Wireless Networks without Infrastructure

Ashutosh Dutta, Maria Papadopouli and Henning Schulzrinne
Dept. of Computer Science
Columbia University, New York
schulzrinne@cs.columbia.edu

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Overview

- Motivation
- Ad-hoc networks
- Application-layer mobility
- Multicast mobility for Internet radio and TV

Motivation

- spectrum is very expensive:

Location	what	cost
UK	3G	$590/person
Germany	3G	$558/person
Italy	3G	$200/person
New York	Verizon (20 MHz)	$220/customer

- does not include any base stations
- 3G bandwidth is decreasing (2 Mb/s $\searrow$ 64 kb/s)

An alternate universe

- metrics: $/customer or b/s/area
- "picocellular" 802.11: about 100 Mb/s/km^2
- cellular: about 2 Mb/s/km^2 (?)
- but:
  - not suited for high-speed mobility
  - no power control ➠ battery, interference
  - no predictable QoS due to L1/L3 interference

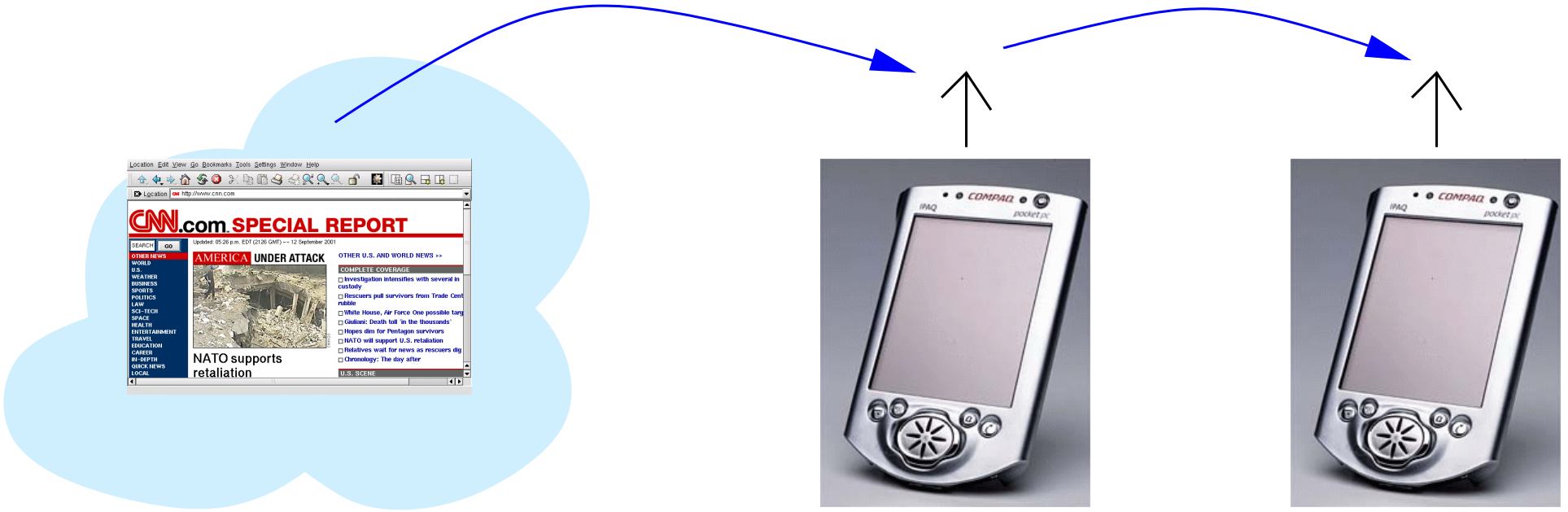
802.11 access infrastructure for NY

- each base station covers 100 m radius
- New York: 8m people in 800 km^2 ➠ need 80,000 base stations
- assume $500/base station
- about $5/person
- instead of tower, donate an SDSL, CM or Ethernet connection to 80,000 lucky New Yorkers

Opportunities

- multiple wireless networks
  - low-rate, wide-area (e.g., GPRS)
  - high-rate in high-density areas
  - incremental cost may be small
- ➠ Internet approach
- also, 3G hybrid CO/PS ➠ high complexity
- 3G – a physical and link layer with “network envy” (cf. ATM, BlueTooth)

7DS


CNN.com SPECIAL REPORT
AMERICA UNDER ATTACK
NATO supports retaliation
COMPAQ
iPAQ
pocket pc
COMPAQ
iPAQ
pocket pc

7DS

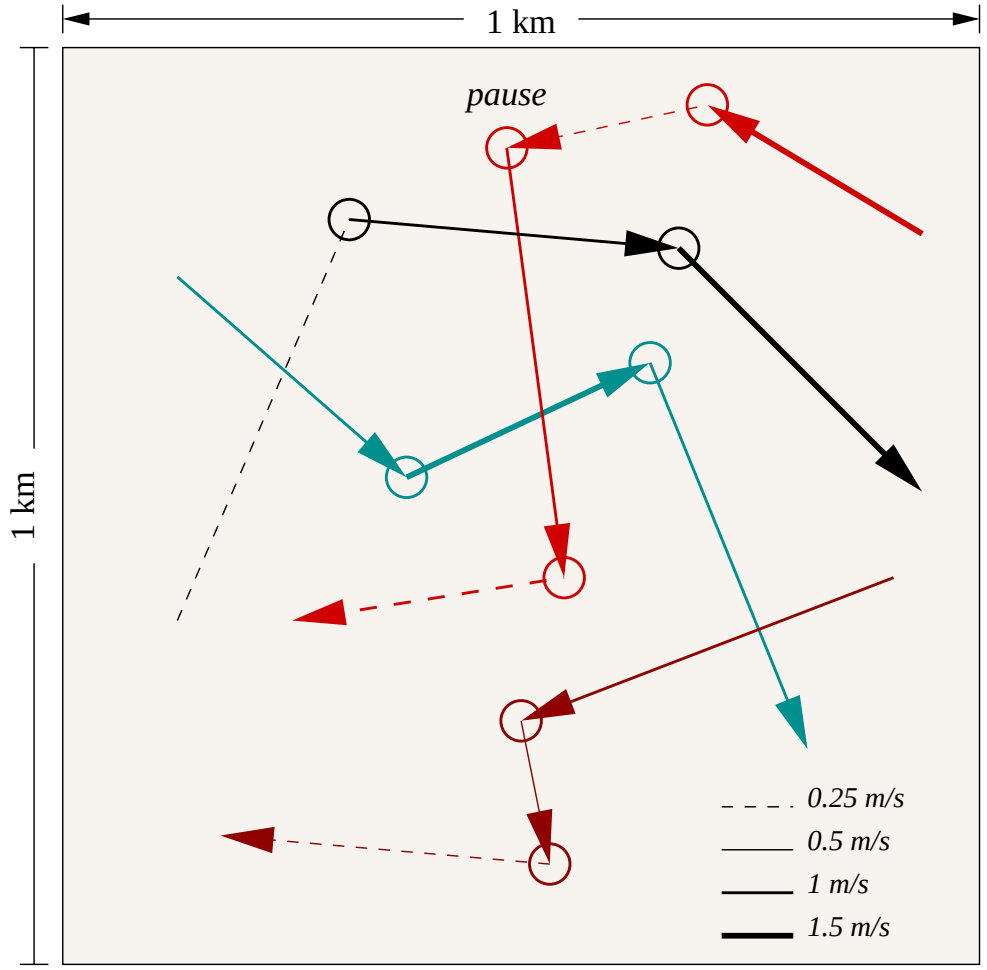
- "*seven* degrees of separation"
- generalization of InfoStation concept
- similar to P2P, but emphasis on data spreading, not searching
- requires zero infrastructure
- however, cooperative systems
- sporadically Internet connected
- power/energy-constrained mobile nodes
- may relay queries, ad-hoc network-style

7DS applications

- any Internet content: web pages, video, music, games
- (original) URL
- keywords (news, weather, map)
- location-based: “map of where I am”, “map of Boston”
- content with advertising
- GPS time & location advertisement
- see also HP Cooltown

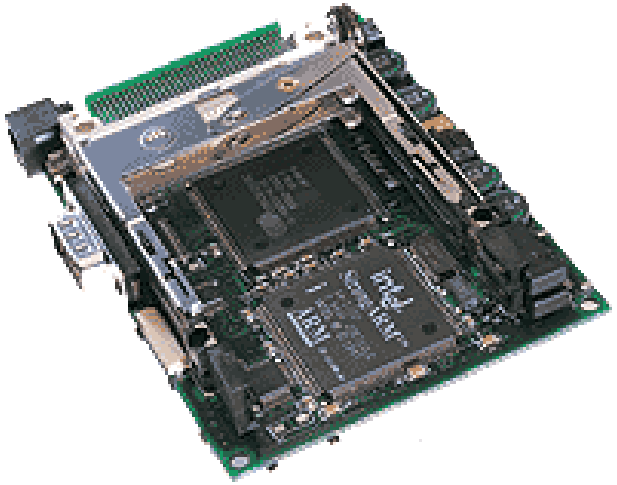
7DS mobility model

Randway model:

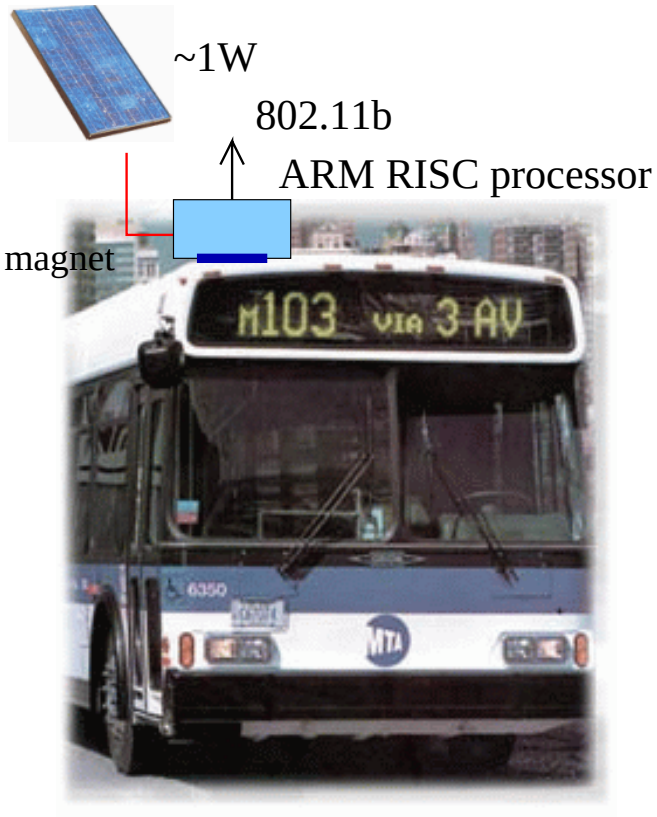


7DS implementation

- initial Java implementation on laptop
- to be done for Compaq Ipaq (Linux or WinCE)
- Inhand Electronics ARM RISC board
  - low-power
  - PCMCIA slot for storage, network or GPS



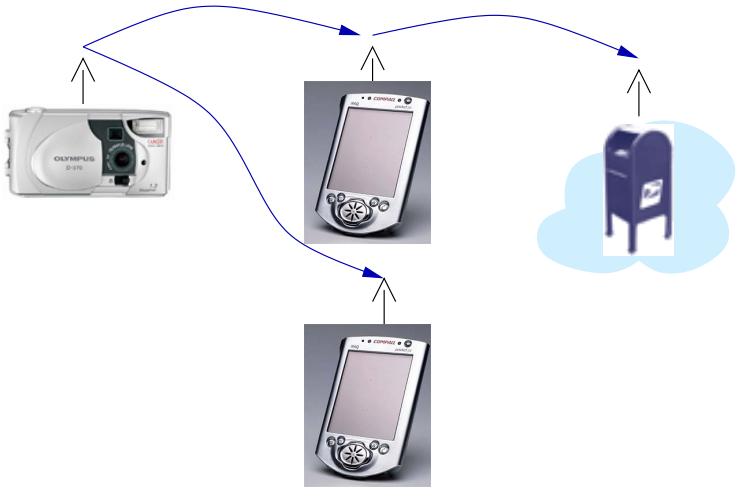
7DS implementation



7DS implementation

- to browser, standard proxy cache
- explicit cache management by user – public/private, expiration
- cache is indexed to allow keyword-based searches
- cache objects expire based on query frequency
- however, may serve expired objects since no origin server
- requestor can choose best match(es)

Future work: 7DS data gathering



- mobile sensors (cameras, biomedical, . . .) submit data to mobile nodes
- mobile nodes “deposit” at nearest Internet AP
- encrypted and signed
- how many – survival vs. energy, network and storage load
- postcard vs. certified mail

Cooperation strategies

Mobility: carrier can be fixed or mobile

Querying: listen (passive) or active

Power conservation: only enable periodically

Forwarding: relay queries and responses to extend range

Performance evaluation

Querying	cooperation strategy			
	no	forwarding	sharing	sharing + forwarding
active	MIS, FIS		P, NP	FW
passive		FIS-NDS		FIS-NP, FIS-NP

power cons.	peer-peer	server-client
disabled	NP	FIS, MIS, FIS-NP, FIS-NDS

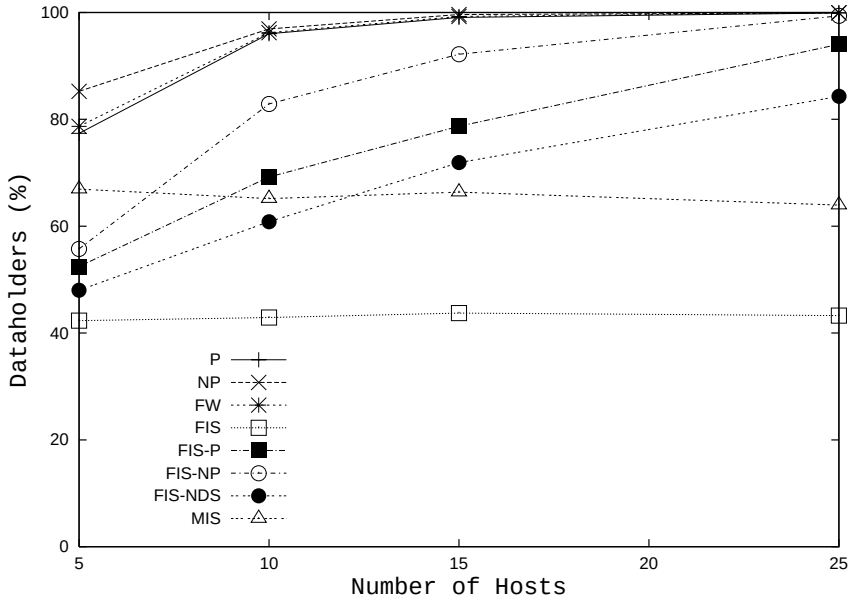
Simulations

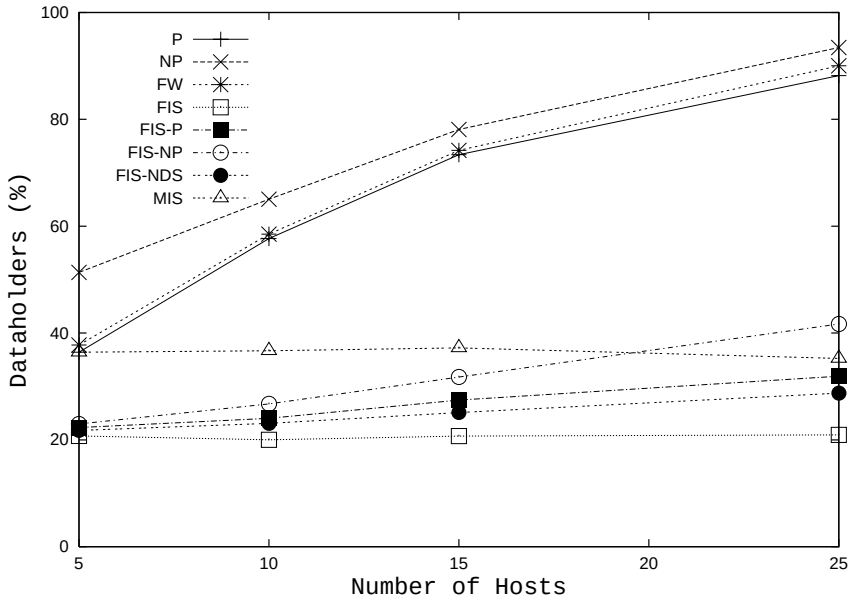
pause time	50 s
mobile user speed	0. . . 1.5 m/s
server advertisement interval	10 s
forward message interval	10 s
simulation time	25’
area	1 km^2
coverage	230 m (H), 115 m (M), 57.5 m (L)

Measure percentage of data holders after 25 minutes (commute)

Dataholders after 25’

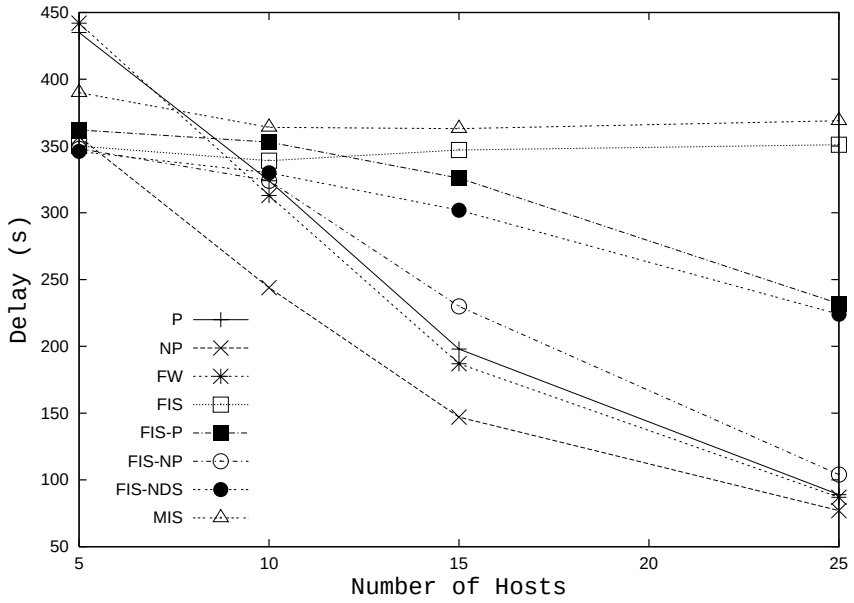
Function of host density:

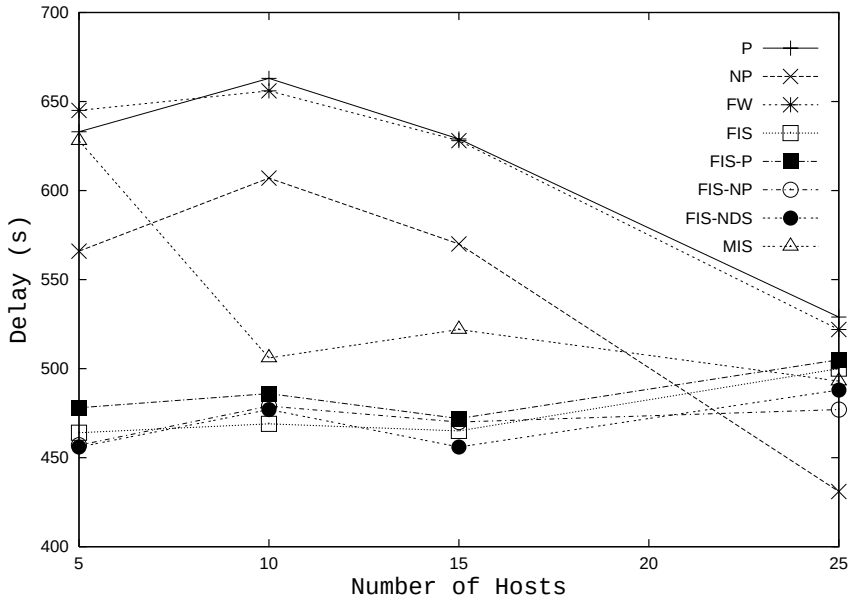




Dataholders after 25’

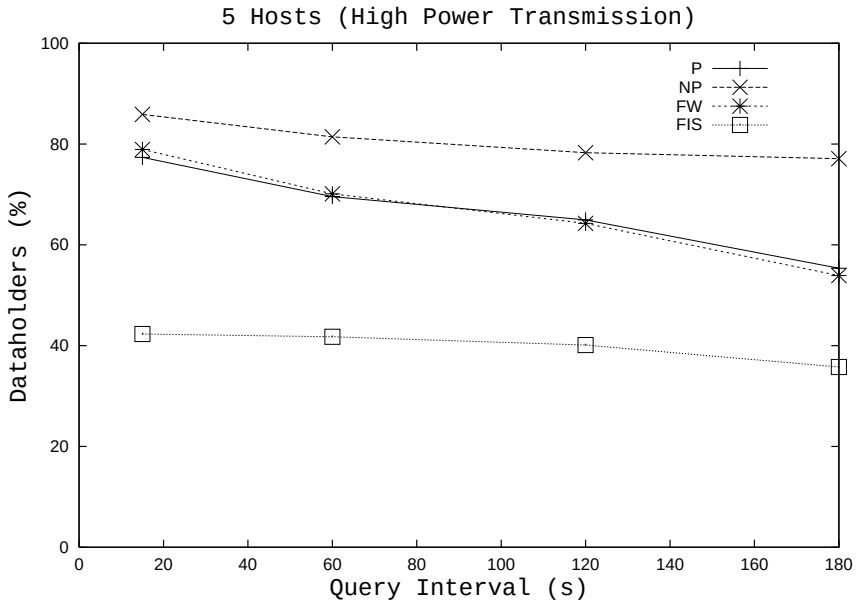
Function of host density:

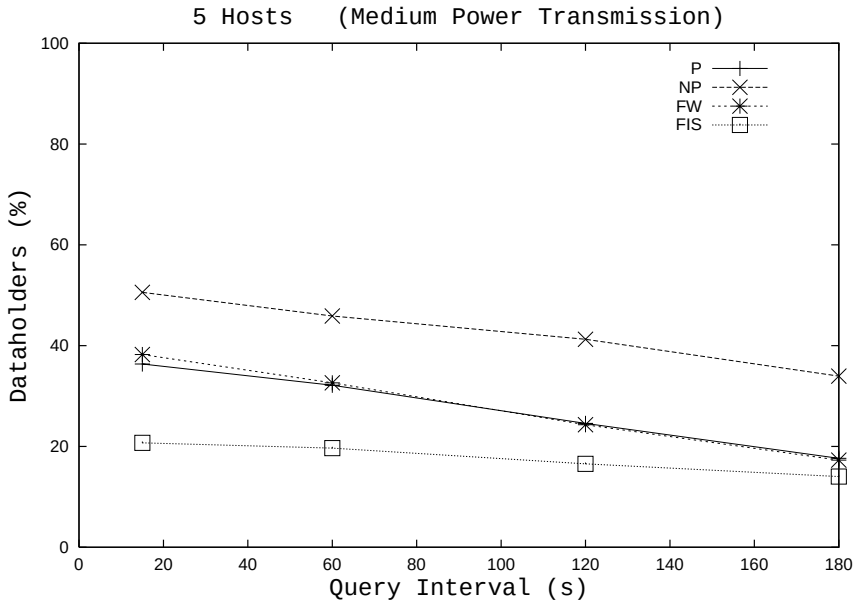




Dataholders after 25', 5 hosts/km^2

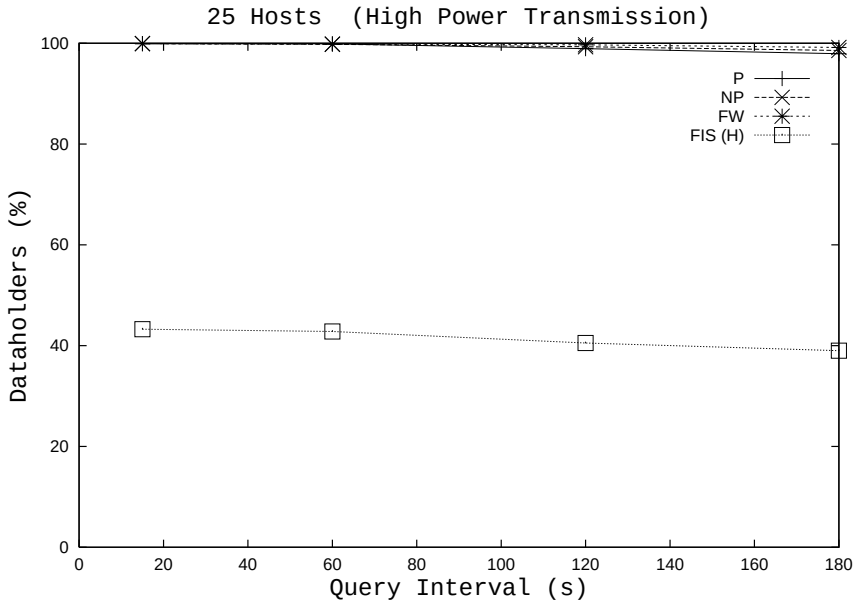
Function of query interval:

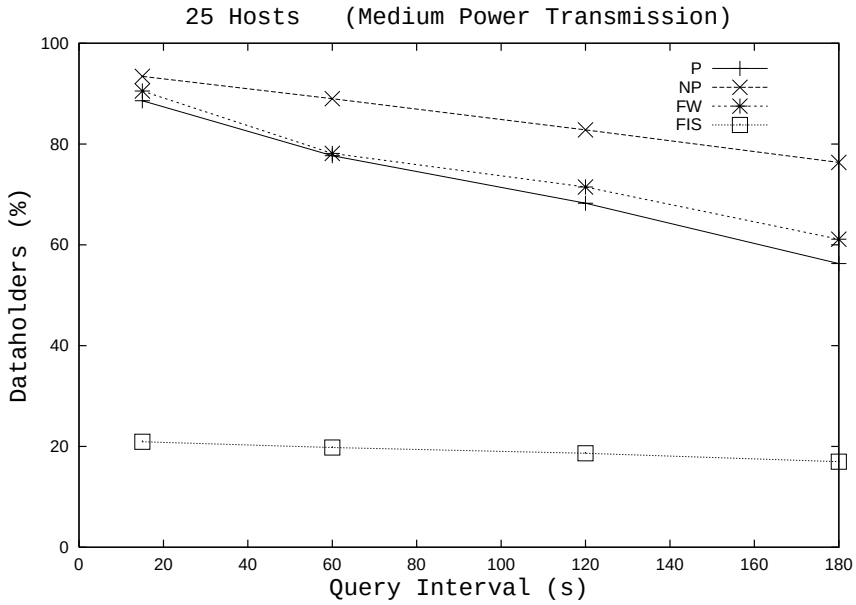




Dataholders after 25', 25 hosts/km^2

Function of query interval:



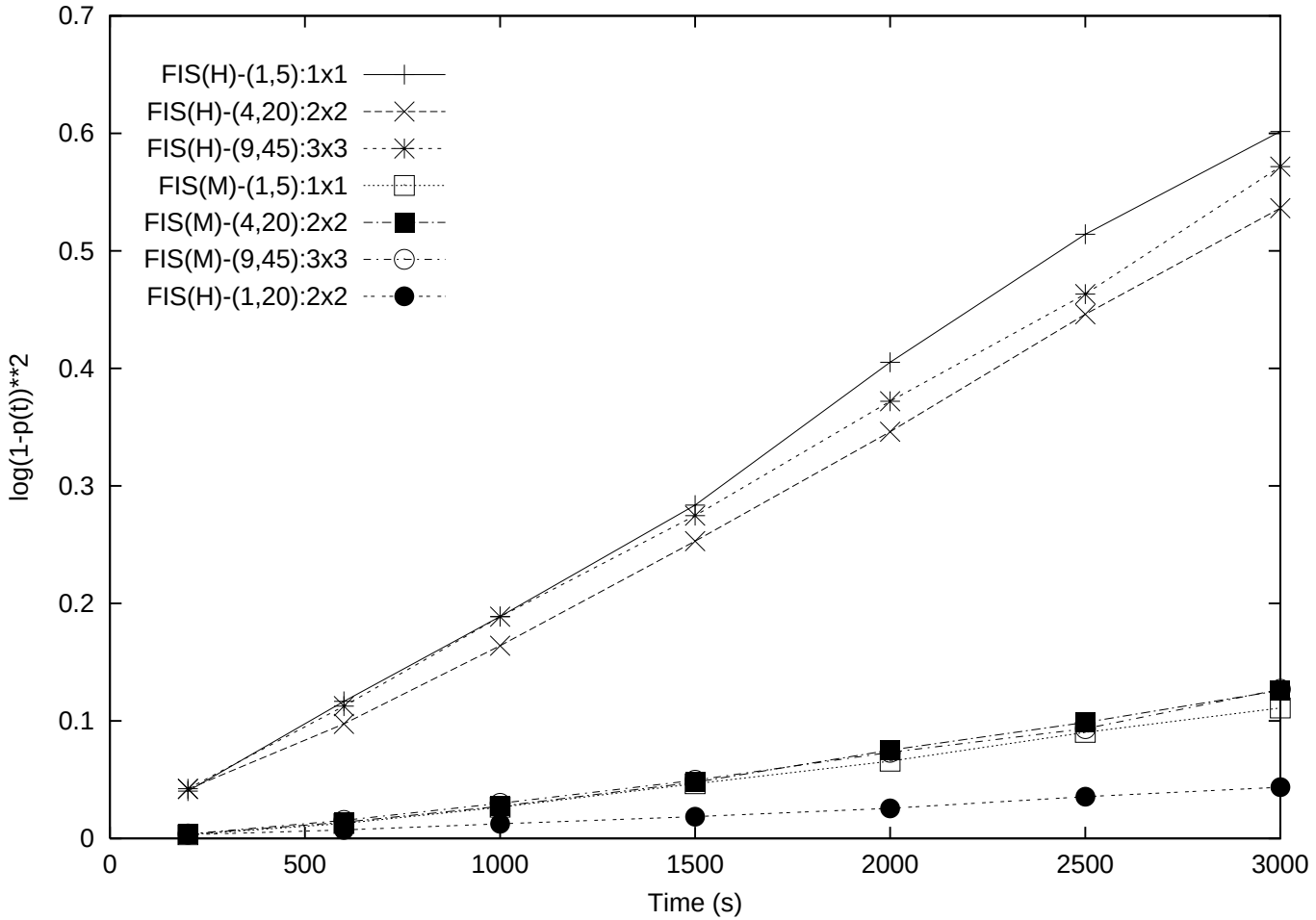


Summary of results

- cooperation and mobility strongly influence results
- P-P outperforms S-C
- forwarding does not help
- host density and query interval don’t influence S-C

Scaling effects

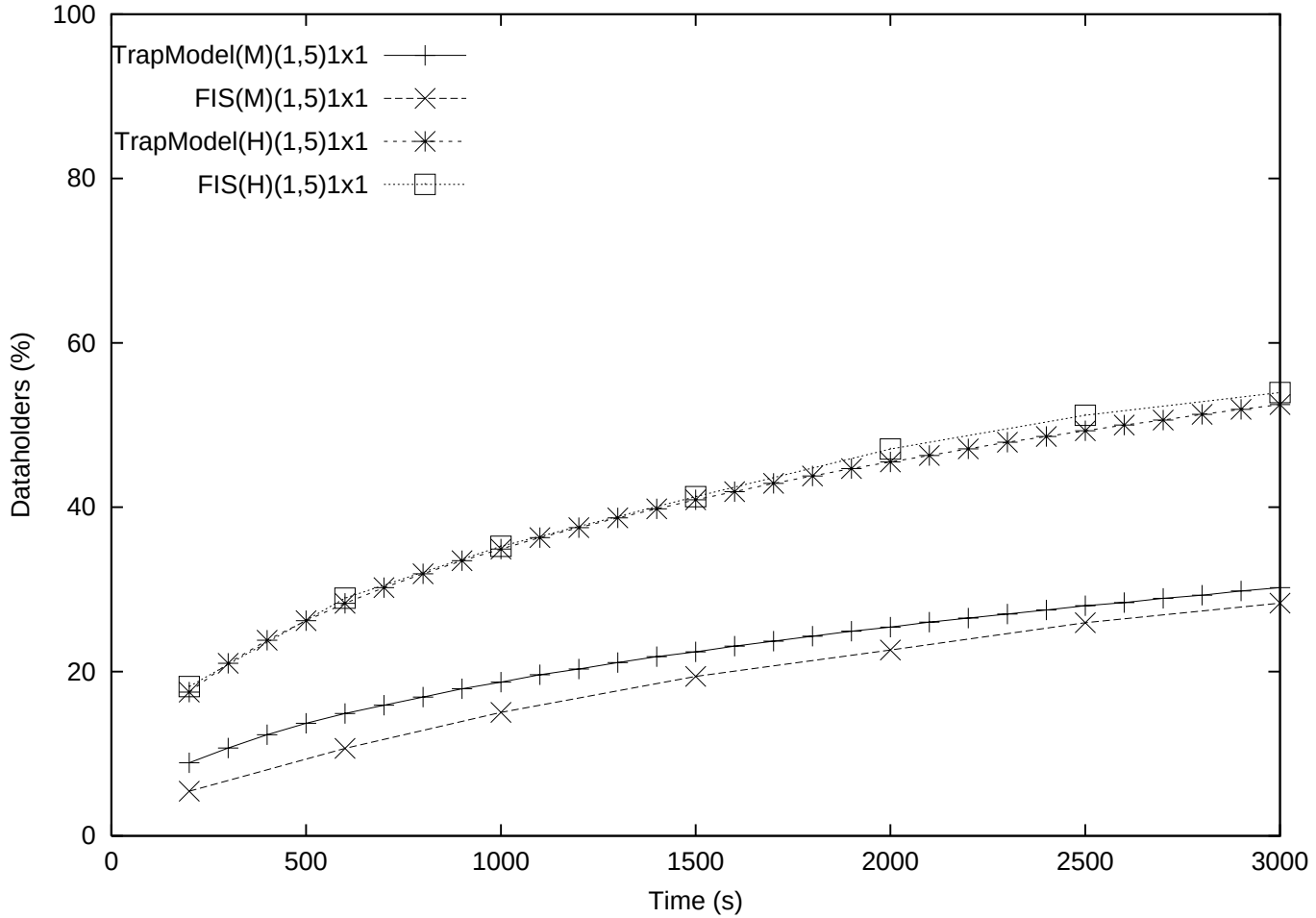
Scheme(power)-(initial data holders,hosts):area



Analytic model of FIS

- diffusion in a medium with randomly distributed static traps
- particles are absorbed when they enter trap
- d dimensions, α lattice constant, q trap concentration
- hosts that receive data “disappear”
- $q = \pi R^2 N/A$, with R as coverage radius
- survival after n steps: $\log(\phi_n) \approx -\alpha[\log(\frac{1}{1-q})]^{2/(d+2)} n^{d/(d+2)}$

Analytic model of FIS



Finite mean-square displacement per square $\longleftrightarrow$ randway

Epidemic model

- carrier is “infected”, hosts are “susceptible”
- transmit to any given host with probability $h\alpha + o(h)$ in interval h
- pure birth process
- T = time until data has spread among all mobiles
- $E[T] = \frac{1}{\alpha} \sum_{i=1}^{N-1} \frac{1}{i(N-1)}$

Application-layer mobility

- what is application layer mobility
- SIP as protocol to support application-layer mobility
- different mobility modalities for interactive communications

Application-layer mobility

- mobility = external identifier (URL, identifying IP address) stays constant as lower-layer identifier changes (IP address, routable IP address)
- mobility support:

  hide: keep layer ignorant of change of network attachment point

  inband: TCP connection migration (Snoeren/Balakrishnan)

  out of band: signaling protocol that changes associations

- always need binding update to existing peers *and* registration update for new peers

Application layer mobility

- if connections are short-lived, TCP state maintenance not too important
- need recovery ➠ useful for robustness
  - HTTP bytes range
  - ftp partial retrievals
- doesn’t work for telnet and X sessions
- easier to install – separation of bit delivery from mobility

SIP: Session Initiation Protocol

IETF-standardized *peer-to-peer* signaling protocol (RFC 2543):

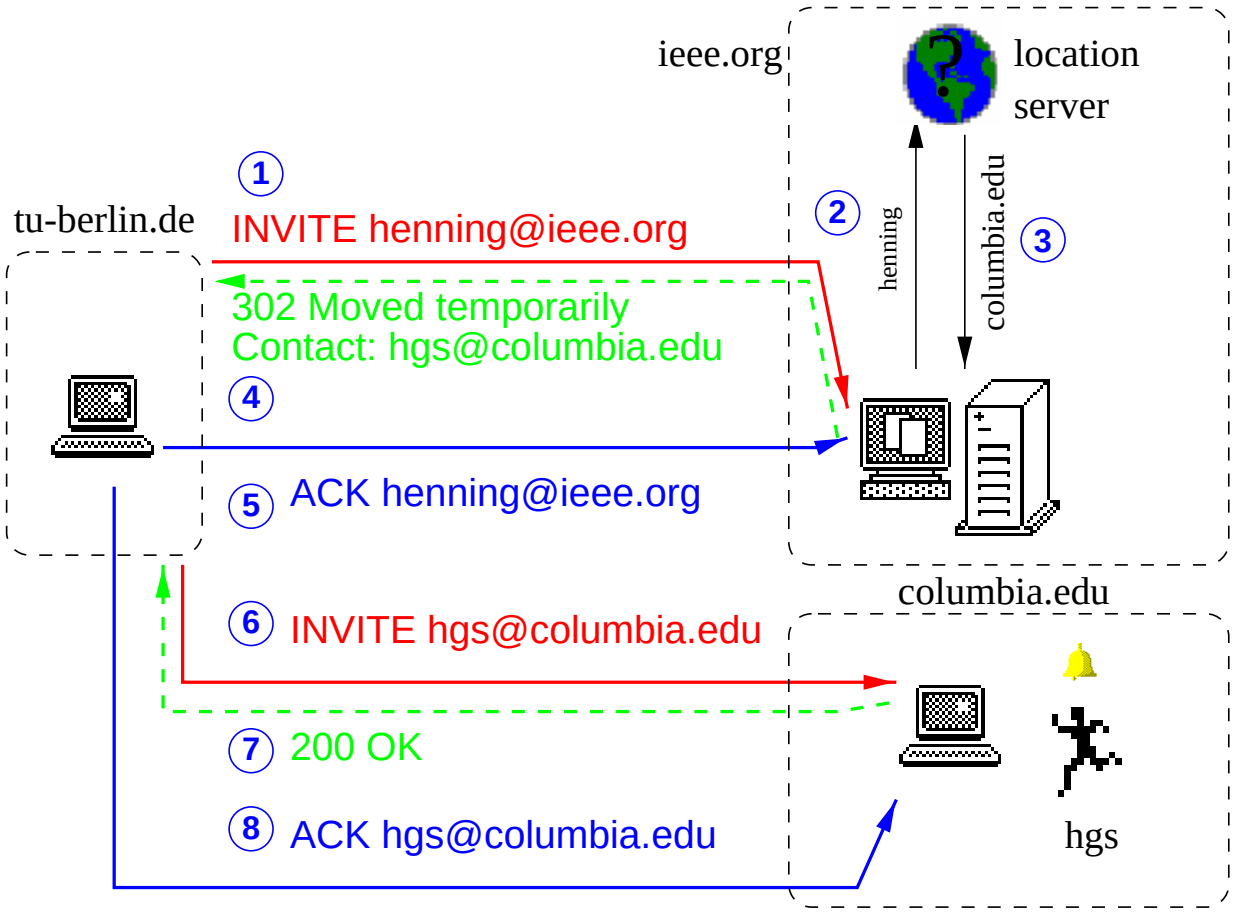
- locate user given email-style address
- set up session
- (re)-negotiate session parameters
- manual and automatic forwarding (“name/number mapping”)
- *personal mobility* ➠ different terminal, same identifier
- “forking” of calls: one call, multiple destinations
- terminate and transfer calls

SIP Components

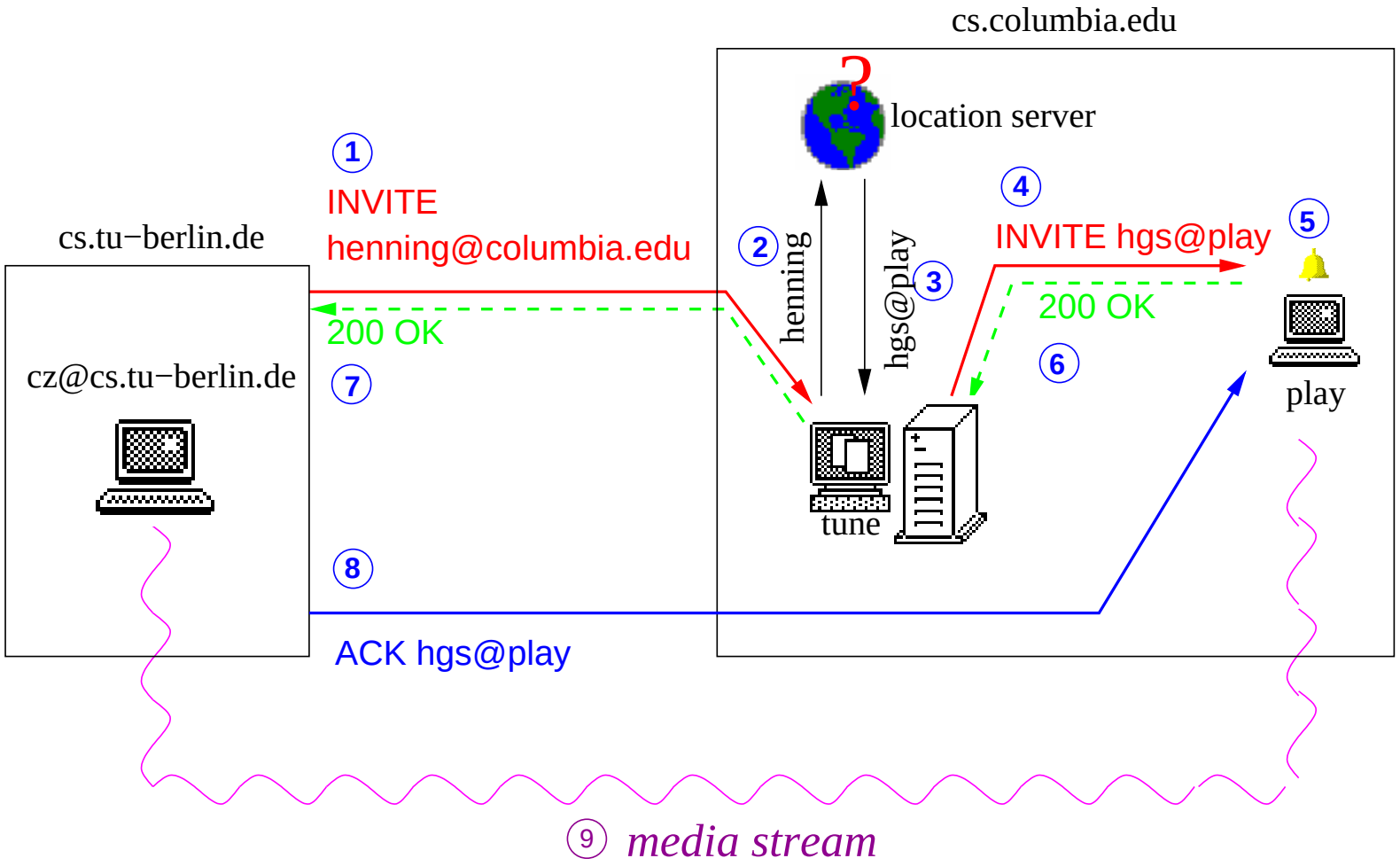
entity	does	examples
proxy server	forward calls	firewall controller, “call router”
redirect server		“application server”
user agent	end system	SIP phone, gateway, “softswitch”
registrar	location mgt.	mobility support

Roles are changeable, on a request-by-request basis

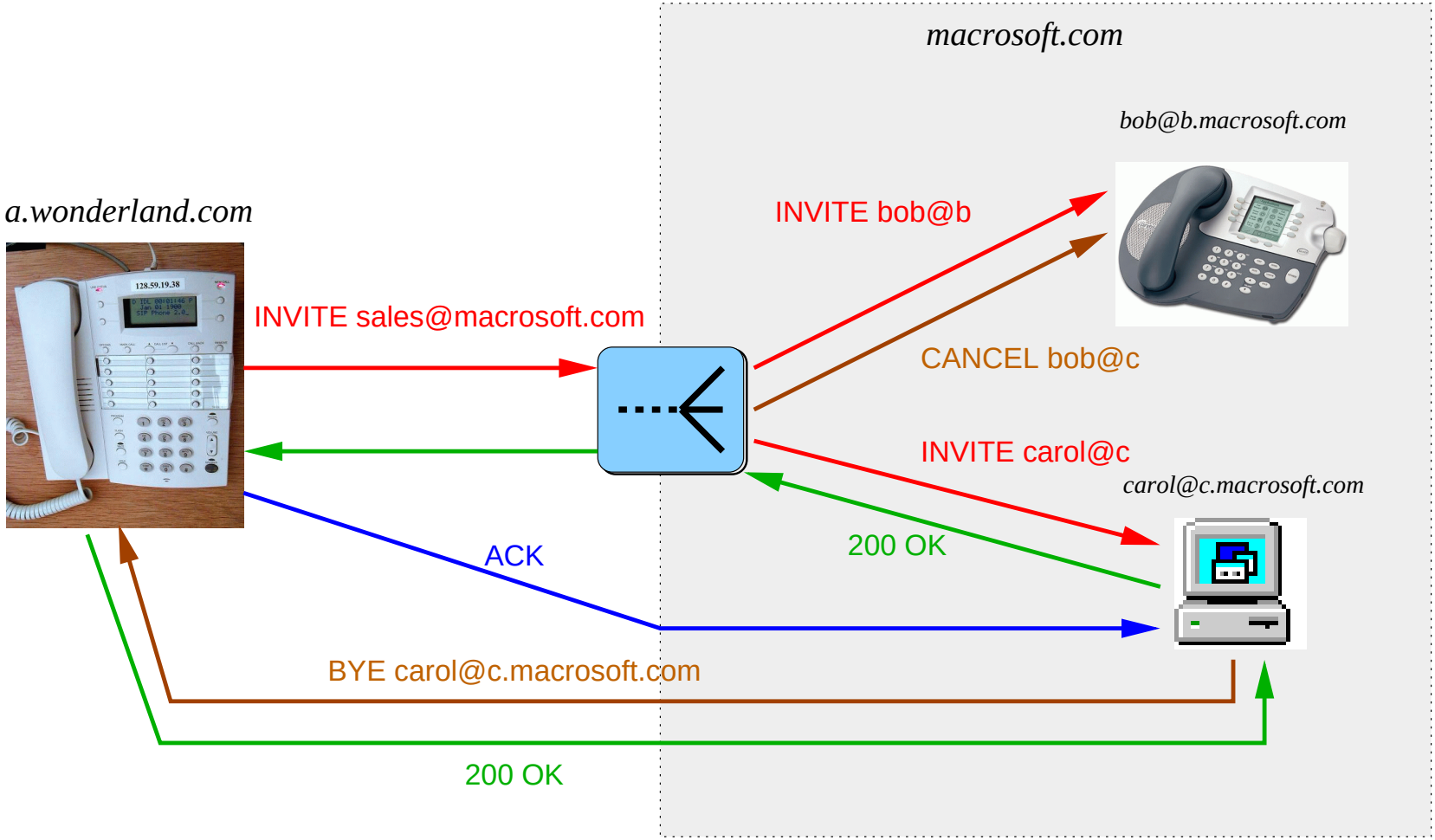
SIP example: redirection



SIP example: proxying



SIP forking proxies



Mobility in an IP environment

Roaming users: logging in away from home network: hotel, home office

Terminal mobility: terminal moves between subnets

Personal mobility: different terminals, same address

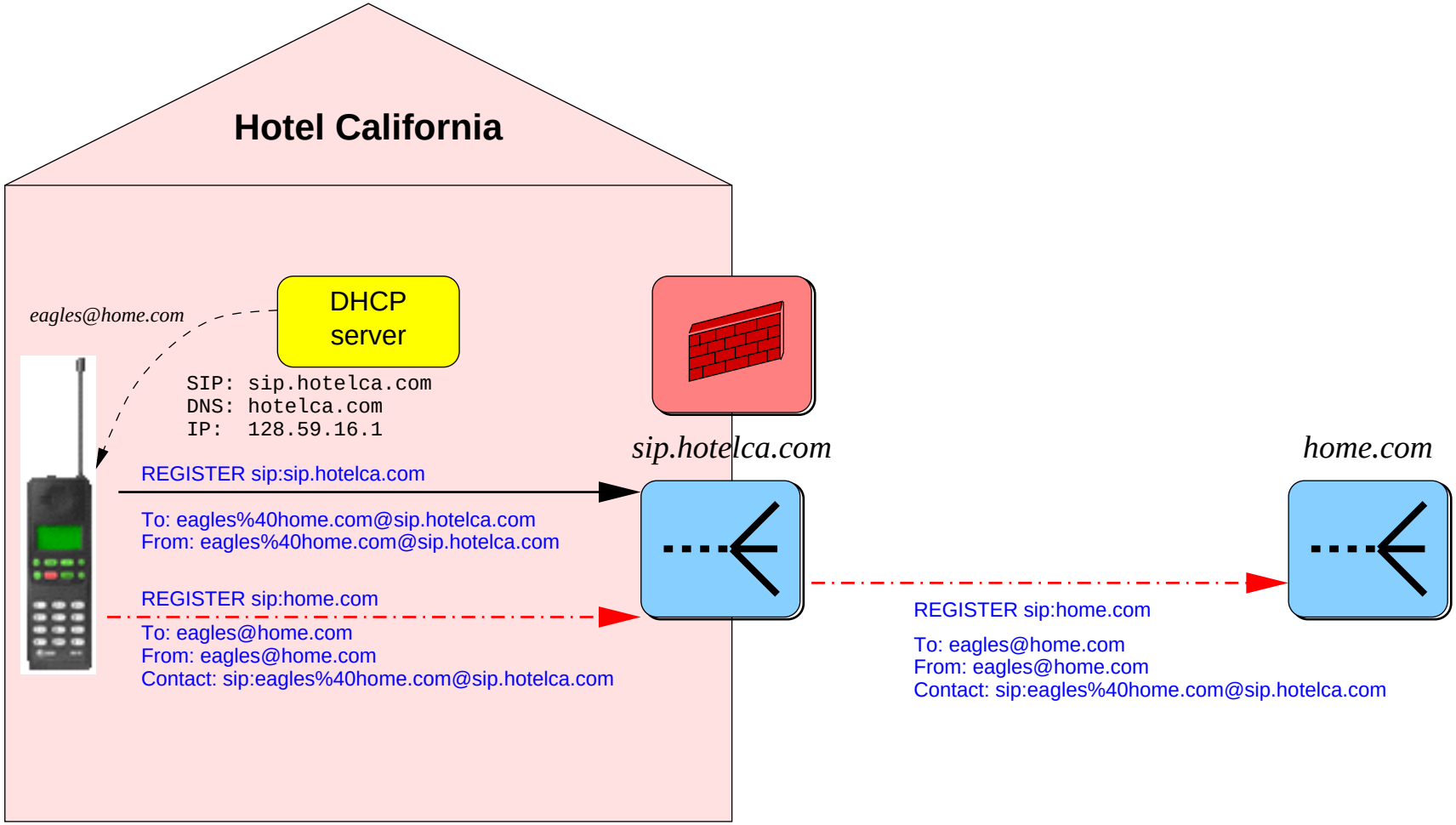
Service mobility: keep same services while mobile

Session mobility: move active session between terminals

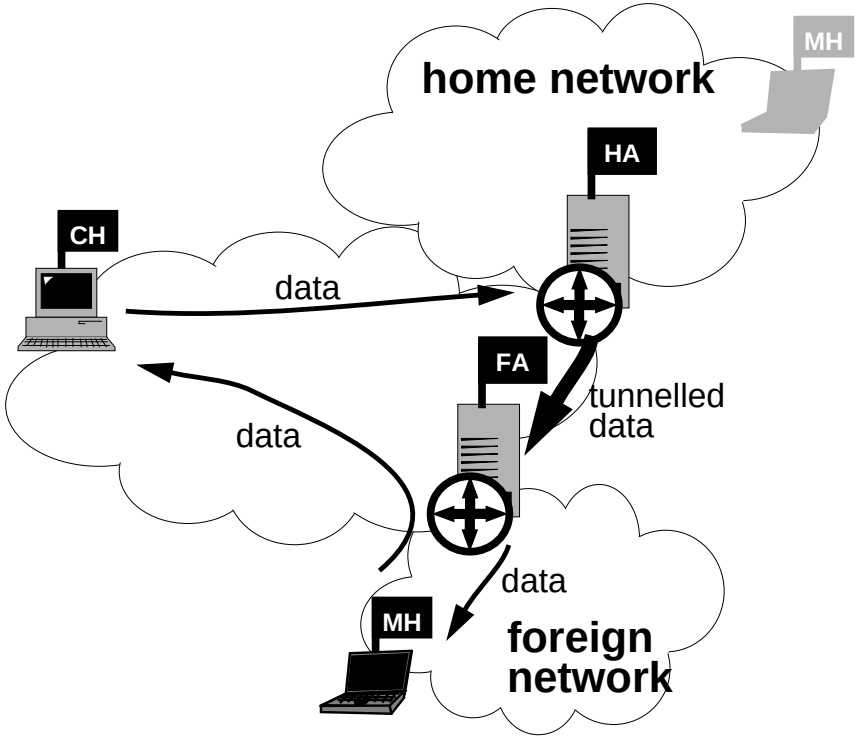
Simple mobility: roaming users

- users visit other networks: laptop, PDA, hotel phone, ...
- want to maintain external identity
- usually, just pass IP address to home registrar
- difficult if firewalls and NATs
  - requests need to use local proxy
  - thus, need to register locally

Roaming Users – Dual Registration



Terminal mobility – mobile IP



- MH mobile host
- CH correspondent host
- HA router with home agent functionality
- HA router with foreign agent functionality

Terminal mobility – mobile IP difficulties

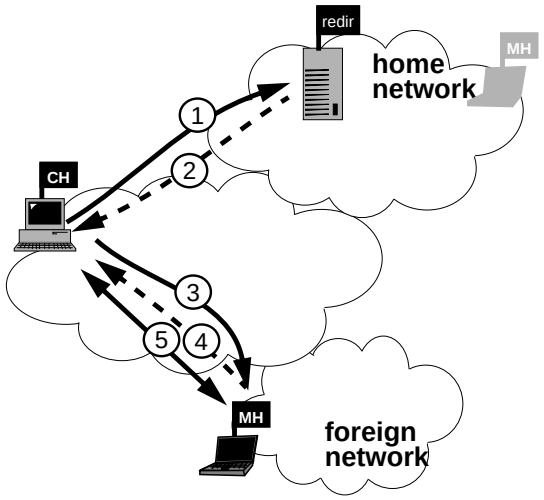
- domain of IEEE 802.11 (link layer), 3GPP (radio access network), mobile IP (network layer), . . .
- network-layer mobility has problems:
  - lack of deployment – home provider has no interest
  - need two addresses – home and visiting
  - dog-legged routing in IPv4
  - may not work with IP address filtering except through triangle routing
  - encapsulation overhead for voice: 8–20 bytes/packet for a 50-byte payload
  - authentication of redirection

SIP terminal mobility overview

- pre-call mobility ➠ SIP proxy, redirect
- mid-call mobility ➠ SIP re-INVITE, RTP
- recovery from disconnection

SIP terminal mobility: pre-call

- MH acquires IP address via DHCP
- optional: MH finds SIP server via multicast REGISTER
- MH updates home SIP server – deregister old, register new
- optimization: hierarchical LR (later)

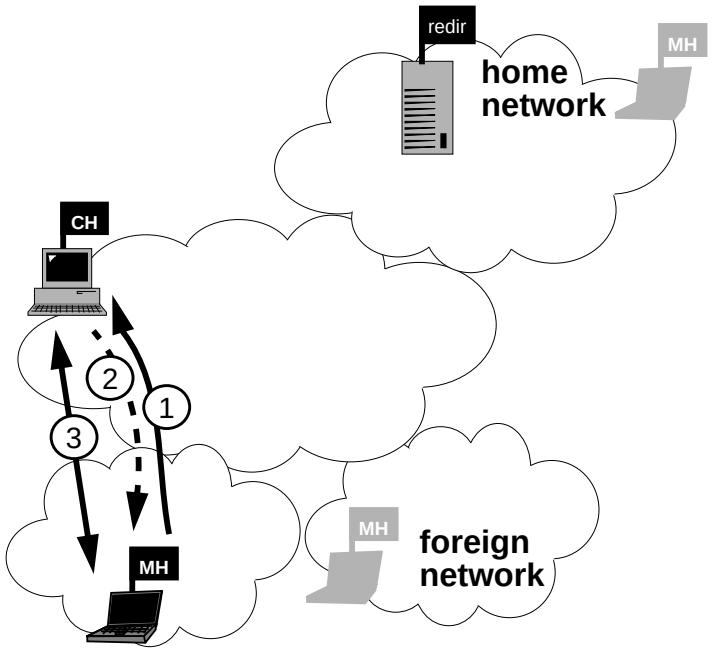


MH mobile host
CH correspondent host
redir SIP redirect server

1 SIP INVITE
2 SIP 302 moved temporarily
3 SIP INVITE
4 SIP OK
5 data

SIP terminal mobility: mid-call

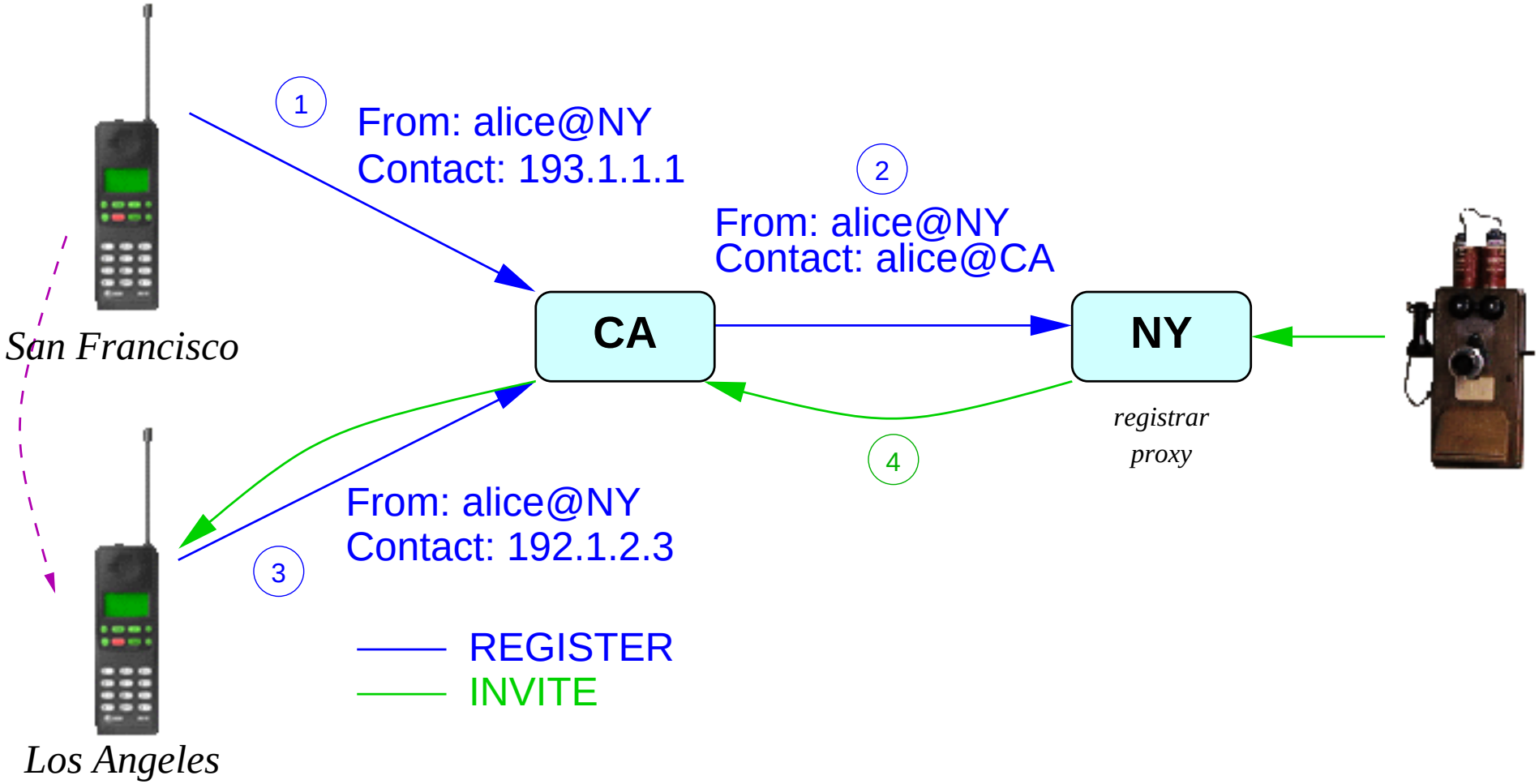
- MH→CH: new INVITE, with Contact header and updated SDP
- re-registers with home registrar
- requires one one-way delay



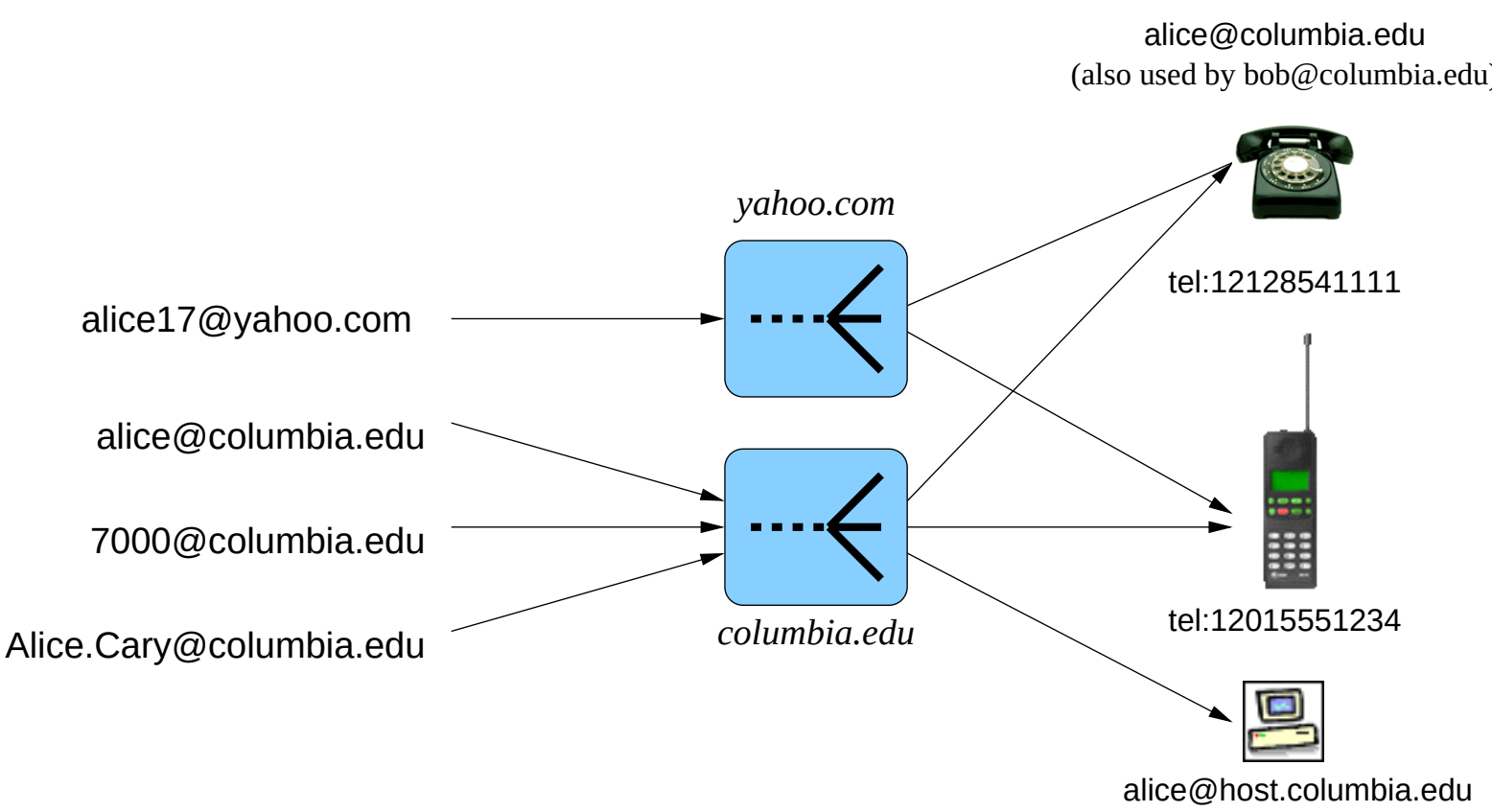
MH mobile host
CH correspondent host
redir SIP redirect server
1 SIP INVITE
2 SIP OK
3 data

SIP terminal mobility: multi-stage registration

Don’t want to bother home registrar with each move



Personal mobility



Personal mobility

- switch between PDA, cell phone, PC, Ethernet phone, Internet appliance, . . .
- several “generic” addresses, one person/function, many terminals
- e.g., `tel:2129397042`, `hgs@cs.columbia.edu`, `schulzrinne@yahoo.com` or `support@acme.com`
- SIP is designed for that – proxying and redirection does translation
- but: need mapping mechanisms to recognize registrations as belonging to the same person
- some possible solutions:
  - dip into LDAP personnel database or `/etc/passwd` to match phone number and variations of name (*J.Doe*, *John.Doe*, *Doe*)
  - need dialing plan to recognize `7042@cs.columbia.edu` and `tel:2129397042` as same

Service mobility

Examples:

- speed dial & address book
- media preferences
- special feature buttons (voice mail, do-not-disturb)
- incoming call handling instructions
- buddy lists
- features in home provider server

$\longrightarrow$ independent of terminal (including pay phone!), across providers

Service mobility

- REGISTER can retrieve configuration information (e.g., speed dial settings, distinctive ringing or voice mail settings)
- but needs to be device-independent
- most such services (e.g., voicemail forwarding, call filtering) should remain on server(s)
- use SIP Route mechanism to direct path of outgoing calls via home server

```
Route: <sip:alice@home.net>, <sip:alice@services-r-us.com>
```

Service mobility – call handling

- need uniform basic service description model $\longrightarrow$ Call Processing Language (CPL)
- CPL for local call handling
- update CPL from terminal: add telemarketer to block list
- harder: synchronize CPL changes across multiple providers
- one possibility: REGISTER updates information, but device needs to know that it has multiple identities
- merging of call logs

SIP and mobility: issues

- doesn't work for TCP applications – solutions:
  - punt: "don't type and drive"
  - application-layer awareness: restart web, email, ftp transfer – need for deep fade anyway...
  - TCP redirect (Snoeren/Balakrishnan)
  - NAT-style boxes controlled by SIP (see Telcordia ITSUMO project)
- fast hand-off via SIP proxies with media translators
- but: works nicely for "vertical handoff" between different technologies - e.g., transfer call from mobile handset to office videophone when arriving at work

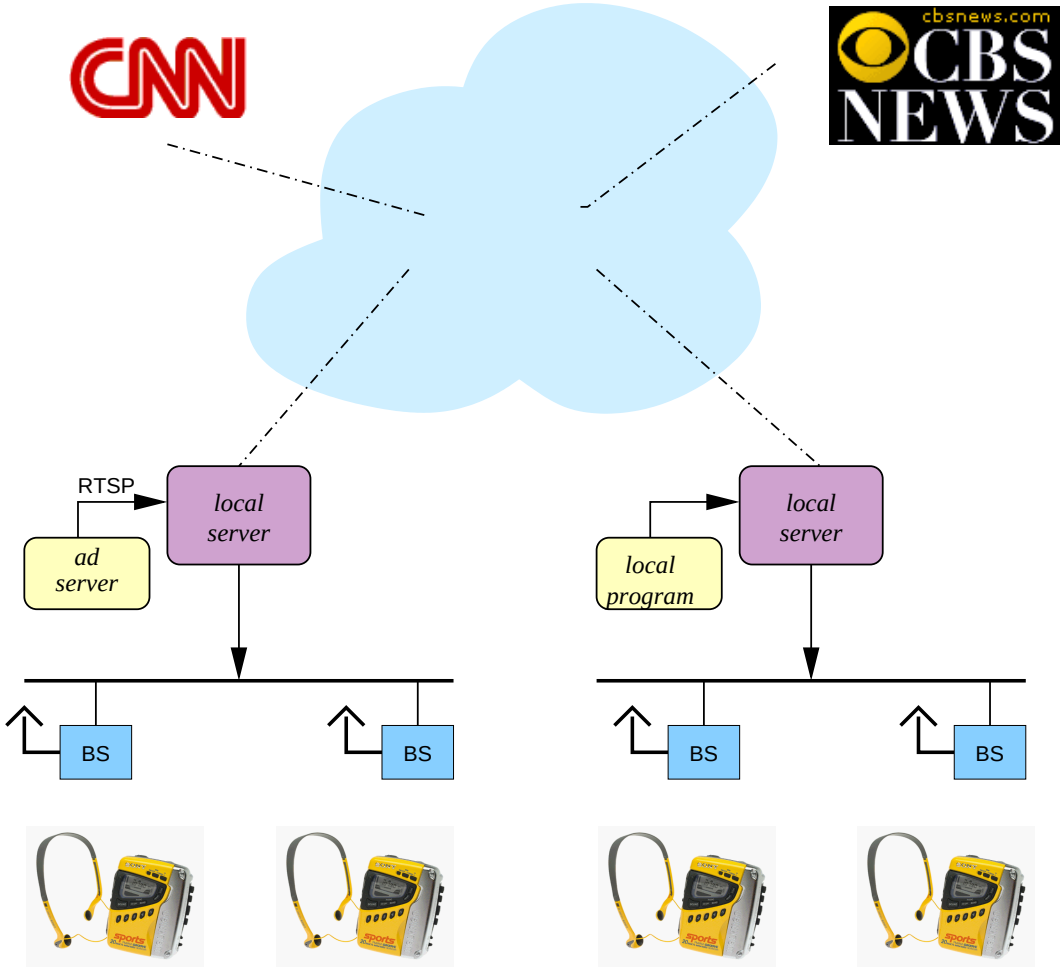
Conclusions for application-layer mobility

- uniform solution for wired and wireless multimedia terminals
- network-layer mobility neither sufficient nor available
- many common services don’t need network-layer support
- application-layer mobility for sessions
- one SIP-based approach for multimedia sessions, presence & events

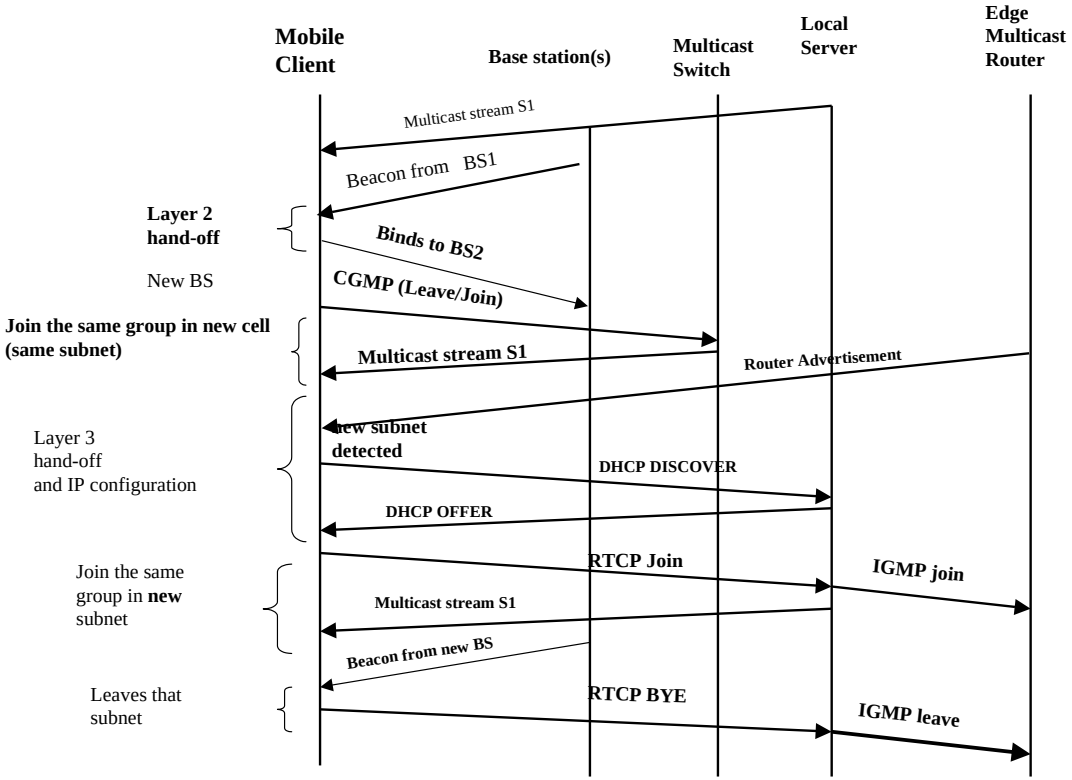
Internet radio

- multicast in LANs widely available
- insert local content and advertisements
- caching if Internet not multicast-enabled
- mobility issues

Internet radio



Multicast handoff



Internet radio

- can either use scoped multicast or re-assign multicast via scoped SAP
- mobility issues:
  - hand-off detection
  - address acquisition
  - IGMP leave latency (bandwidth)
  - IGMP join latency

Conclusion

- next-generation wireless expensive, late, slow
- ➠ non-traditional mobility
- non-traditional infrastructure
- sporadic connections
- complementary mobility at the application layer
- mobility for multicast, not just unicast