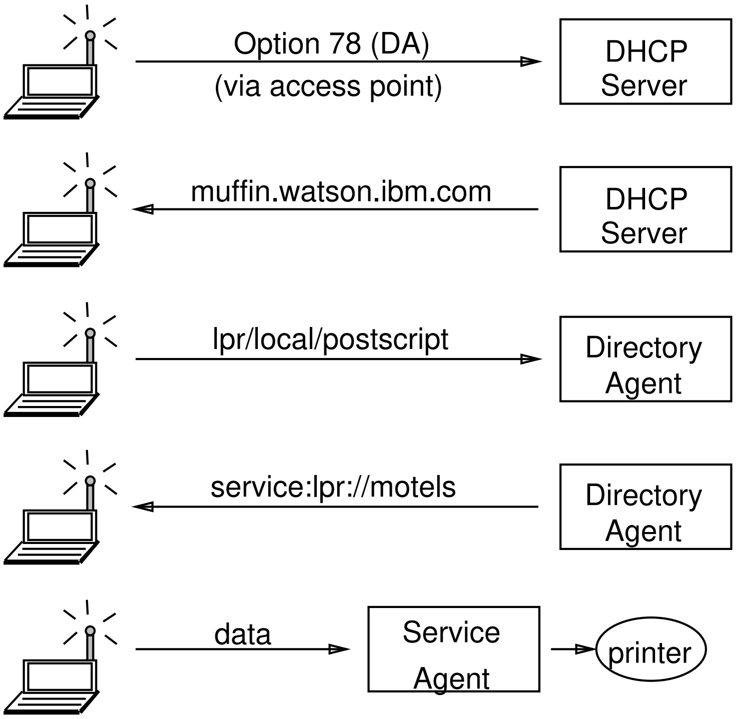
```
scheme://host:port/opaque
```

Some examples of valid URL replies are:

```
nfs://slag.watson.ibm.com/src/rdp
http://www.research.ibm.com/
printer://motels.watson.ibm.com/j1j25ps
```

Naming authorities define (possibly local) meanings for each scheme. IANA (the default) is the standard Naming Authority.

Service Location Protocol Operation



Example: Discovering a Print Service

Mobile computer contacts DHCP to discover a Directory Agent

- Could use multicast, or static configuration, too

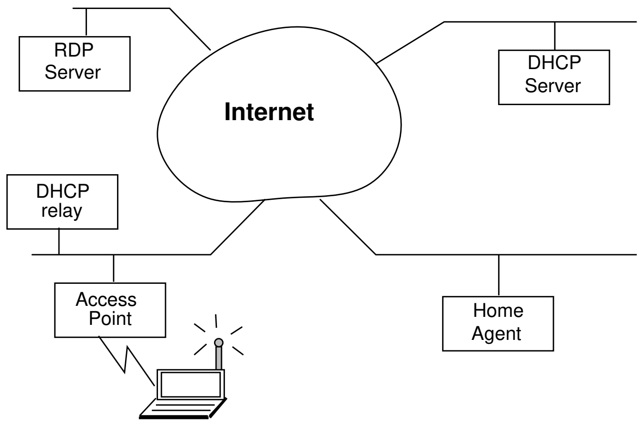
Mobile computer contacts *muffin* for a printer URL

- May need to specify print attributes or locality

Finally, mobile computer sends print job to *dukprunz*

- Spooler should *adapt* to new printer name, protocol, ...

Mobile-IP, DHCP, and Service Location



- Mobile discovers that a cell switch is needed
- Mobile queries DHCP for a IP address (to be used as a Care-of Address), and includes option 78 (Directory Agent)
- Mobile registers new DHCP Address with home agent
- Mobile queries Directory Agent for local resources

Nomadicity

Problem: What happens when a cell switch occurs

- Information isn't available to applications
- Services need to be located again
- Proxy management may require attention
- User profiles may indicate performance changes

Disseminating information about cell switches to mobile-aware applications will require new systems facilities.

- An inter-process communication facility needed
- Mobile-IP has some of the required information
- SNMP one possible solution
- New UDP message types also possible

Nomadic Services for Higher Level Protocols

Objective: to allow application protocols to remain aware of changing network connection and environment parameters

- Callback service for applications, after a *trigger event*
- Upon demand, the application may need to again resolve access to a named resource via SLP
- enable *application* adaptivity
- One idea: `SIG_CELLSWITCH`

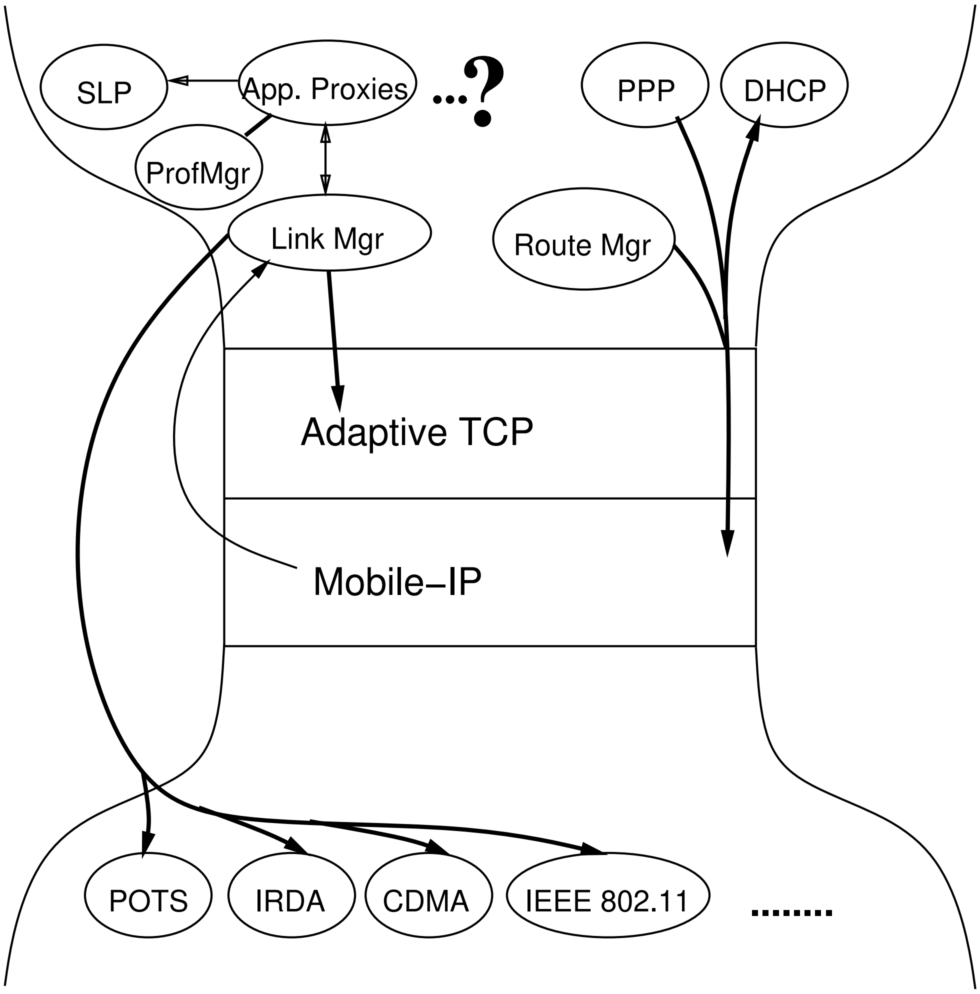
Mobile-IP can provide the trigger and notification

- Connection events
- Care-of Addresses

Other Nomadic Services for Higher Level Protocols

- Link monitor for information about link quality, fidelity
  - Bandwidth
  - Cost
  - Latency
  - Error rate
  - Security
- The application should specify desired granularity of update
- Profile services
- Proxy services

An architectural view of Nomadicity



- Mobile-IP at network layer, gets care-of addresses
- TCP balances between congestion and error recovery
- What *middleware* really consists of is the BIG unknown here.

IETF status

- Mobile-IP interoperability testing in fall 1995 quite successful
- Base document, two encapsulation drafts, and MIB documents are RFCs 2002-2006.
- Draft Standard status likely within a few months.
- IPv6 mobility hopefully going to last call before this presentation.
- Route Optimization has undergone revision to resemble more closely the more popular IPv6 draft.
- New IETF working groups in formation for "ad-hoc" networking, dial-in roaming.
- Service Location has gone to Proposed Standard.
- IETF does not standardize APIs (won't help with Nomadicity).