# Advanced Computer Networks

Network Architectures

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Summer 2015

# More on the course

- Course project (55%)
  - any topic related to computer networks
    - it's your job to justify (and I can help)
    - let me know the team/**topics**/resources by May 19
  - possible approaches: measurement, experimentation, modeling, analysis, simulation, emulation, evaluation
    - pick at least two of the above approaches
    - csc466: survey and qualitative evaluation
    - csc579: survey, qualitative and quantitative evaluation
  - final deliverables
    - project presentations (one mid, one final), project report

# From topics to ideas...

- Your course project “ideas”
  - rough ideas: use my feedback on your A0 as well
  - individual or team; resources possibly needed
  - to extend existing things, or create something new
    - extend your existing projects; new work evaluated
  - due to me by email next *Monday*
    - email subject: [csc466] or [csc579] project ideas
    - group project: only one mail, copy to all team members
  - please discuss (on connex) and submit on time
  - I will aggregate and report to you next Thursday
    - so you can attract/recruit your team members
  - project proposal due by the end of this month

# More on the course

- Course reading and presentation (25%)
  - pick topics from the reading list
    - Internet design, network architectures
    - **overlay networks, peer-to-peer networking**
    - congestion control, network routing, traffic management
    - network characterization and your proposed topics
  - choose papers from the reading list
    - the reading list is still being updated
    - **you can also recommend papers (not in the list yet)!**
      - from recent ACM/IEEE/USENIX conferences
      - SIGCOMM, IMC, Mobicom, MobiHoc, INFOCOM, ICNP, P2P, Globecom, ICC, etc

# Internet Design

- What do we have so far (in early 90's)?
  - Internet Protocol Suite
    - store-and-forward packet switching
    - end-to-end arguments
    - TCP/IP designed, implemented and deployed
  - a growing Internet
    - connected machines, users, coverage, traffic
  - Web
    - in addition to remote login, file transfer, electronic mail



* internet history 1962 to 1992 http://www.computerhistory.org/internet_history/

# “What's next?”

- [She95] **S. Shenker, "Fundamental Design Issues for the Future Internet". IEEE Journal on Selected Areas in Communications, Vol. 13, No. 7, September 1995, p p. 1176-1188.**
- [CWRB02] D. Clark, J. Wroclawski, K. Sollins, and R. Braden, Tussle in Cyberspace: Defining Tomorrow's Internet , Proceedings of ACM SIGCOMM '2002. [tussle]



* SDN?

# “The current Internet”

- Best-effort [BE] data service
  - no admission control
  - no service assurance
    - no guarantee on delivery
    - reliability achieved end-to-end (mostly by TCP)
  - still mostly true TODAY!
- Well-suited for ***elastic*** applications
  - adaptive to available bandwidth, delay, loss, etc
  - adaptive to network congestion

* philosophy?

# What's new?

- Multimedia “real-time” applications
  - voice over IP (VoIP)
    - delay, jitter
  - IP television (IPTV)
    - bandwidth, delay
  - massive multi-player online gaming (MMOG)
    - delay, many users
- The problems: how to
  - fit into the BE architecture
  - coexist with existing applications

# The goal of network design

- Network is an infrastructure
  - to make user/application “happy”
  - the applications just get diversified
    - so do the application requirement
- How to measure the user “happiness”?
  - utility function
    - as a function of performance measures
    - e.g., throughput, delay, loss
  - proportional to how much the user is willing to pay
- The network efficacy: the sum of utilities



* utility function examples on blackboard

# How to increase network efficacy

- Throw in more resources
  - e.g., overprovisioning
    - when resources are really cheap
  - no extra mechanisms necessary
- Service differentiation
  - example: priority queue
    - M/M/1 queue
    - different utility functions
  - increase system complexity
- Integrated or separate networks?



* IntServ and DiffServ

# Internet architectures

- Design principles
  - store-and-forward packet switching
  - end-to-end arguments
  - “best-effort” services
- “Hour glass” protocol model
  - application: telnet, ftp, email, web, voip, ...
  - transport: TCP, UDP, RTP, SCTP
  - network: IP/ICMP
  - subnetwork: Ethernet, ATM, FDDI, PPP, ...

# New requirements

- Service
  - better than “best-effort”, quality of service (QoS)
- **Scalability (growth)**
  - next generation IP (IPv6) vs NAT
- Multicast
  - IP Multicast vs application/overlay multicast
- Mobility
  - Mobile IP (MIP)
- Security



* computation, storage, communication and energy efficiency

# Middle boxes

- Challenges to “end-to-end arguments”
- Application
  - e.g., web proxy, cache server, load balancer
  - e.g., SIP border controller
- Transport
  - e.g., SOCK
- Network
  - e.g., stateful firewall
  - e.g., network address translator (NAT)

# How does NAT work?

- Address translation
  - address mapping creation
- Packet filtering
  - based on created address mapping
- NAT behaviors
  - full cone, restricted cone, port-restricted cone
  - symmetric

# NAT: pros and cons

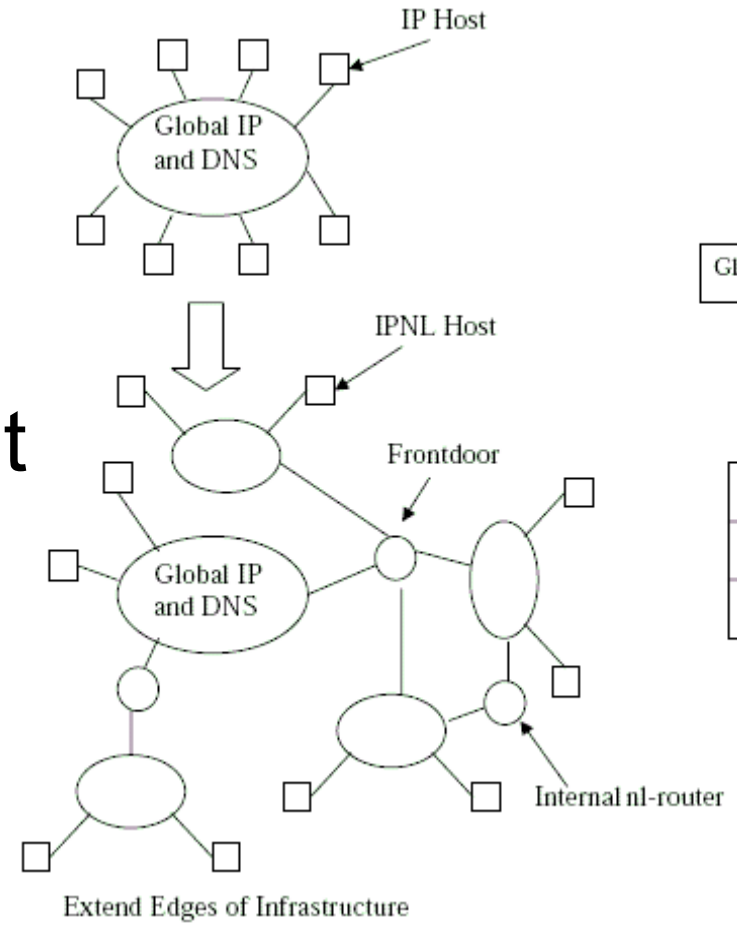
- Pros
  - extend IPv4 address space
  - make site renumbering easy
    - address isolation
- Cons
  - no longer always “global addressable”
    - need extra mechanisms (e.g., NAT traversal)
  - the loss of “end-to-end”
    - complicate network design and operation

# What's next?

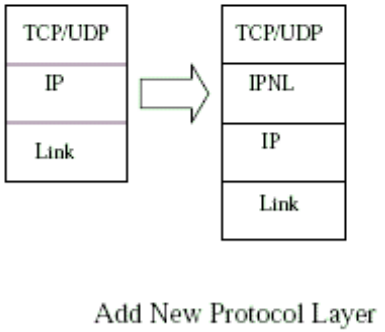
- Think out of the box!
- IP Next Layer (IPNL) [FG01]
  - reuse the existing infrastructure
    - IPNL is just above IPv4 and routed by NAT boxes
  - use FQDN as end-host identifier
    - fully qualified domain name
  - extend IP address space
    - global (unique) address + private (reusable) address
  - isolate site addressing
    - easy site renumbering

# IPNL at the edge

- Growth at edge
  - front-door NL router
  - internal NL router
- IPNL only “visible” at
  - end-host
    - above IPv4
  - NL routers

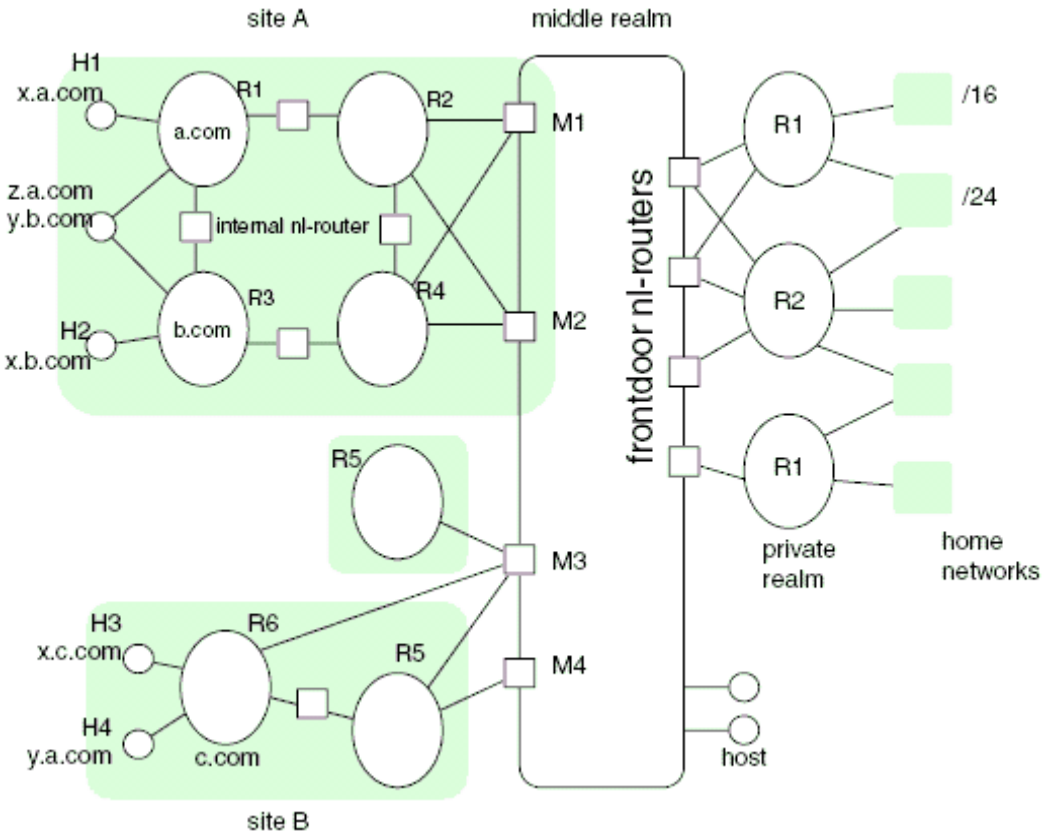






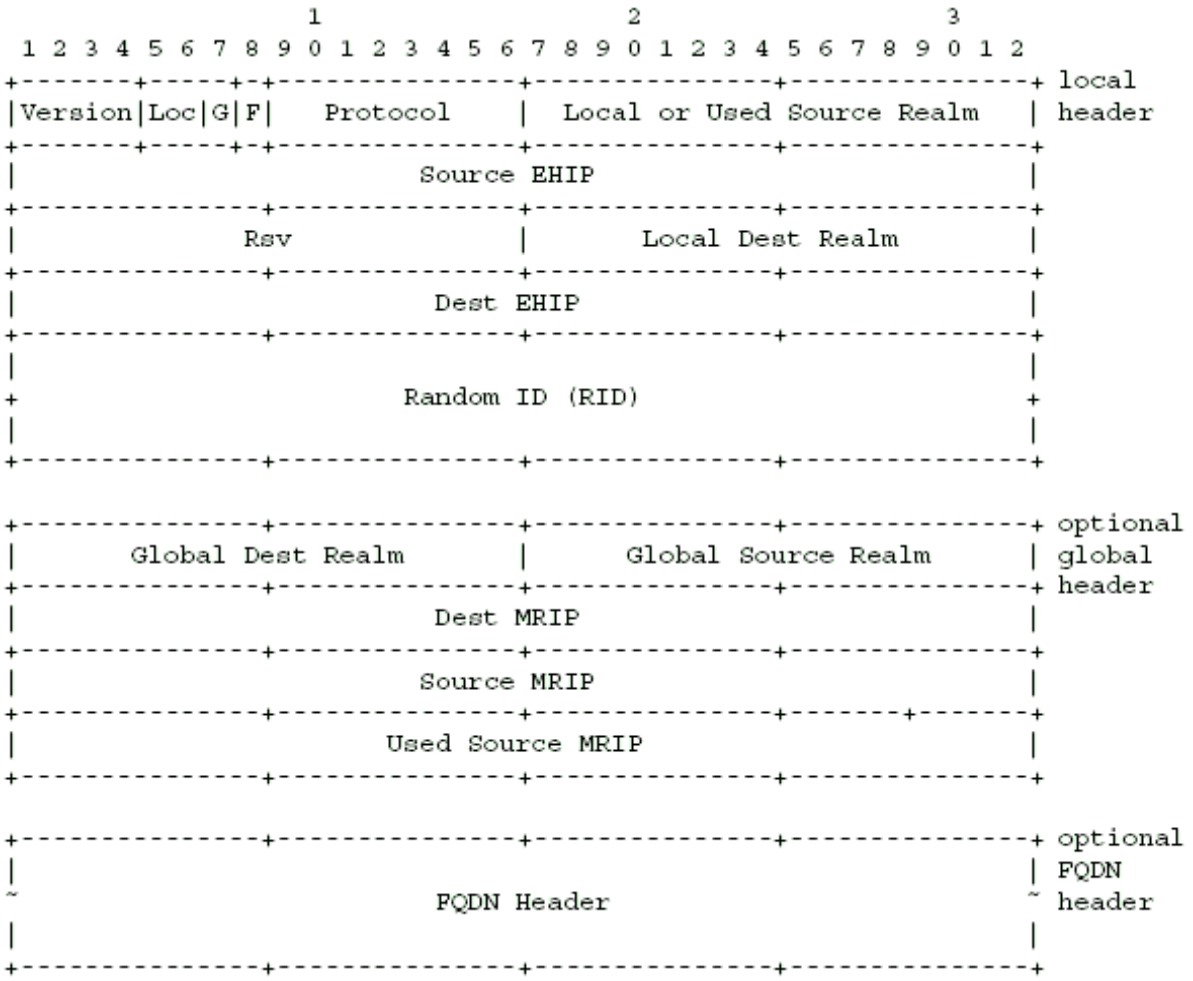
# IPNL: more details

- Multi-homing
  - z.a.com
  - y.b.com
- Mobility
  - visiting: y.a.com
  - visited: c.com
- Realm vs site



# IPNL routing: address and name

- MRIP
  - middle realm IP
  - frontdoor's
- RN
  - realm number
  - behind frontdoor
- EHIP
  - end-host IP
  - within a realm



# Site address isolation

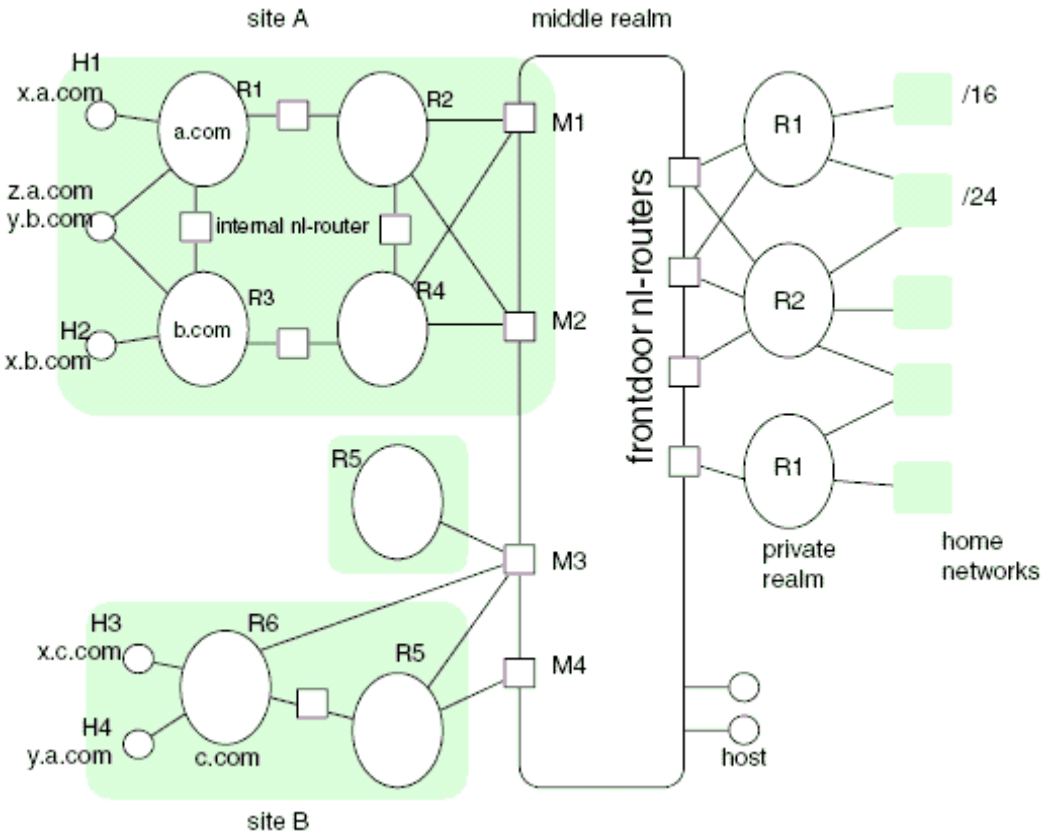
- Separate local vs global header
  - end-host is only configured with
    - EHIP: local identity in a realm
    - FQDN: global identity (long term, unique)
  - “local” packets have no MRIP
    - behind the same frontdoor
- Realm number independence
  - local vs global realm number
  - global RN allocated by the frontdoor

# More on site isolation

- In-flight IPNL address resolution (late-binding)
  - End host should know the destination's FQDN
    - destination MRIP resolved by frontdoor
    - source RN and MRIP added by internal/frontdoor
      - received “used source” for return packets
    - destination RN and EHIP added by dest frontdoor/internal
- Location field (2-bit)
  - behind the source frontdoor
  - in the middle
  - behind the destination frontdoor

# Examples

- H1-H3
  - through middle realm
- H1-H2
  - behind the same frontdoor
- H1-z.a.com
  - in the same realm
- H1-H4
  - “redirect”



# Robustness

- In-band trace
  - learn how to send from what has been received
    - list of MRIP for the destination
    - list of MRIP+RN for the destination
    - the latest “used source MRIP+RN” for the destination
- Path discovery
  - progressive path discovery

# Discussion

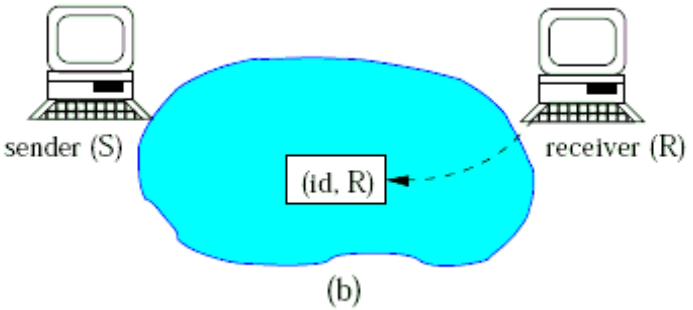
- Internet addressing and routing
  - IP address has both roles
    - 5-tuple for session identification
  - difficult to support mobility
  - discourage spoofing somehow
- IPNL approach
  - FQDN primarily as an identifier
  - IPNL address primarily as a locater
  - random ID (RID) for session protection

# Internet Indirection Infrastructure [I3]

- "any computer science problems can be solved by introducing another layer of indirection..."
- Traditional client-server model
  - server should be ready first
  - client is active, server is passive
    - client request followed by server response
- Traditional send-receive model
  - receive should be ready first
  - send is active, receive is passive

# Rendezvous-based communication

- insertTrigger(t);
- sendPacket(p);
- removeTrigger(t); // optional



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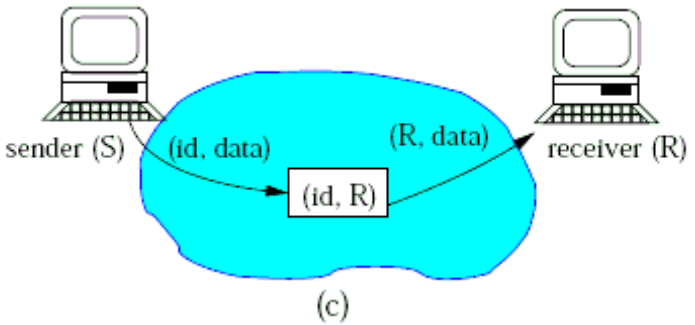
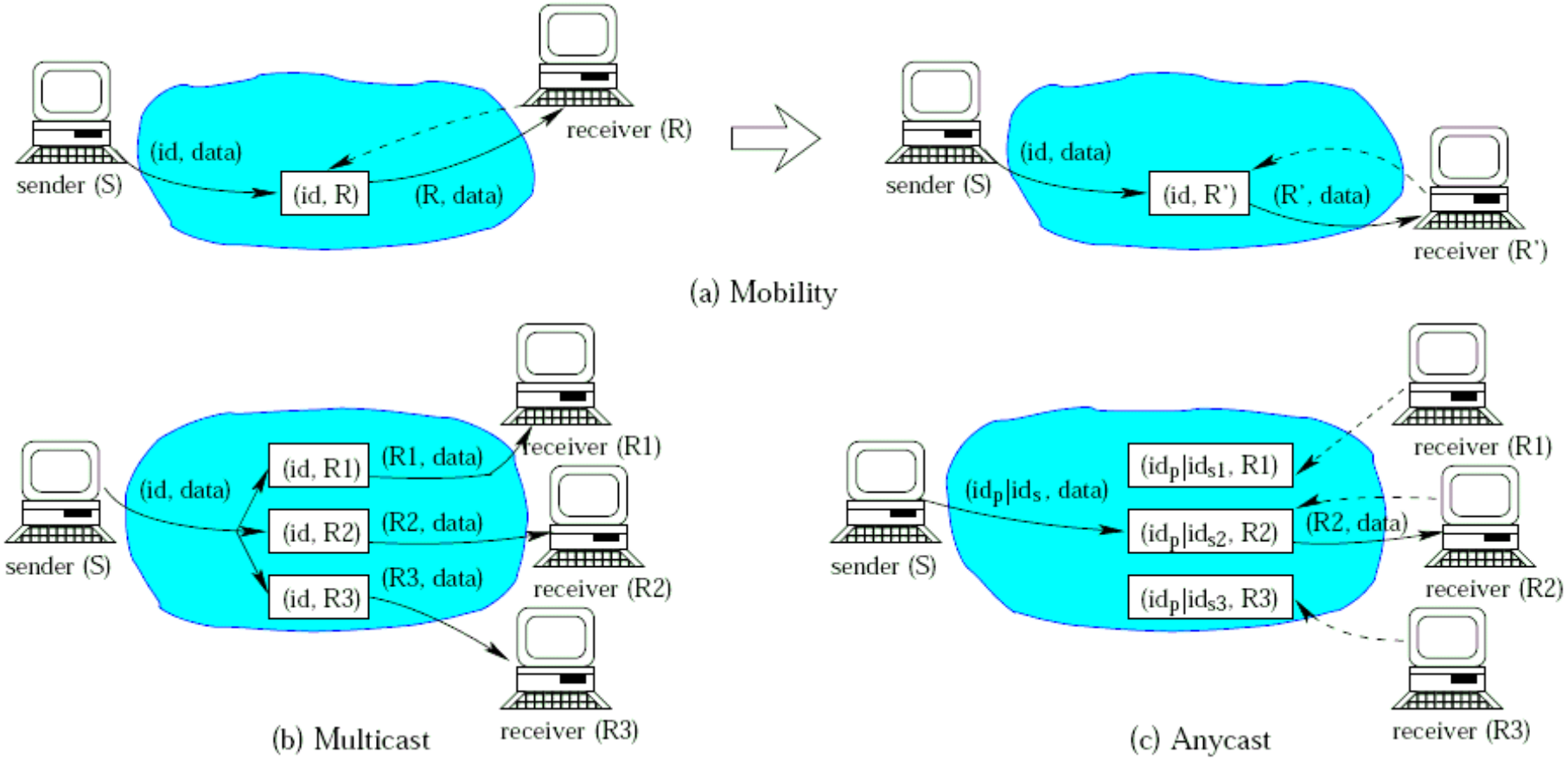
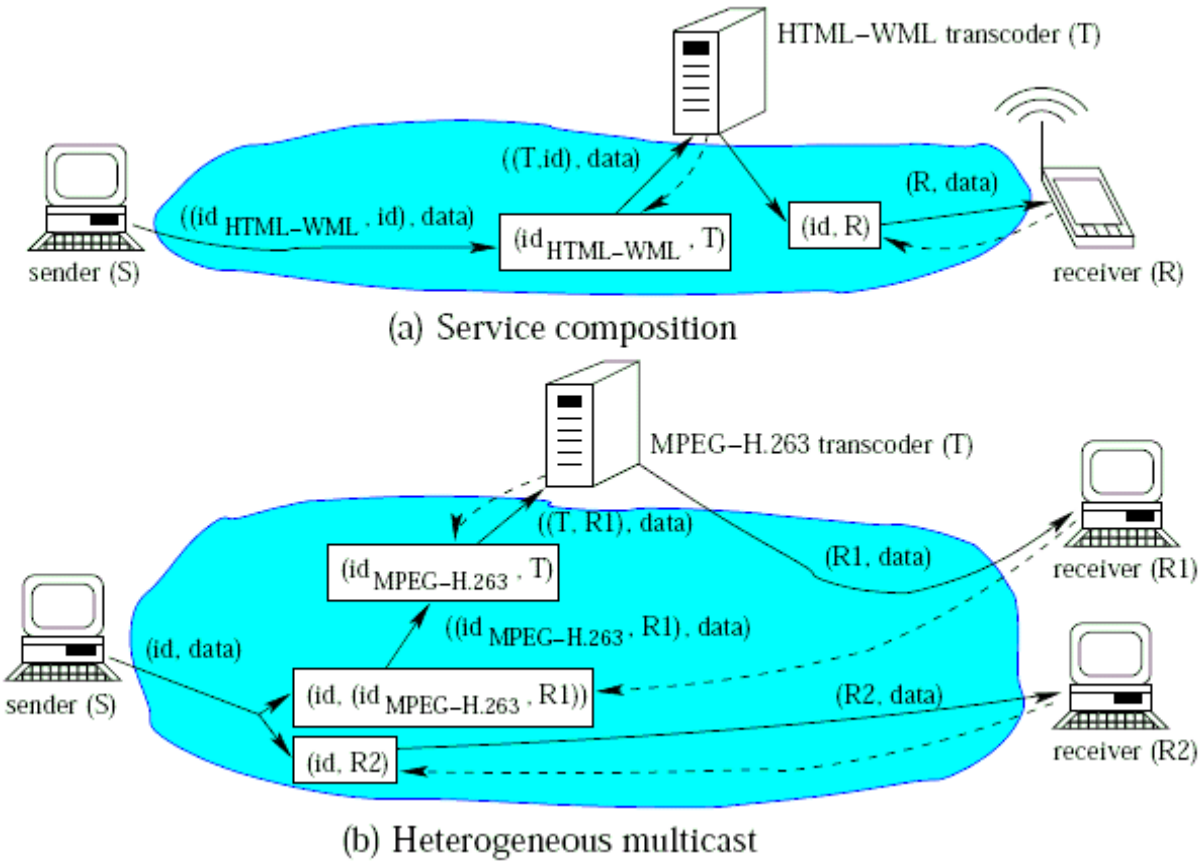


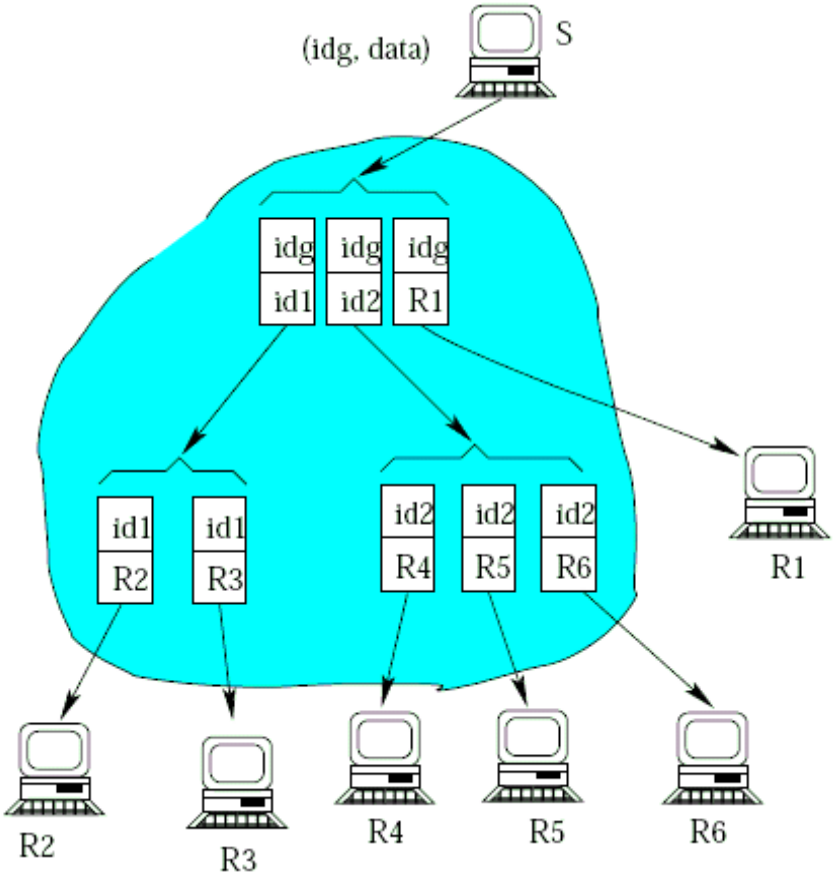
(c)

# Some applications



# More examples



# This lecture

- (some new) Internet architecture designs
  - IPNL: an extension to NAT
  - I3: indirection
- A1: course project ideas
  - due May 19, to pan@uvic.ca
  - any topic related to computer networks
    - you should justify it and I can help
    - final deliverables: report+presentation plus prototype
  - next checkpoint (end of May)
    - 1-page project proposal

# Explore further

- NSF Future Internet Network Design (FIND)
- NSF Future Internet Architecture (FIA)
  - Named Data Networking (NDN)
  - MobilityFirst
  - NEBULA
  - eXpressive Internet Architecture (XIA)
  - ChoiceNet
- Similar/related initiatives in Canada, Europe, Asia, etc

# Next lectures

- Overlay and peer-to-peer networking
  - required reading
    - [ABKM01] D. Anderson, H. Balakrishnan, F. Kaashoek, R. Morris, Resilient Overlay Networks, In Proc. of SOSP '01. [RON]
    - [SMKKB01] Ion Stoica, Robert Morris, David Karger, Frans Kaashoek, Hari Balakrishnan, "Chord: A Scalable Peer-to-peer Lookup Service for Internet Applications," Proceedings of the 2001 ACM SIGCOMM Conference, August 2001. [Chord]

# Interested in problem solving?

- UVic Programming Club
  - also selection for ACM ICPC competition
    - http://www.csc.uvic.ca/icpc
  - mailing list
    - http://groups.google.com/group/uvicicpc
  - recruitment for
    - undergrad and first-year grad: potential contestants
    - all students: student coaches
  - previous achievements
    - http://panlab.cs.uvic.ca/webb/viewtopic.php?t=3414
- Training sessions planned
  - first meeting May 20, 5:30pm in ECS660