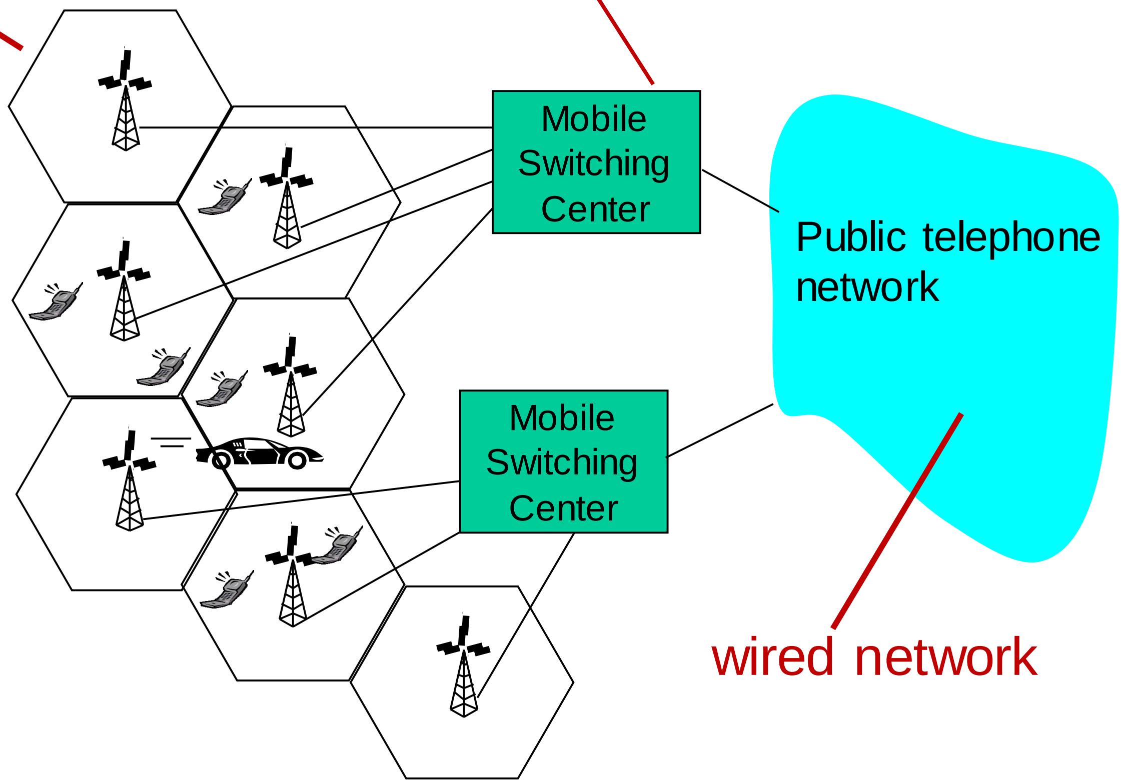
Module 4
Wireless and Mobile Networks
Q & A

1. Briefly explain the components of cellular architecture with a neat diagram

Components of cellular network architecture

MSC
- connects cells to wired tel. net.
- manages call setup (more later!)
- handles mobility (more later!)

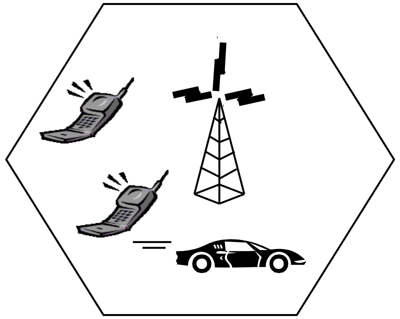
cell
- covers geographical region
- *base station* (BS) analogous to 802.11 AP
- *mobile users* attach to network through BS
- *air-interface:* physical and link layer protocol between mobile and BS

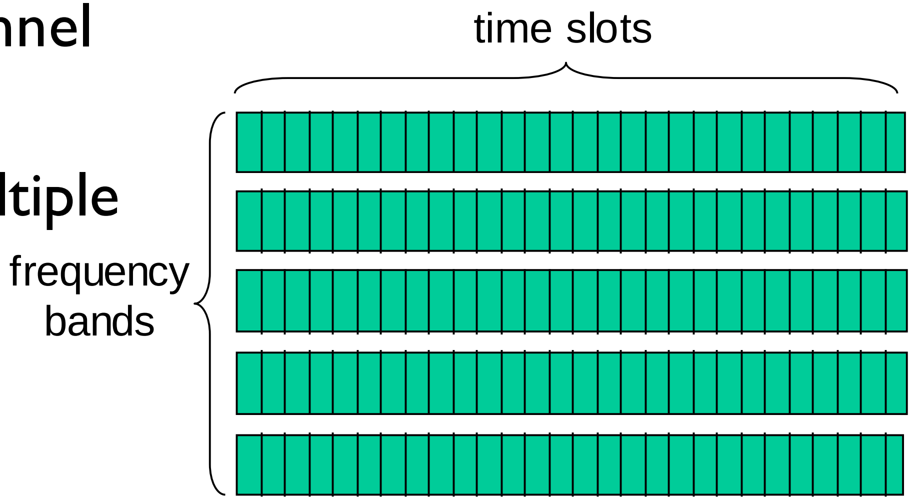


Cellular networks: the first hop

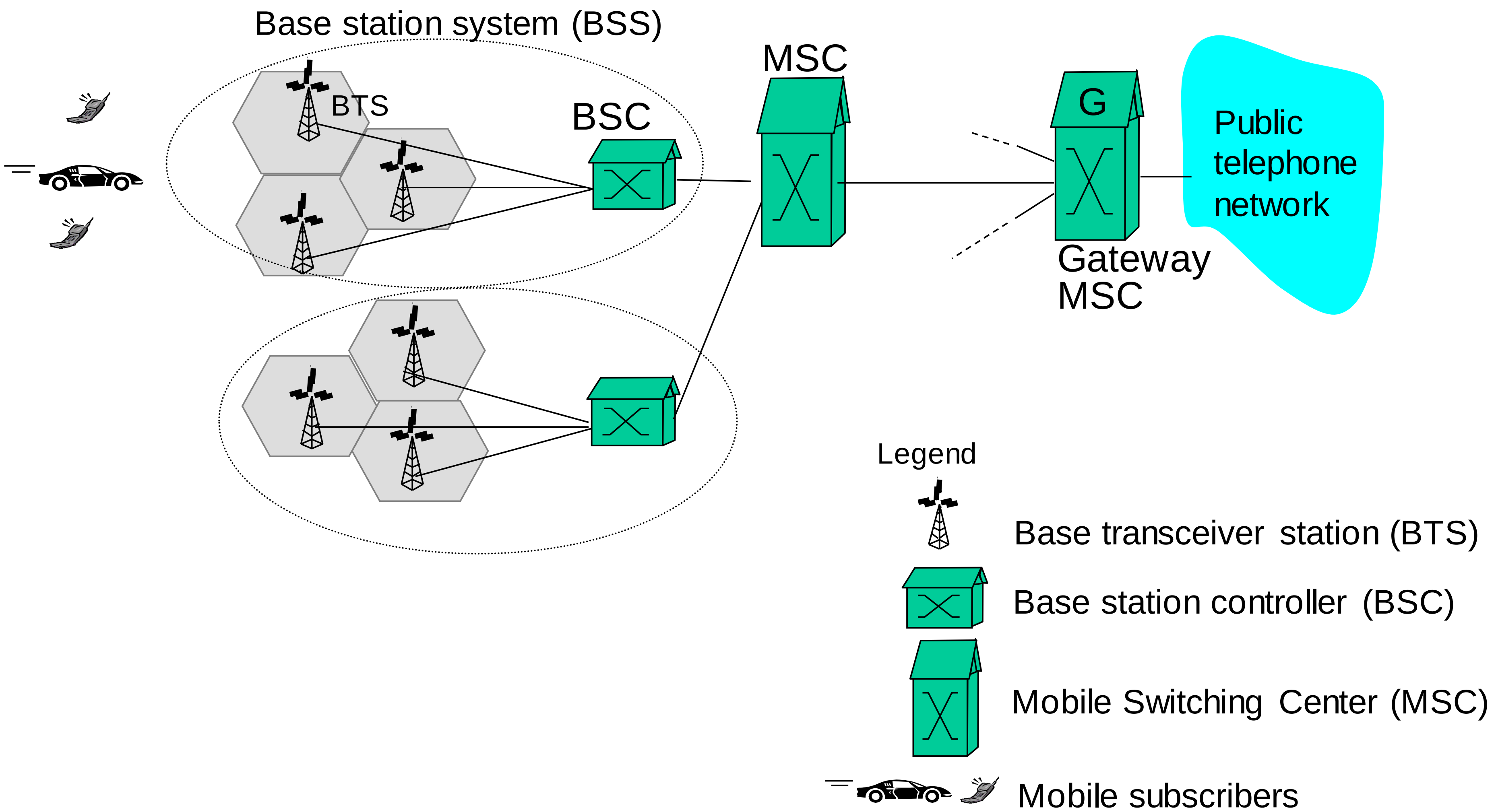
Two techniques for sharing mobile-to-BS radio spectrum

- combined FDMA/TDMA: divide spectrum in frequency channels, divide each channel into time slots
- CDMA: code division multiple access

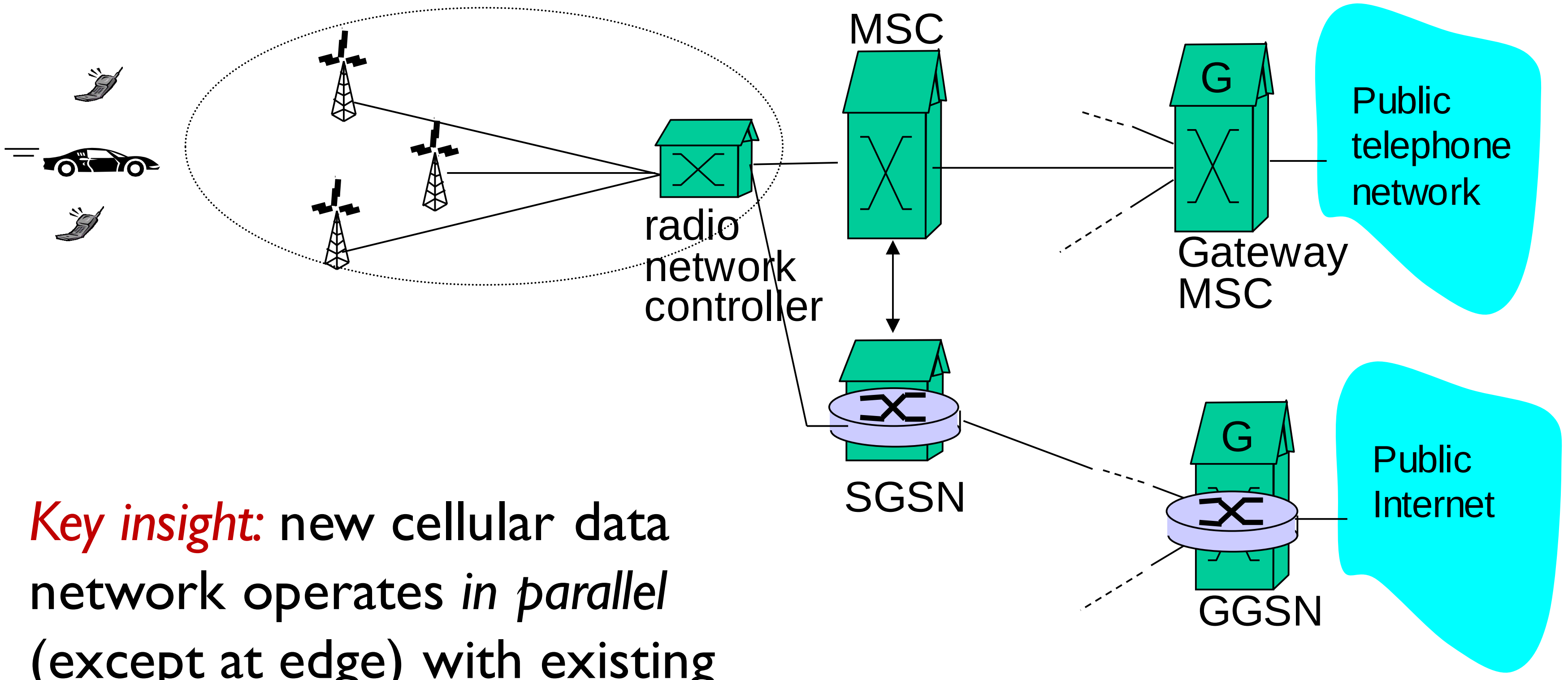




2G (voice) network architecture

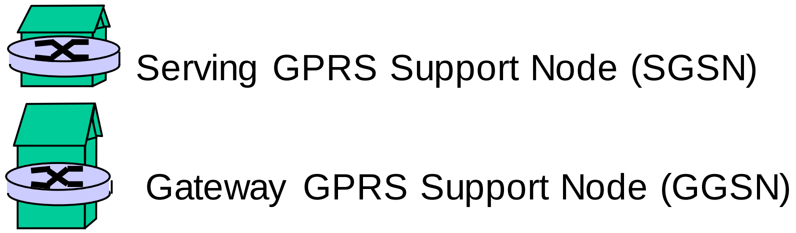


3G (voice+data) network architecture

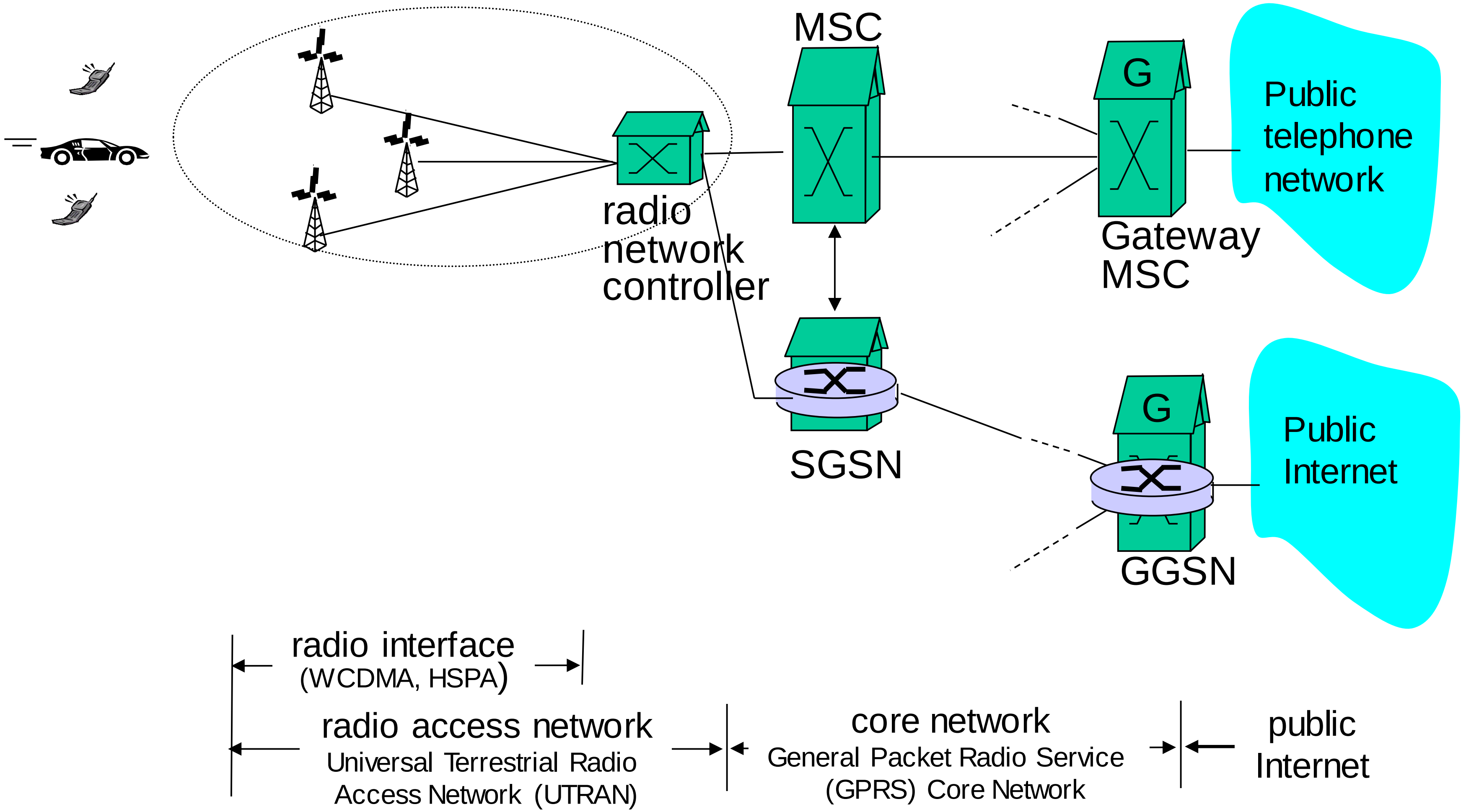


Key insight: new cellular data network operates *in parallel* (except at edge) with existing cellular voice network

- voice network unchanged in core
- data network operates in parallel



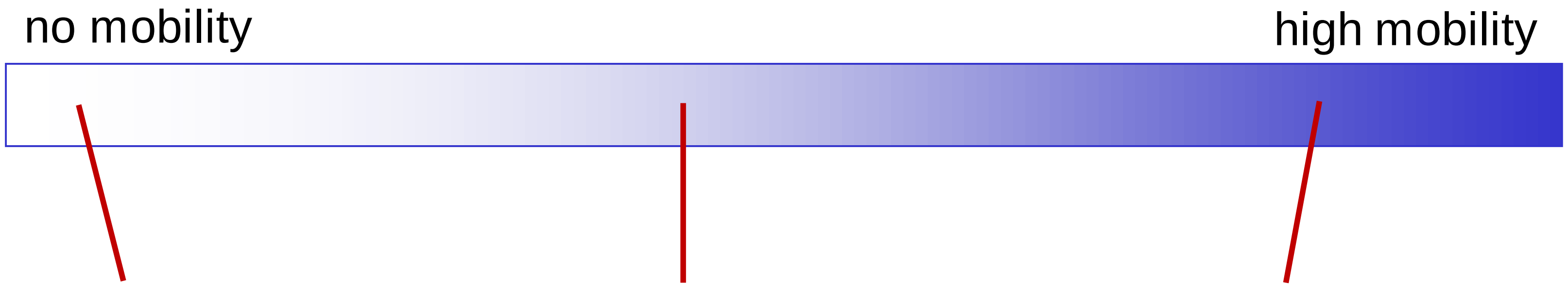
3G (voice+data) network architecture



2. What is mobility? Mention the approaches of mobility with a neat diagram

What is mobility?

- spectrum of mobility, from the *network* perspective:



mobile wireless user, using same access point

mobile user, connecting/ disconnecting from network using DHCP.

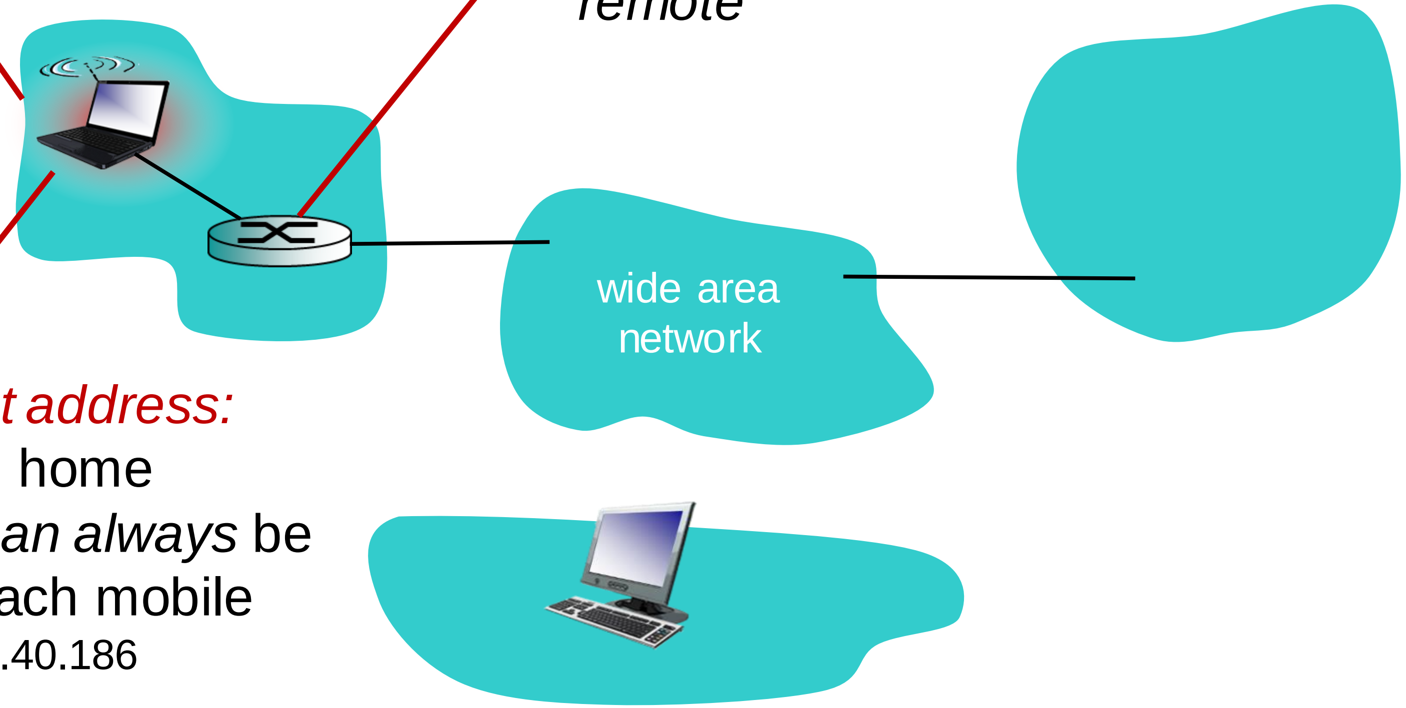
mobile user, passing through multiple access point while maintaining ongoing connections (like cell phone)

Mobility:

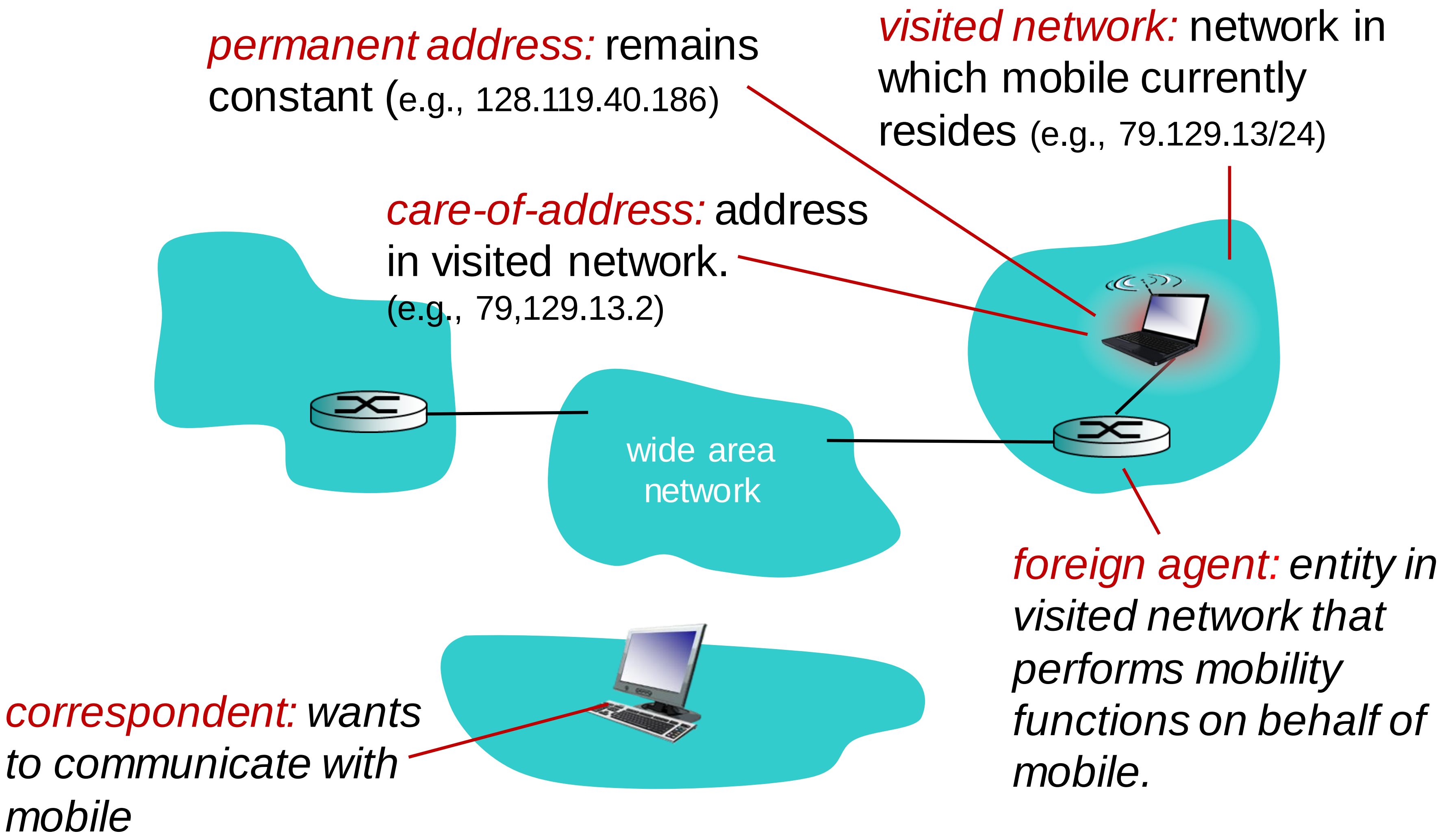
home network: permanent "home" of mobile
(e.g., 128.119.40/24)

home agent: entity that will perform mobility functions on behalf of mobile, when mobile is remote

permanent address:
address in home network, *can always* be used to reach mobile
e.g., 128.119.40.186



Mobility:



permanent address: remains constant (e.g., 128.119.40.186)
visited network: network in which mobile currently resides (e.g., 79.129.13/24)
care-of-address: address in visited network. (e.g., 79,129.13.2)
wide area network
foreign agent: entity in visited network that performs mobility functions on behalf of mobile.
correspondent: wants to communicate with mobile

Mobility: approaches

- *let routing handle it:* routers advertise permanent address of mobile-nodes-in-residence via usual routing table exchange.
  - routing tables indicate where each mobile located
  - no changes to end-systems
- *let end-systems handle it:*
  - *indirect routing:* communication from correspondent to mobile goes through home agent, then forwarded to remote
  - *direct routing:* correspondent gets foreign address of mobile, sends directly to mobile

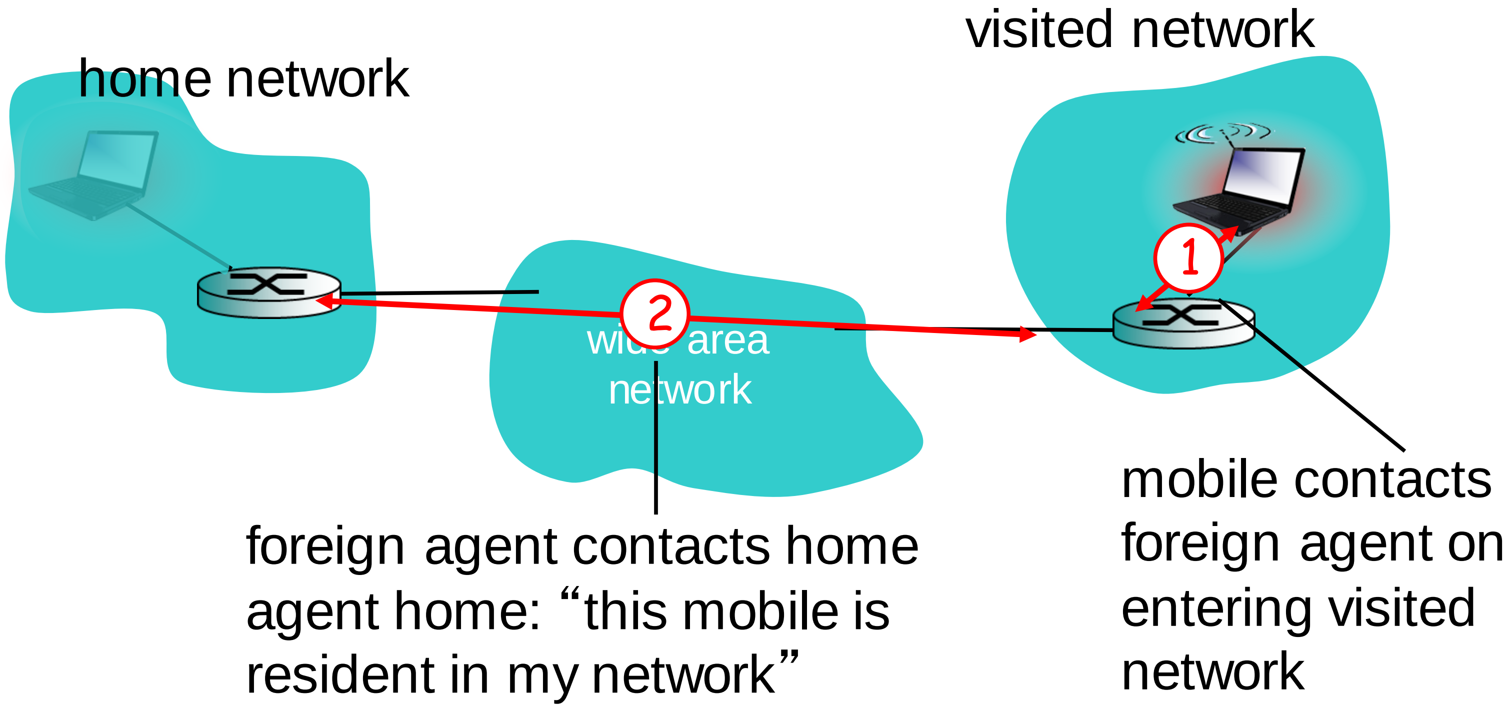
Mobility: approaches

- *let routing handle it:* ro... advertise permanent address of mobile-nodes-in-r... sual routing table exchange.
  - routing tables ... each mobile located
  - no changes to e...

not scalable to millions of mobiles

- *let end-systems handle it:*
  - *indirect routing:* communication from correspondent to mobile goes through home agent, then forwarded to remote
  - *direct routing:* correspondent gets foreign address of mobile, sends directly to mobile

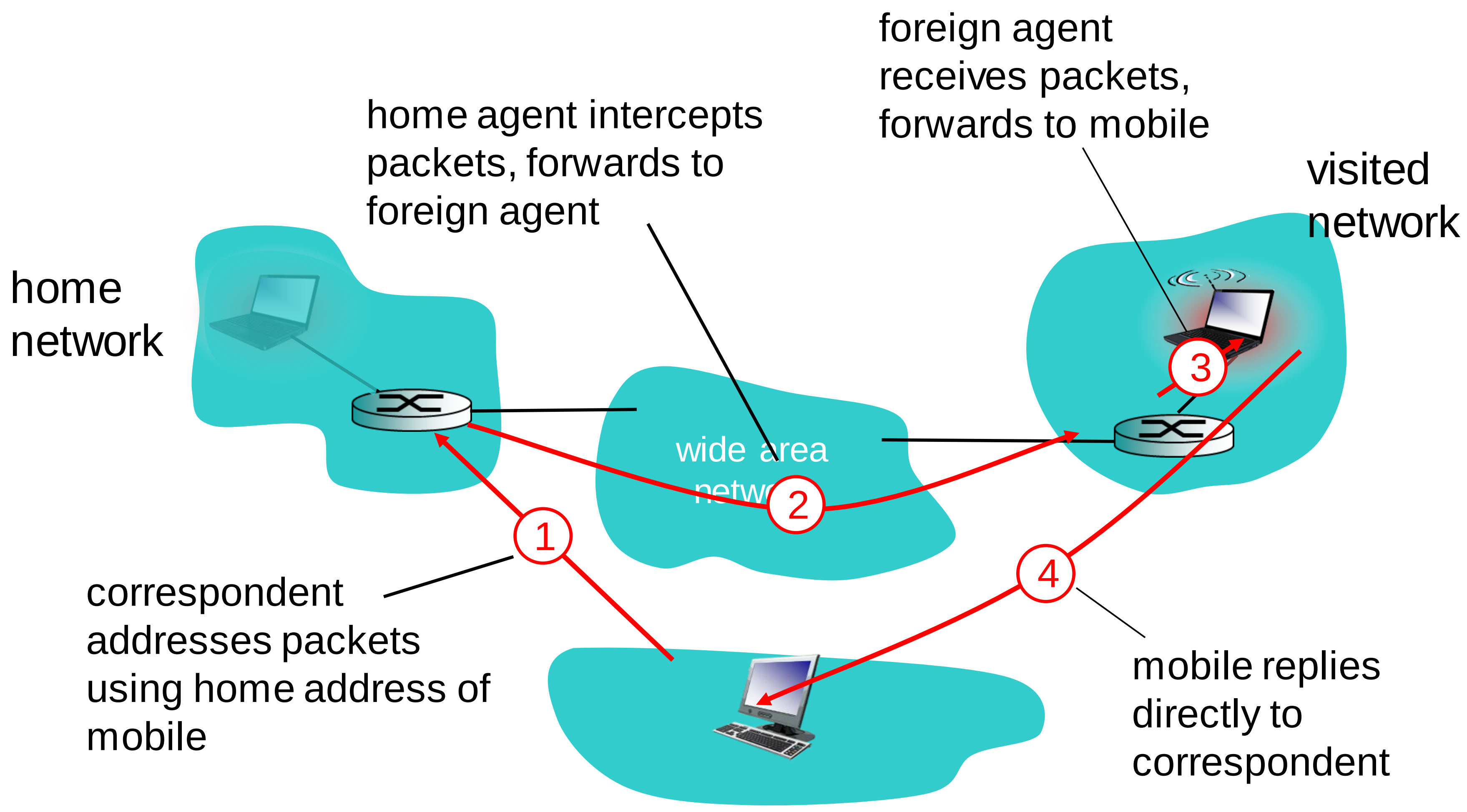
Mobility: registration



end result:

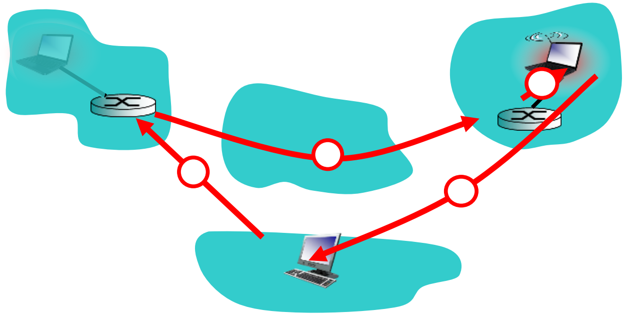
- foreign agent knows about mobile
- home agent knows location of mobile

Mobility via indirect routing



Indirect Routing: comments

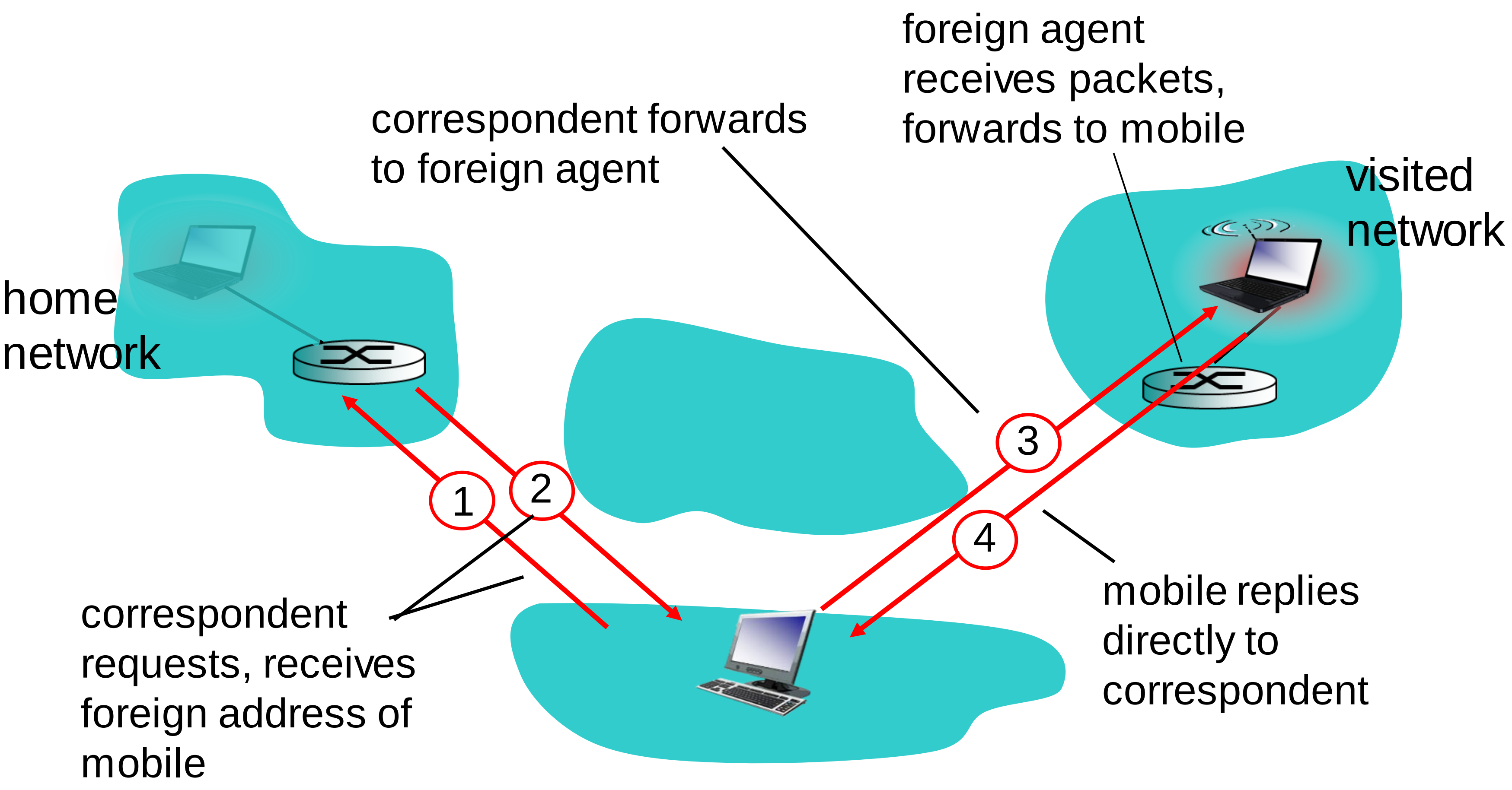
- mobile uses two addresses:
  - permanent address: used by correspondent (hence mobile location is *transparent* to correspondent)
  - care-of-address: used by home agent to forward datagrams to mobile
- foreign agent functions may be done by mobile itself
- triangle routing: correspondent-home-network-mobile
  - inefficient when correspondent, mobile are in same network



Indirect routing: moving between networks

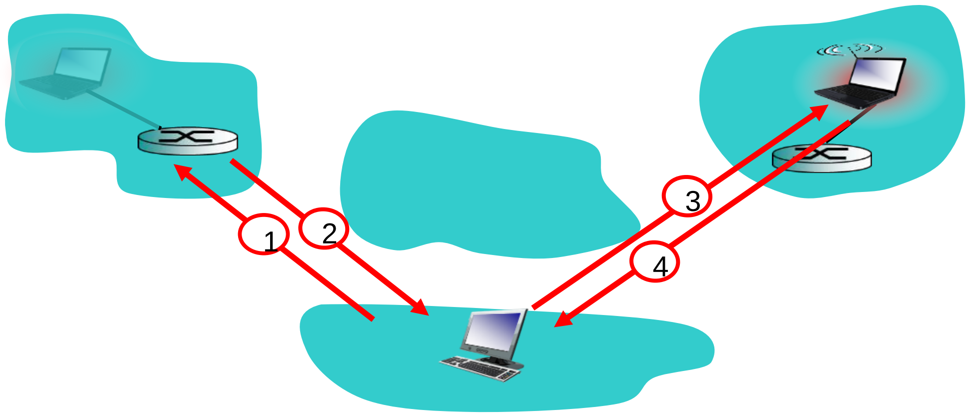
- suppose mobile user moves to another network
  - registers with new foreign agent
  - new foreign agent registers with home agent
  - home agent update care-of-address for mobile
  - packets continue to be forwarded to mobile (but with new care-of-address)
- mobility, changing foreign networks transparent: *on going connections can be maintained!*

Mobility via direct routing



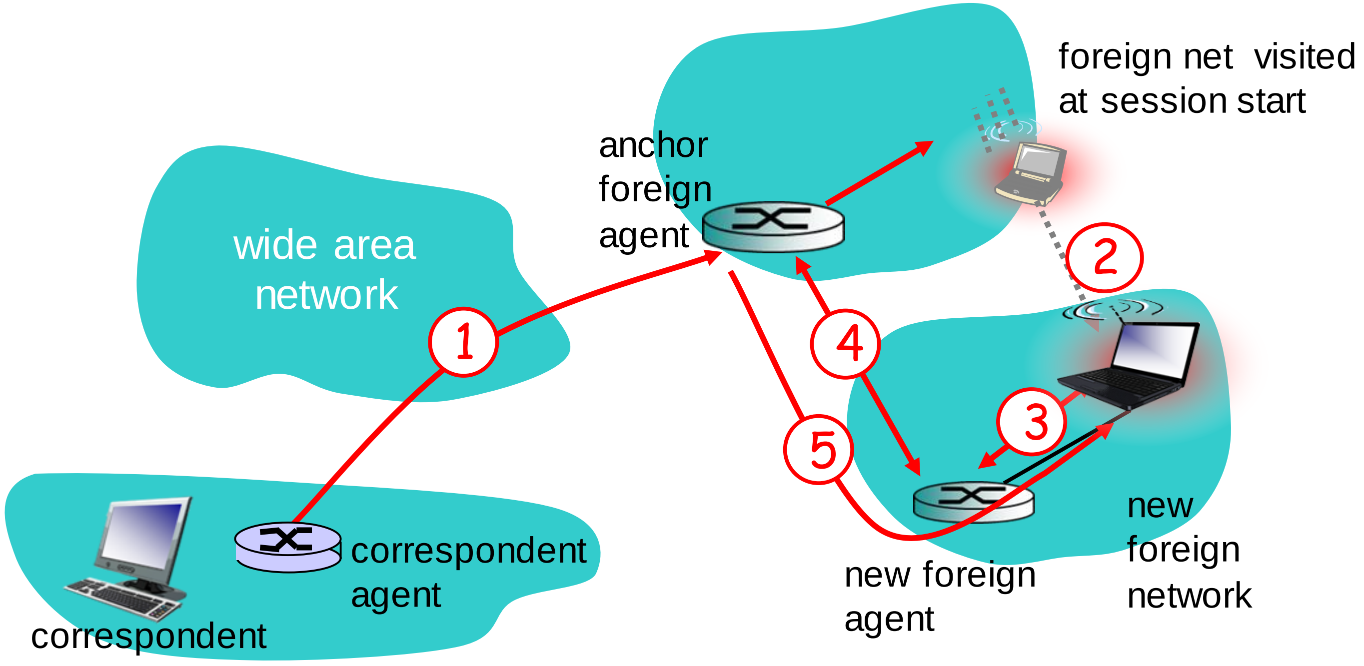
Mobility via direct routing: comments

- overcome triangle routing problem
- *non-transparent to correspondent:* correspondent must get care-of-address from home agent
  - what if mobile changes visited network?



Accommodating mobility with direct routing

- anchor foreign agent: FA in first visited network
- data always routed first to anchor FA
- when mobile moves: new FA arranges to have data forwarded from old FA (chaining)

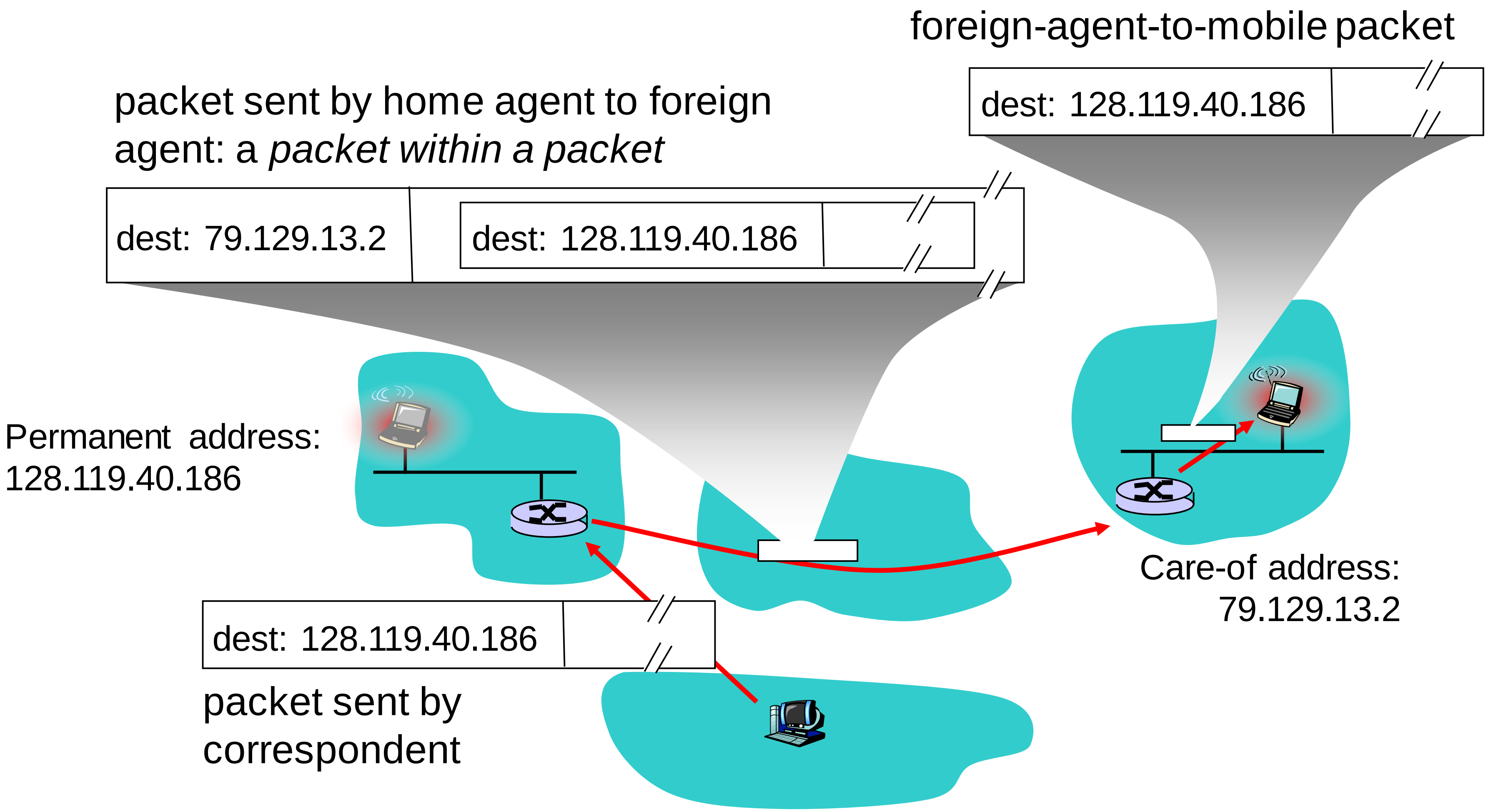


3. Write a short notes on MobileIP and explain the components of MobileIP with a neat diagram

Mobile IP

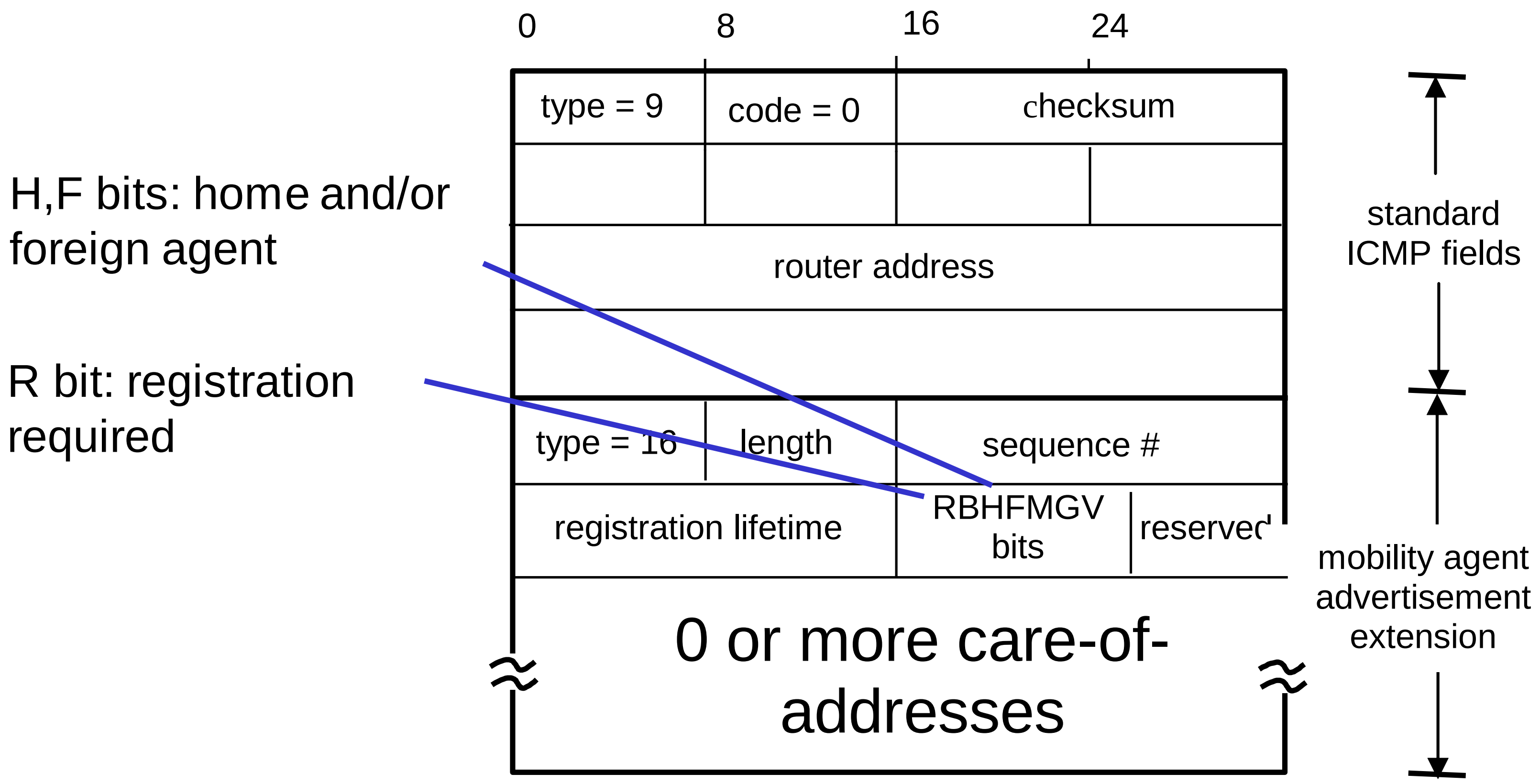
- RFC 3344
- has many features we' ve seen:
  - home agents, foreign agents, foreign-agent registration, care-of-addresses, encapsulation (packet-within-a-packet)
- three components to standard:
  - indirect routing of datagrams
  - agent discovery
  - registration with home agent

Mobile IP: indirect routing

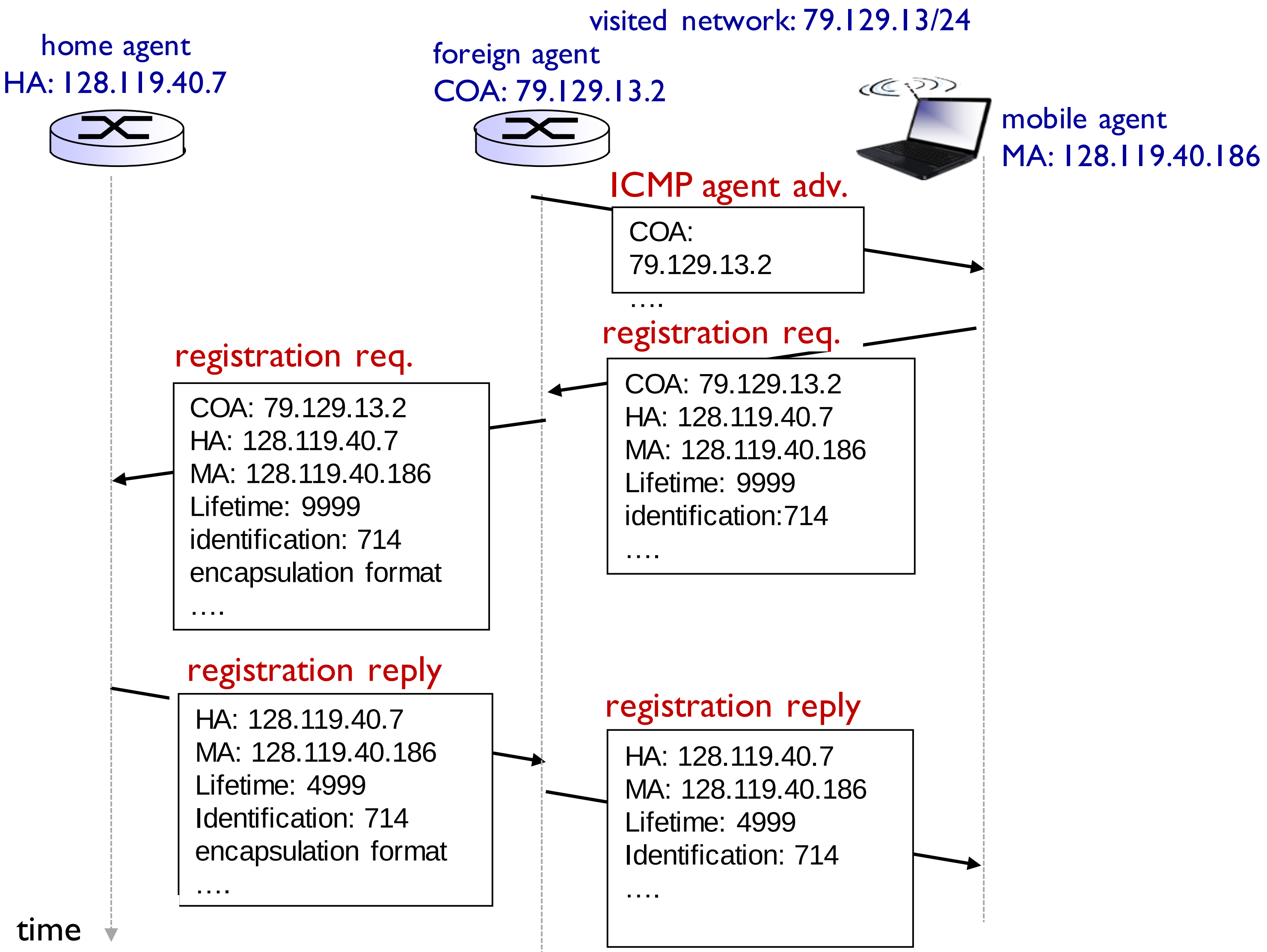


Mobile IP: agent discovery

- *agent advertisement:* foreign/home agents advertise service by broadcasting ICMP messages (typefield = 9)



Mobile IP: registration example



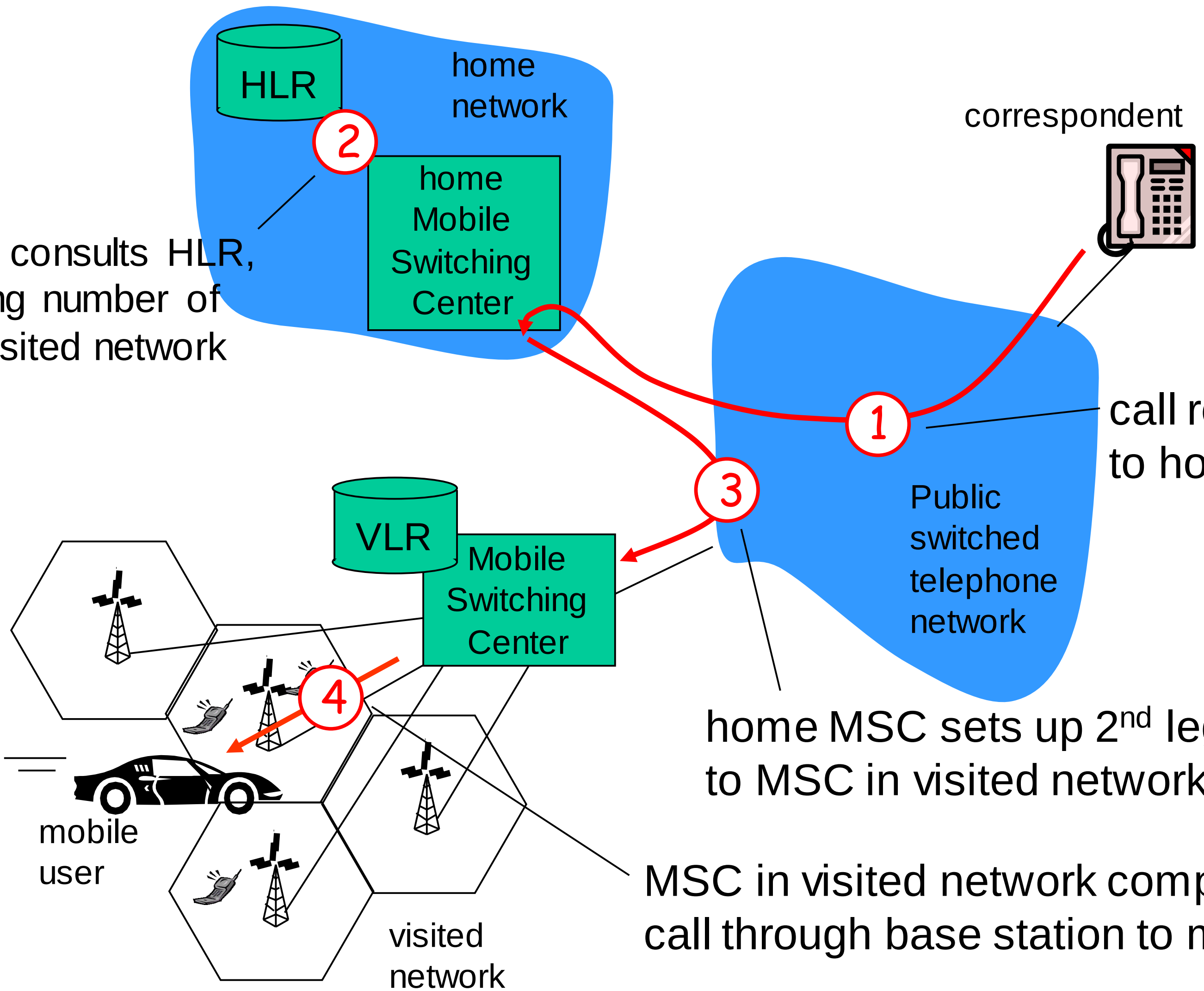
4. How to handle the mobility in cellular networks

Handling mobility in cellular networks

- *home network:* network of cellular provider you subscribe to (e.g., Sprint PCS, Verizon)
  - *home location register (HLR):* database in home network containing permanent cell phone #, profile information (services, preferences, billing), information about current location (could be in another network)
- *visited network:* network in which mobile currently resides
  - *visitor location register (VLR):* database with entry for each user currently in network
  - could be home network

5. Write short notes on GSM and explain the process of handoff

GSM: indirect routing to mobile



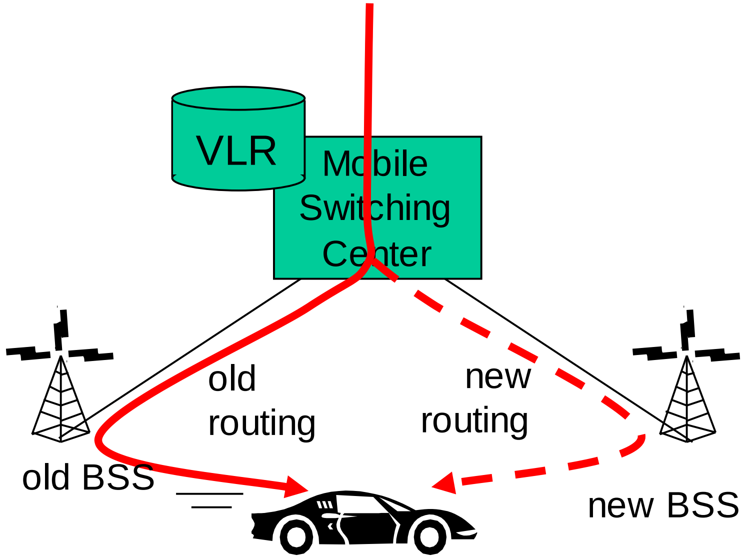
home MSC consults HLR, gets roaming number of mobile in visited network

call routed to home network

home MSC sets up 2nd leg of call to MSC in visited network

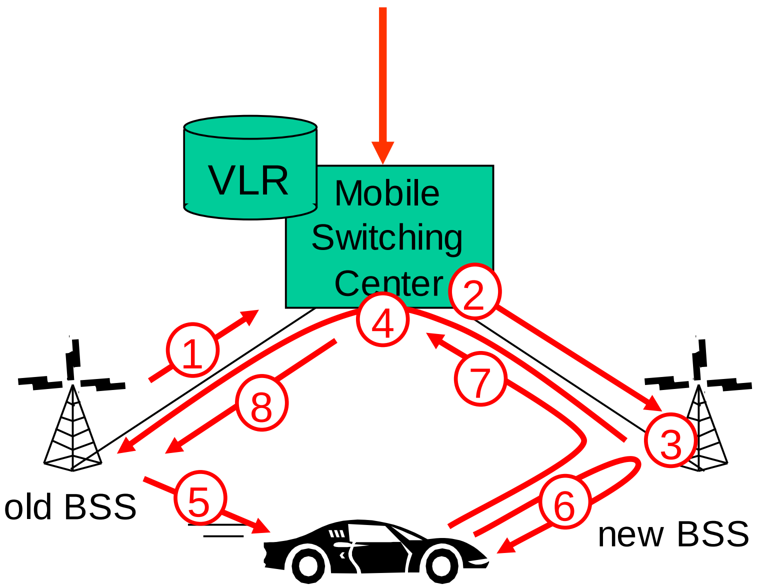
MSC in visited network completes call through base station to mobile

GSM: handoff with common MSC



- *handoff goal:* route call via new base station (without interruption)
- reasons for handoff:
  - stronger signal to/from new BSS (continuing connectivity, less battery drain)
  - load balance: free up channel in current BSS
  - GSM doesnt mandate why to perform handoff (policy), only how (mechanism)
- handoff initiated by old BSS

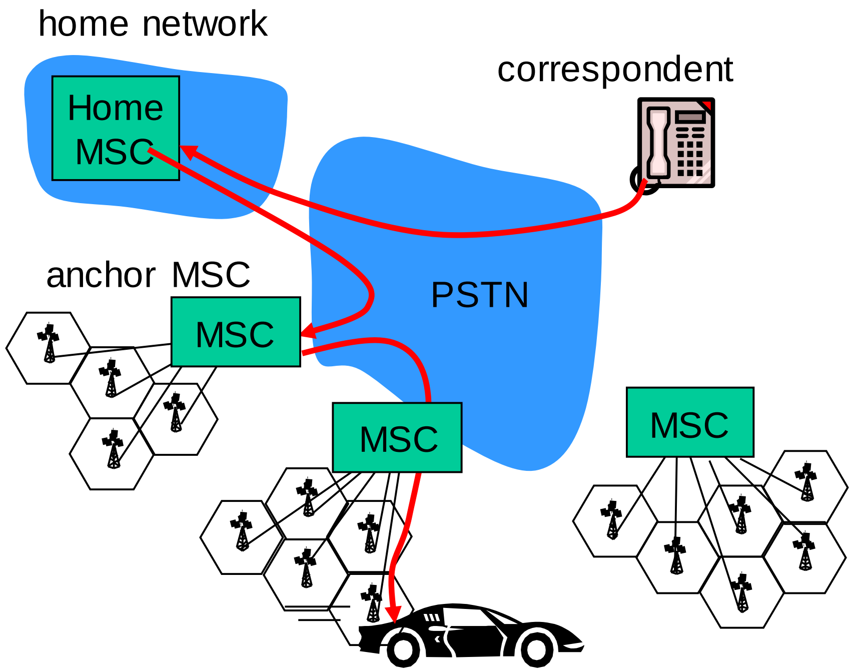
GSM: handoff with common MSC



1. old BSS informs MSC of impending handoff, provides list of 1^+ new BSSs
2. MSC sets up path (allocates resources) to new BSS
3. new BSS allocates radio channel for use by mobile
4. new BSS signals MSC, old BSS: ready
5. old BSS tells mobile: perform handoff to new BSS
6. mobile, new BSS signal to activate new channel
7. mobile signals via new BSS to MSC: handoff complete. MSC reroutes call

8 MSC-old-BSS resources released

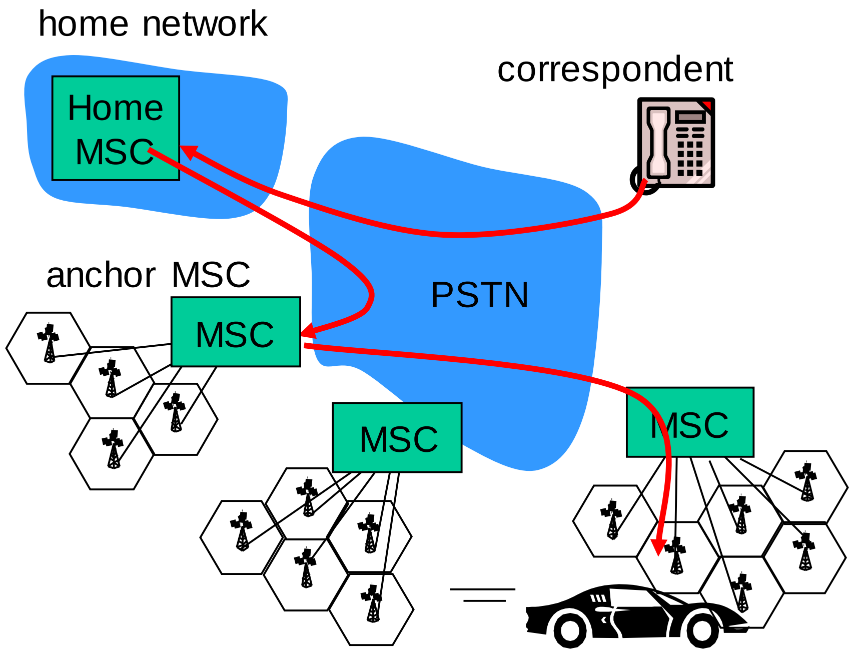
GSM: handoff between MSCs



(a) before handoff

- *anchor MSC:* first MSC visited during call
  - call remains routed through anchor MSC
- new MSCs add on to end of MSC chain as mobile moves to new MSC
- optional path minimization step to shorten multi-MSC chain

GSM: handoff between MSCs



(b) after handoff

- *anchor MSC:* first MSC visited during call
  - call remains routed through anchor MSC
- new MSCs add on to end of MSC chain as mobile moves to new MSC
- optional path minimization step to shorten multi-MSC chain

6. Write the difference between GSM and MobileIP

Mobility: GSM versus Mobile IP

GSM element	Comment on GSM element	Mobile IP element
Home system	Network to which mobile user's permanent phone number belongs	**Home network**
Gateway Mobile Switching Center, or "home MSC". Home Location Register (HLR)	Home MSC: point of contact to obtain routable address of mobile user. HLR: database in home system containing permanent phone number, profile information, current location of mobile user, subscription information	**Home agent**
Visited System	Network other than home system where mobile user is currently residing	**Visited network**
Visited Mobile services Switching Center. Visitor Location Record (VLR)	Visited MSC: responsible for setting up calls to/from mobile nodes in cells associated with MSC. VLR: temporary database entry in visited system, containing subscription information for each visiting mobile user	**Foreign agent**
Mobile Station Roaming Number (MSRN), or "roaming number"	Routable address for telephone call segment between home MSC and visited MSC, visible to neither the mobile nor the correspondent.	**Care-of-address**

7. Mention the Impact on higher layer protocols w.r.t Mobility

Wireless, mobility: impact on higher layer protocols

- logically, impact *should* be minimal …
  - best effort service model remains unchanged
  - TCP and UDP can (and do) run over wireless, mobile
- … but performance-wise:
  - packet loss/delay due to bit-errors (discarded packets, delays for link-layer retransmissions), and handoff
  - TCP interprets loss as congestion, will decrease congestion window un-necessarily
  - delay impairments for real-time traffic
  - limited bandwidth of wireless links

THE END

Module 5

MULTIMEDIA NETWORKING APPLICATIONS

Q & A

1. Write and explain the classes of multimedia applications

MM Networking Applications

Classes of MM applications:

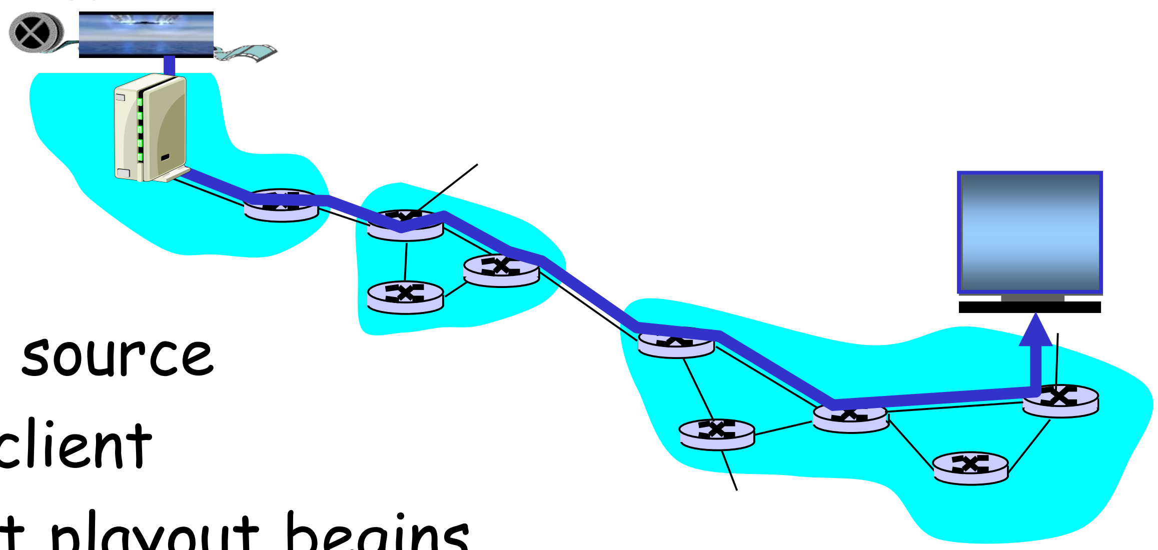
1) stored streaming
2) live streaming
3) interactive, real-time

Jitter is the variability of packet delays within the same packet stream

Fundamental characteristics:

- typically **delay sensitive**
  - end-to-end delay
  - delay jitter
- **loss tolerant**: infrequent losses cause minor glitches
- antithesis of data, which are loss *intolerant* but delay *tolerant*.

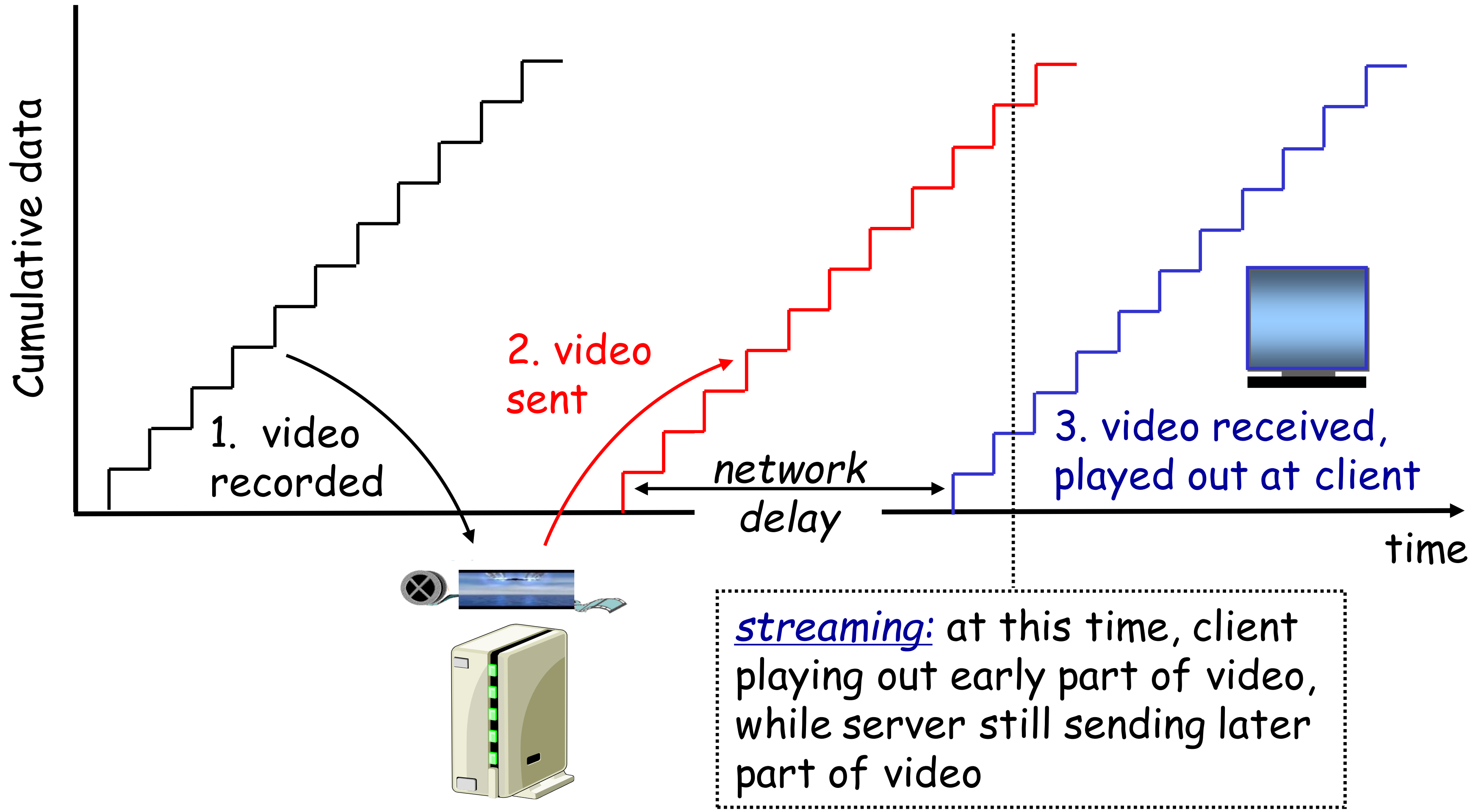
Streaming Stored Multimedia



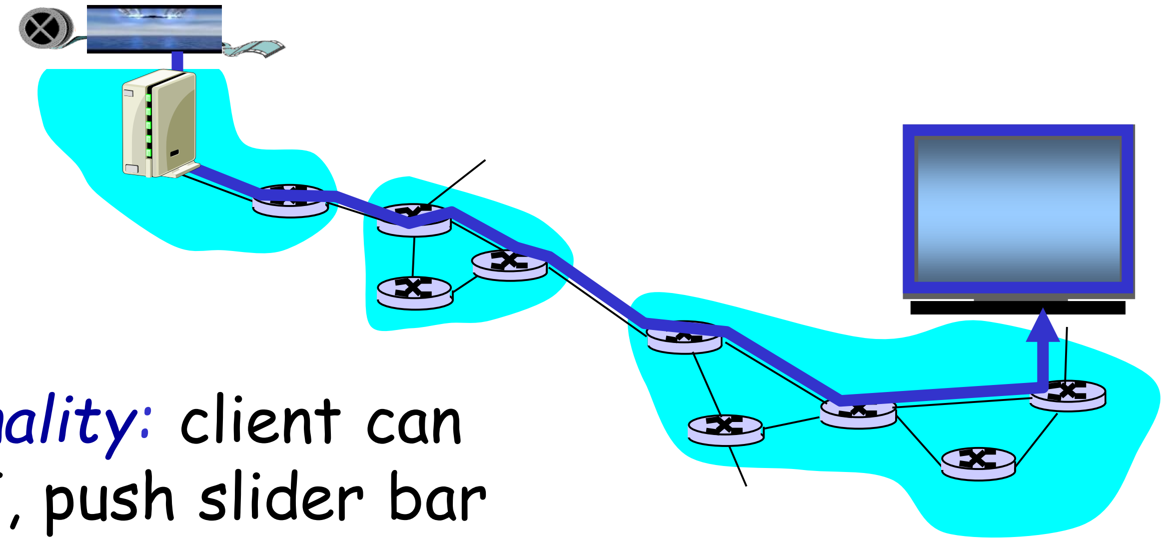
Stored streaming:

- media stored at source
- transmitted to client
- *streaming:* client playout begins *before* all data has arrived
  - timing constraint for still-to-be transmitted data: in time for playout

Streaming Stored Multimedia: What is it?



Streaming *Stored* Multimedia: Interactivity



- *VCR-like functionality:* client can pause, rewind, FF, push slider bar
  - 10 sec initial delay OK
  - 1-2 sec until command effect OK

- timing constraint for still-to-be transmitted data: in time for playout

Streaming *Live* Multimedia

Examples:

- Internet radio talk show
- live sporting event

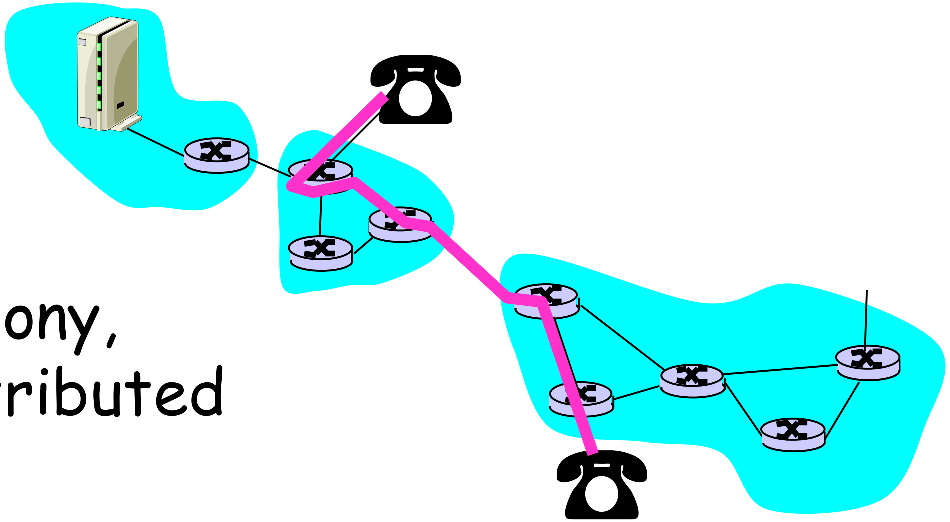
Streaming (as with streaming *stored* multimedia)

- playback buffer
- playback can lag tens of seconds after transmission
- still have timing constraint

Interactivity

- fast forward impossible
- rewind, pause possible!

Real-Time Interactive Multimedia



- applications: IP telephony, video conference, distributed interactive worlds
- end-end delay requirements:
  - audio: < 150 msec good, < 400 msec OK
    - includes application-level (packetization) and network delays
    - higher delays noticeable, impair interactivity
- session initialization
  - how does callee advertise its IP address, port number, encoding algorithms?

2. Explain the process of streaming stored audio and video

Streaming Stored Multimedia

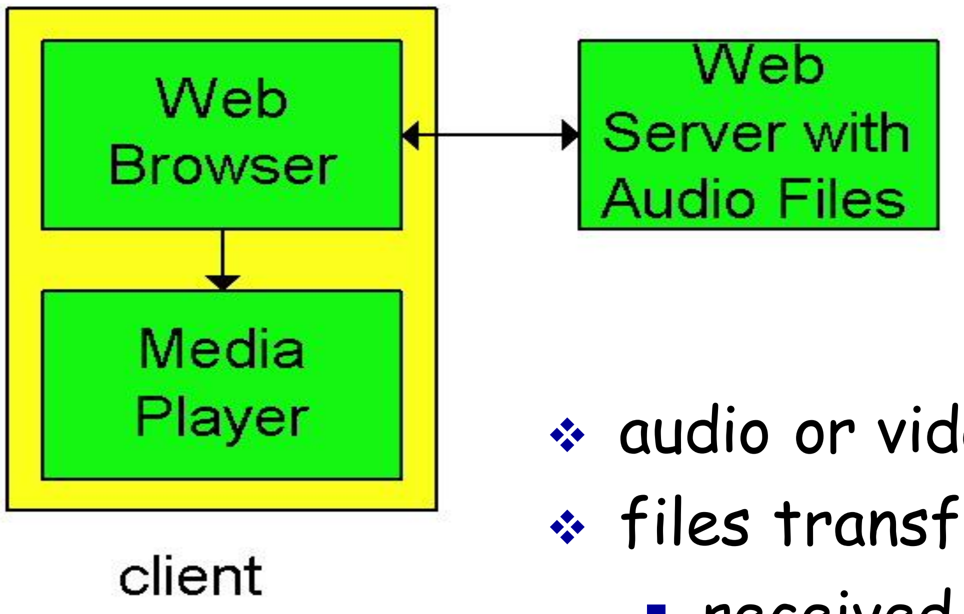
application-level streaming techniques for making the best out of best effort service:

- client-side buffering
- use of UDP versus TCP
- multiple encodings of multimedia

Media Player

- jitter removal
- decompression
- error concealment
- graphical user interface w/ controls for interactivity

Internet multimedia: simplest approach

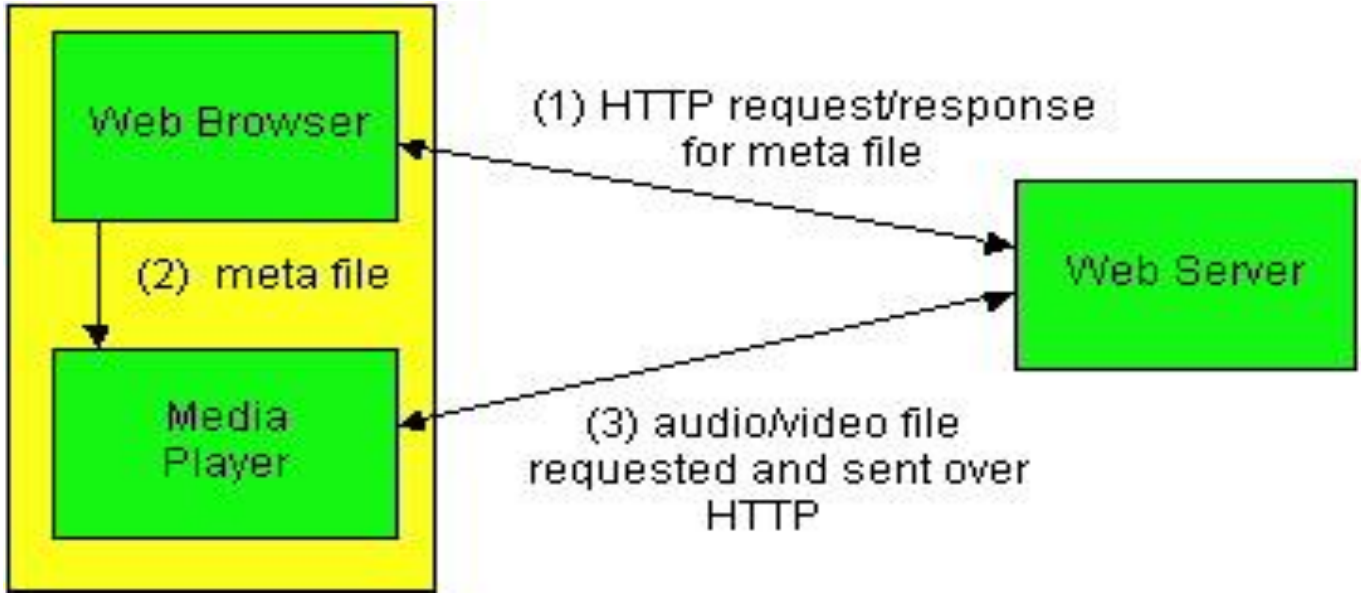


- audio or video stored in file
- files transferred as HTTP object
  - received in entirety at client
  - then passed to player

audio, video not streamed:

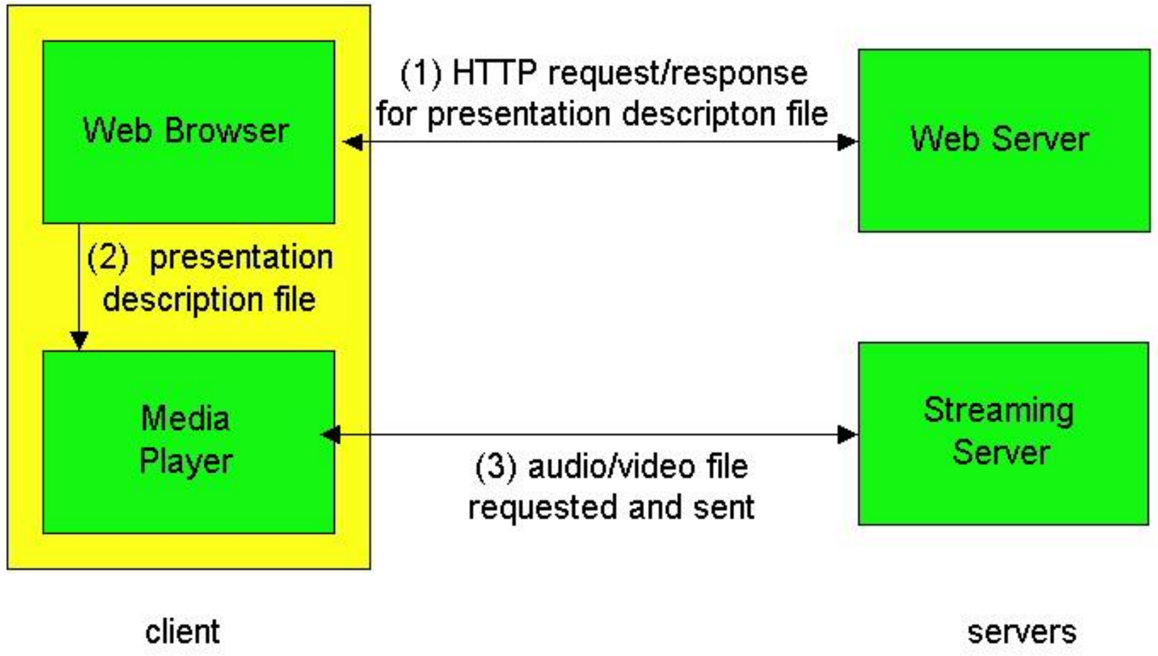
- no, "pipelining," long delays until playout!

Internet multimedia: streaming approach



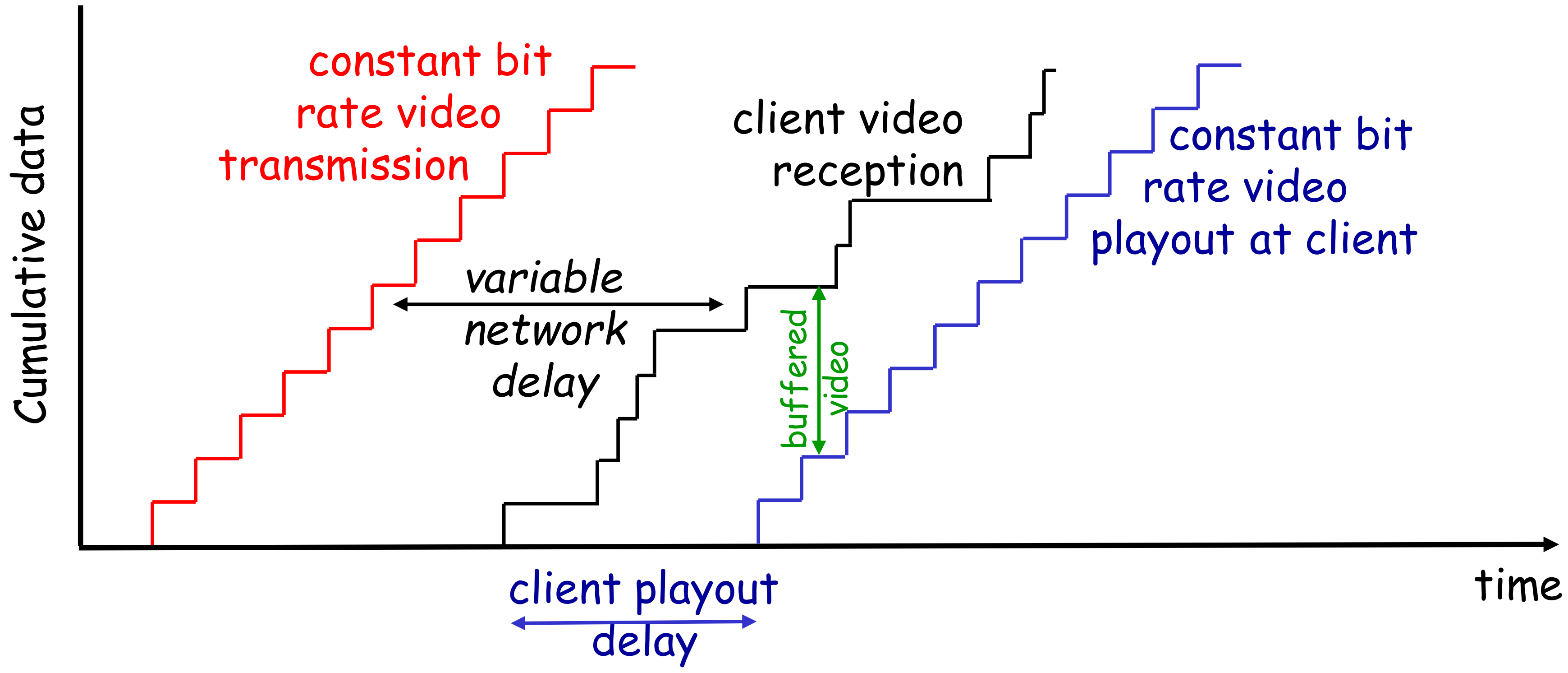
- browser GETs **metafile**
- browser launches player, passing metafile
- player contacts server
- server streams audio/video to player

Streaming from a streaming server



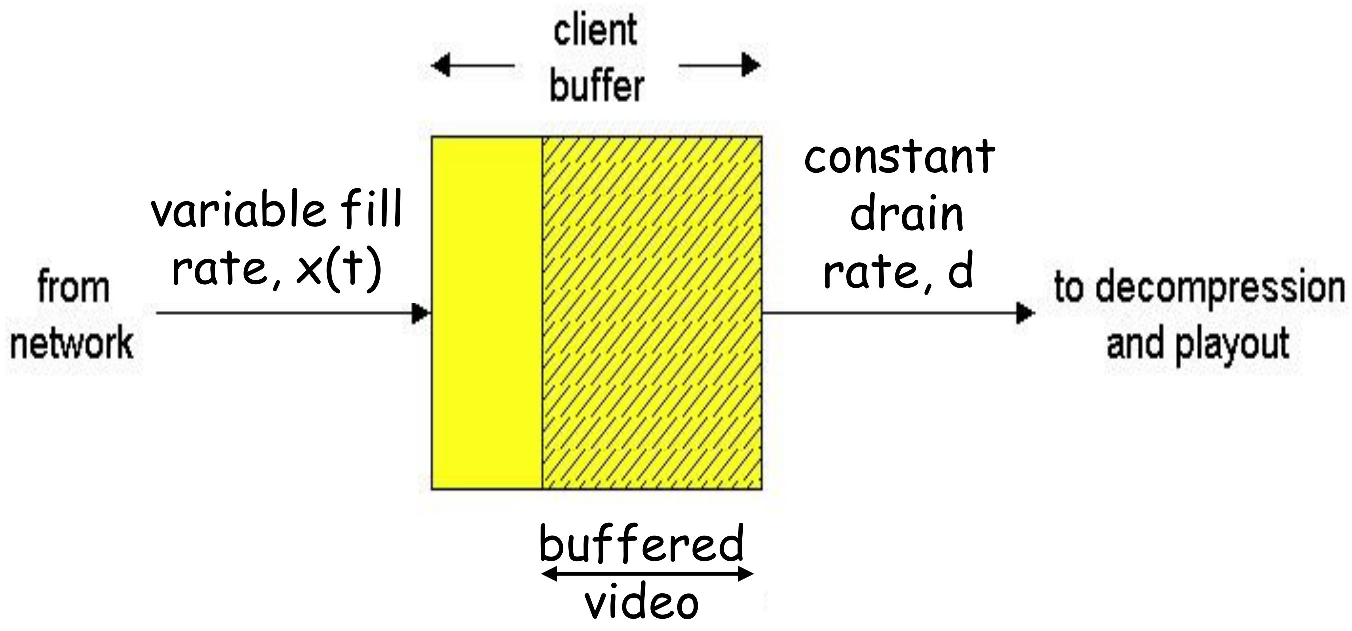
- allows for non-HTTP protocol between server, media player
- UDP or TCP for step (3), more shortly

Streaming Multimedia: Client Buffering



- client-side buffering, playout delay compensate for network-added delay, delay jitter

Streaming Multimedia: Client Buffering



- client-side buffering, playout delay compensate for network-added delay, delay jitter

Streaming Multimedia: UDP or TCP?

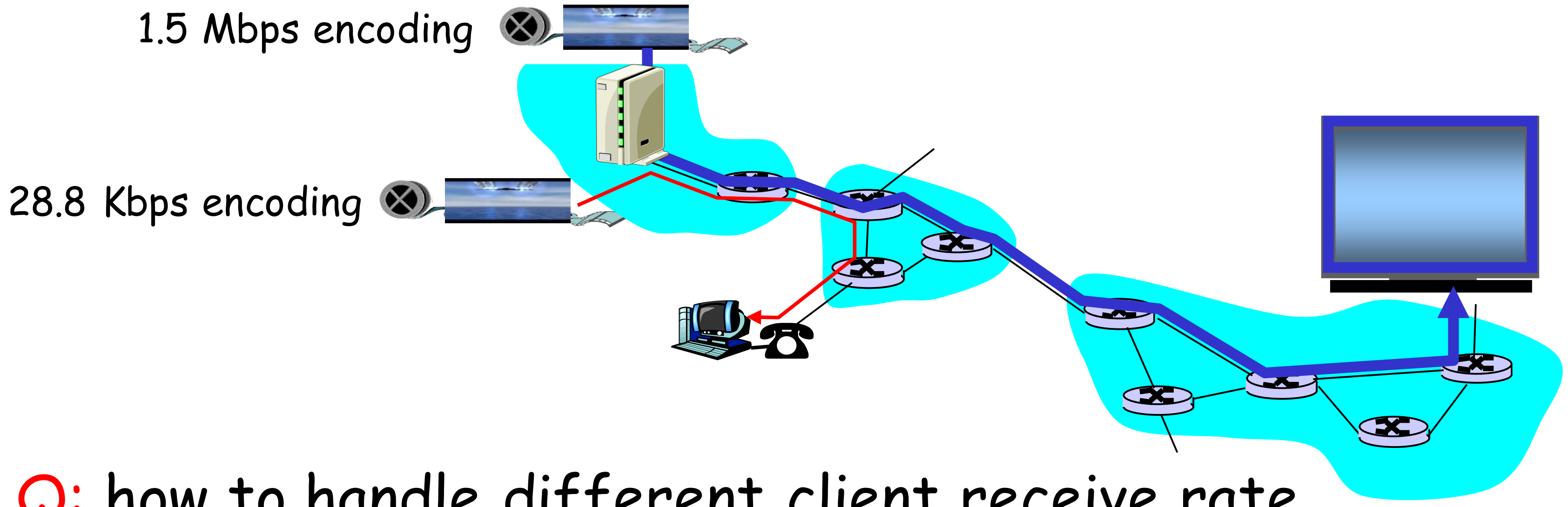
UDP

- server sends at rate appropriate for client (oblivious to network congestion !)
  - often send rate = encoding rate = constant rate
  - then, fill rate = constant rate - packet loss
- short playout delay (2-5 seconds) to remove network jitter
- error recover: time permitting

TCP

- send at maximum possible rate under TCP
- fill rate fluctuates due to TCP congestion control
- larger playout delay: smooth TCP delivery rate
- HTTP/TCP passes more easily through firewalls

Streaming Multimedia: client rate(s)



Q: how to handle different client receive rate capabilities?

- 28.8 Kbps dialup
- 100 Mbps Ethernet

A: server stores, transmits multiple copies of video, encoded at different rates

3. Explain briefly about RTSP and its operations

User Control of Streaming Media: RTSP

HTTP

- does not target multimedia content
- no commands for fast forward, etc.

RTSP: RFC 2326

- client-server application layer protocol
- user control: rewind, fast forward, pause, resume, repositioning, etc…

What it doesn't do:

- doesn't define how audio/video is encapsulated for streaming over network
- doesn't restrict how streamed media is transported (UDP or TCP possible)
- doesn't specify how media player buffers audio/video

RTSP: out of band control

FTP uses an "out-of-band" control channel:

- file transferred over one TCP connection.
- control info (directory changes, file deletion, rename) sent over separate TCP connection
- "out-of-band", "in-band" channels use different port numbers

RTSP messages also sent out-of-band:

- RTSP control messages use different port numbers than media stream: out-of-band.
  - port 554
- media stream is considered "in-band".

RTSP Example

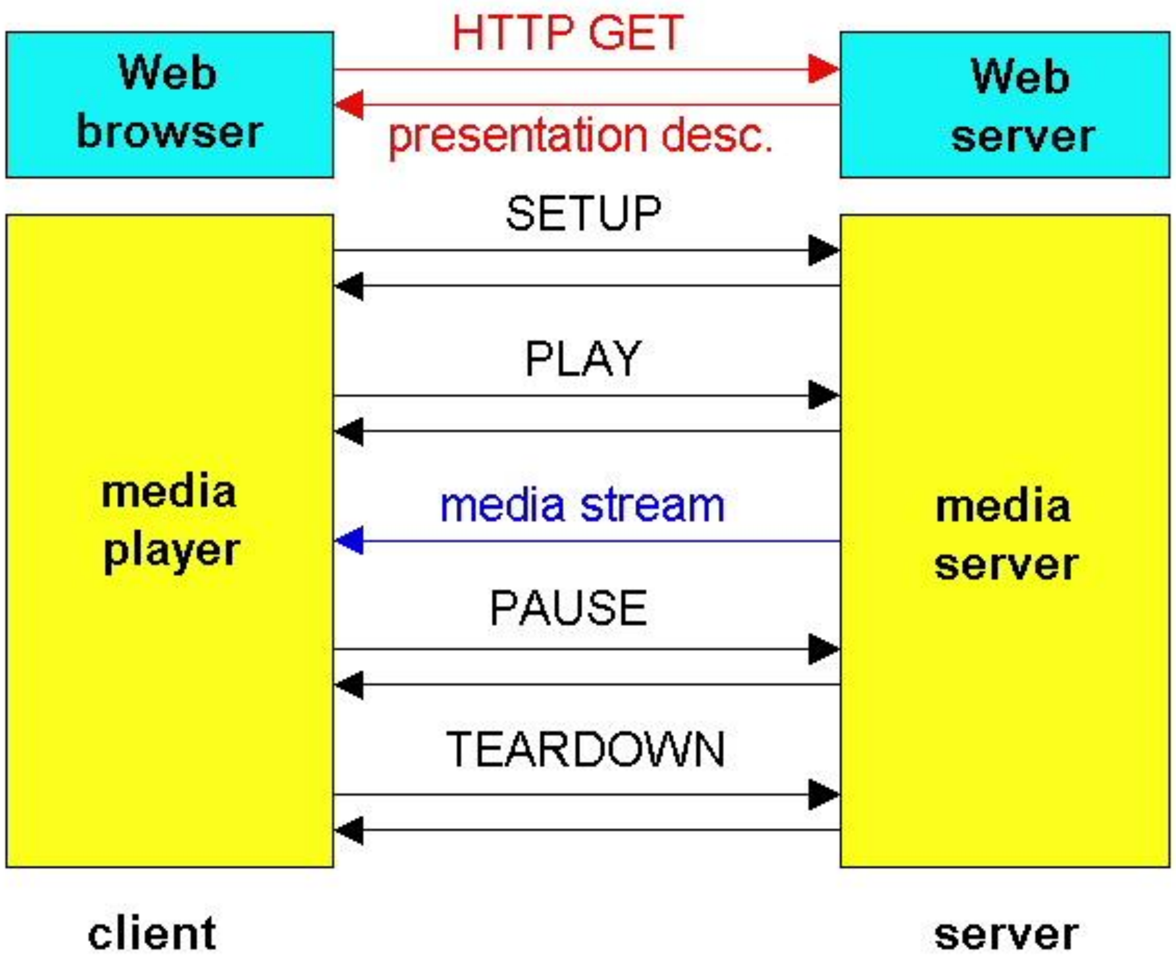
Scenario:

- metafile communicated to web browser
- browser launches player
- player sets up an RTSP control connection, data connection to streaming server

Metafile Example

```
<title>Twister</title>
<session>
      <group language=en lipsync>
            <switch>
              <track type=audio
                  e="PCMU/8000/1"
                  src = "rtsp://audio.example.com/twister/audio.en/lofi">
              <track type=audio
                  e="DVI4/16000/2" pt="90 DVI4/8000/1"
                  src="rtsp://audio.example.com/twister/audio.en/hifi">
            </switch>
          <track type="video/jpeg"
                  src="rtsp://video.example.com/twister/video">
       </group>
</session>
```

RTSP Operation



RTSP Exchange Example

C: SETUP rtsp://audio.example.com/twister/audio RTSP/1.0
Transport: rtp/udp; compression; port=3056; mode=PLAY

S: RTSP/1.0 200 1 OK
Session 4231

C: PLAY rtsp://audio.example.com/twister/audio.en/lofi RTSP/1.0
Session: 4231
Range: npt=0-

C: PAUSE rtsp://audio.example.com/twister/audio.en/lofi RTSP/1.0
Session: 4231
Range: npt=37

C: TEARDOWN rtsp://audio.example.com/twister/audio.en/lofi RTSP/1.0
Session: 4231

S: 200 3 OK

4. Write the principles of QoS?

Principle 1

packet marking needed for router to distinguish between different classes; and new router policy to treat packets accordingly

Principle 2

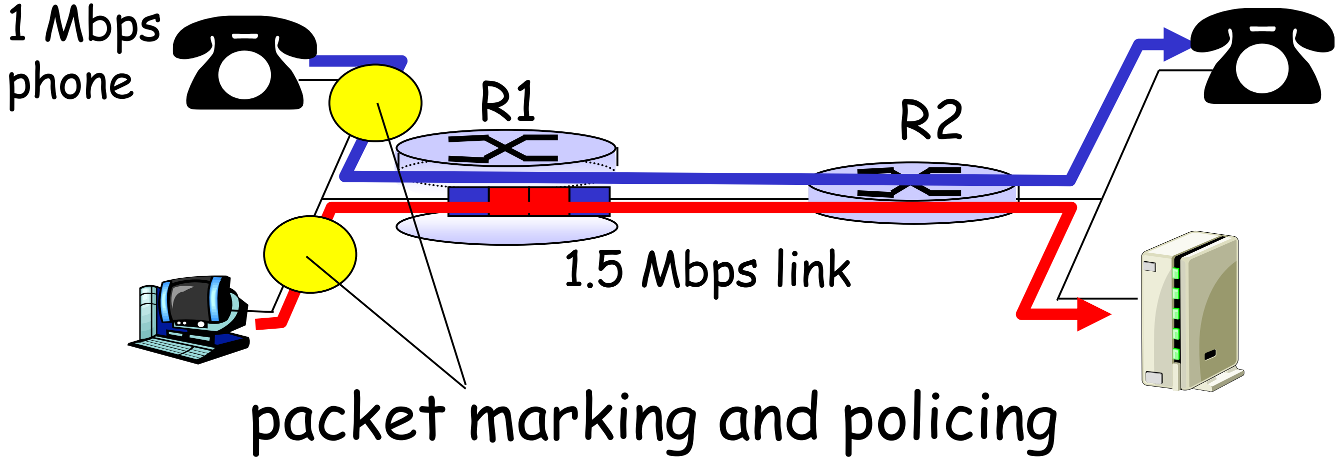
provide protection (*isolation*) for one class from others

Principle 3

While providing isolation, it is desirable to use resources as efficiently as possible

Principles for QOS Guarantees (more)

- what if applications misbehave (audio sends higher than declared rate)
  - policing: force source adherence to bandwidth allocations
- marking and policing at network edge:
  - similar to ATM UNI (User Network Interface)

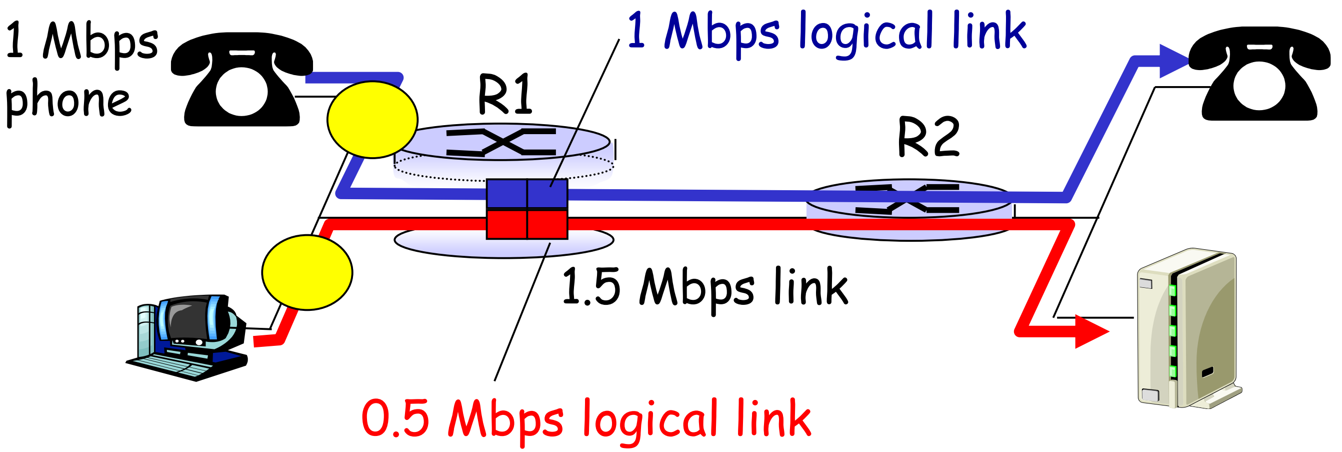


Principle 2

provide protection (*isolation*) for one class from others

Principles for QOS Guarantees (more)

- Allocating *fixed* (non-sharable) bandwidth to flow: *inefficient* use of bandwidth if flow doesn't use its allocation

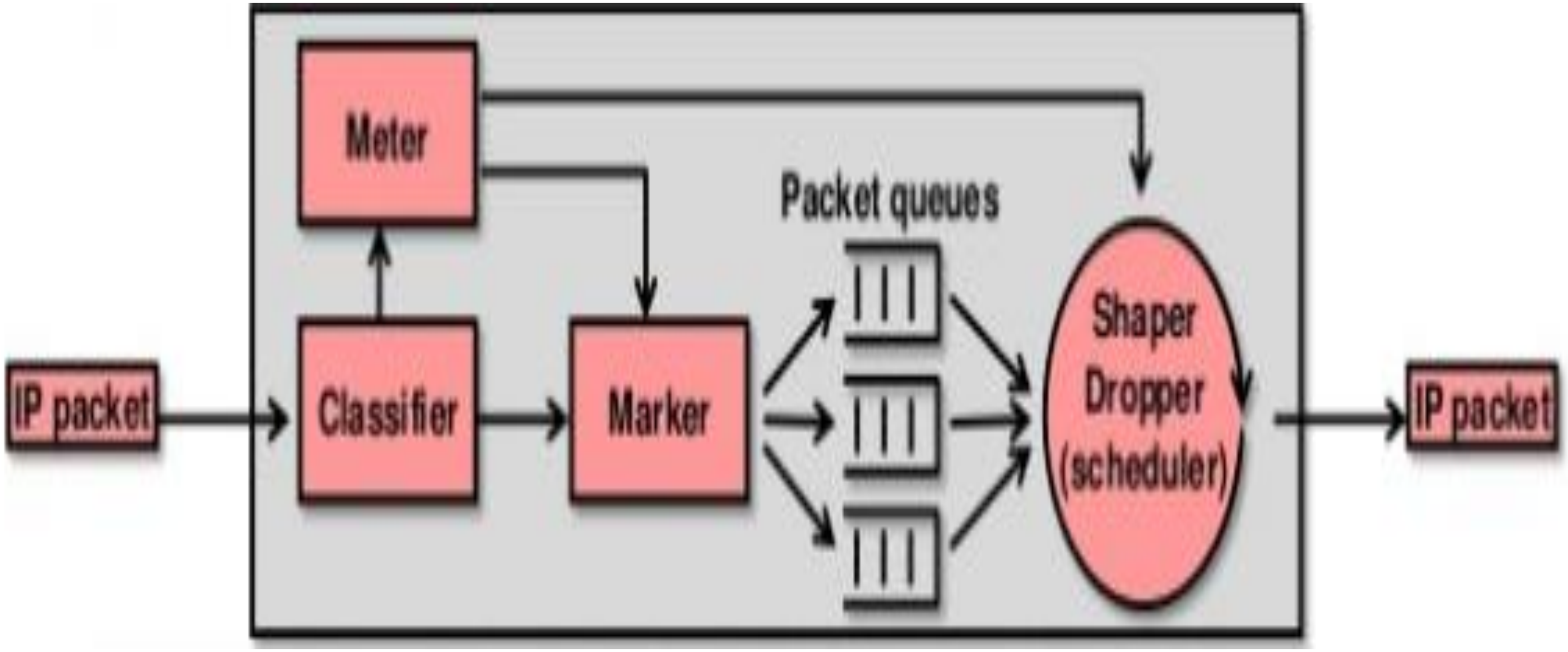


Principle 3

While providing isolation, it is desirable to use resources as efficiently as possible

4. Explain about the differentiated QoS?

DIFFERENTIATED QoS



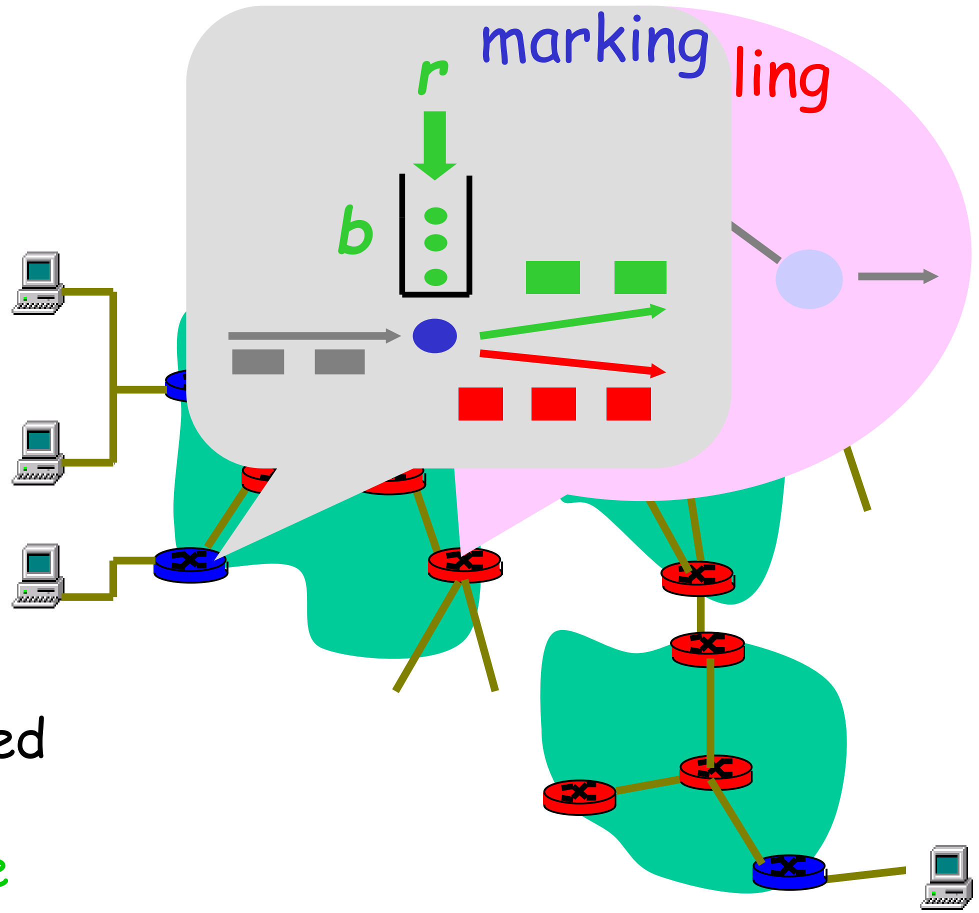
IETF Differentiated Services

- want "qualitative" service classes
  - "behaves like a wire"
  - relative service distinction: Platinum, Gold, Silver
- *scalability:* simple functions in network core, relatively complex functions at edge routers (or hosts)
  - signaling, maintaining per-flow router state difficult with large number of flows
- don't define define service classes, provide functional components to build service classes

Diffserv Architecture

Edge router:

- per-flow traffic management
- marks packets as in-profile and out-profile

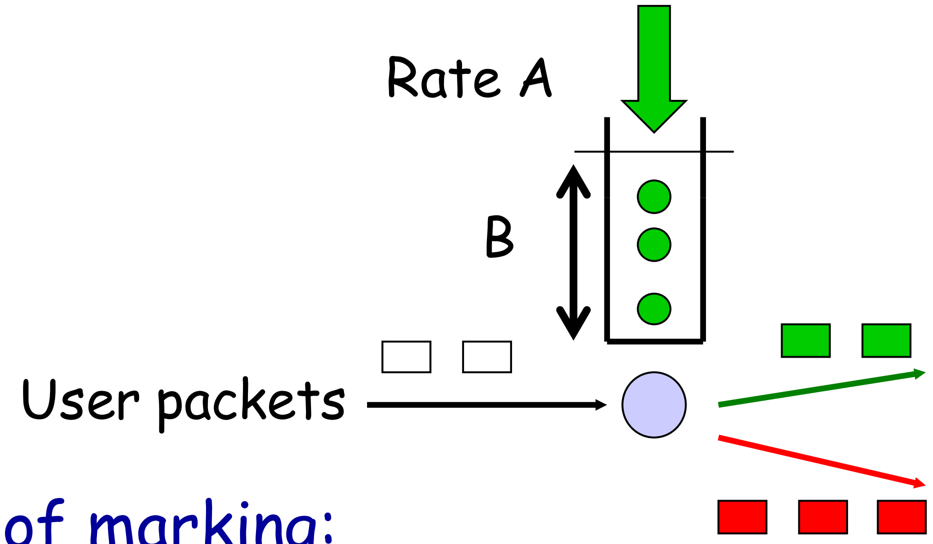


Core router:

- per class traffic management
- buffering and scheduling based on marking at edge
- preference given to in-profile packets

Edge-router Packet Marking

- profile: pre-negotiated rate A, bucket size B
- packet marking at edge based on per-flow profile



Possible usage of marking:

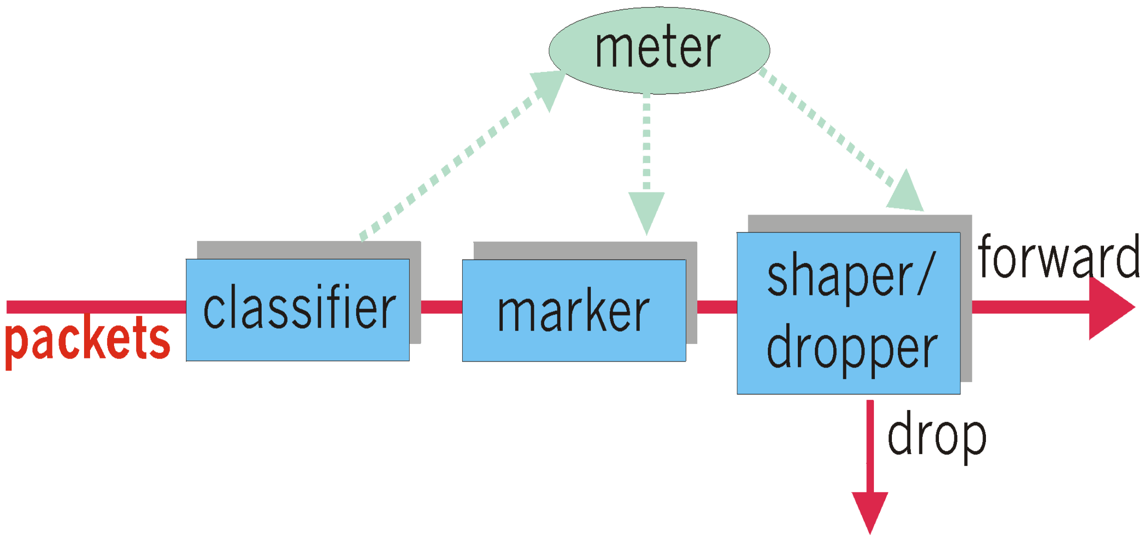
- class-based marking: packets of different classes marked differently
- intra-class marking: conforming portion of flow marked differently than non-conforming one

Classification and Conditioning

- Packet is marked in the Type of Service (TOS) in IPv4, and Traffic Class in IPv6
- 6 bits used for Differentiated Service Code Point (DSCP) and determine PHB that the packet will receive
- 2 bits are currently unused

Classification and Conditioning

may be desirable to limit traffic injection rate of some class:
- user declares traffic profile (e.g., rate, burst size)
- traffic metered, shaped if non-conforming



Forwarding (PHB)

- PHB result in a different observable (measurable) forwarding performance behavior
- PHB does not specify what mechanisms to use to ensure required PHB performance behavior
- Examples:
  - Class A gets x% of outgoing link bandwidth over time intervals of a specified length
  - Class A packets leave first before packets from class B

Forwarding (PHB)

PHBs being developed:

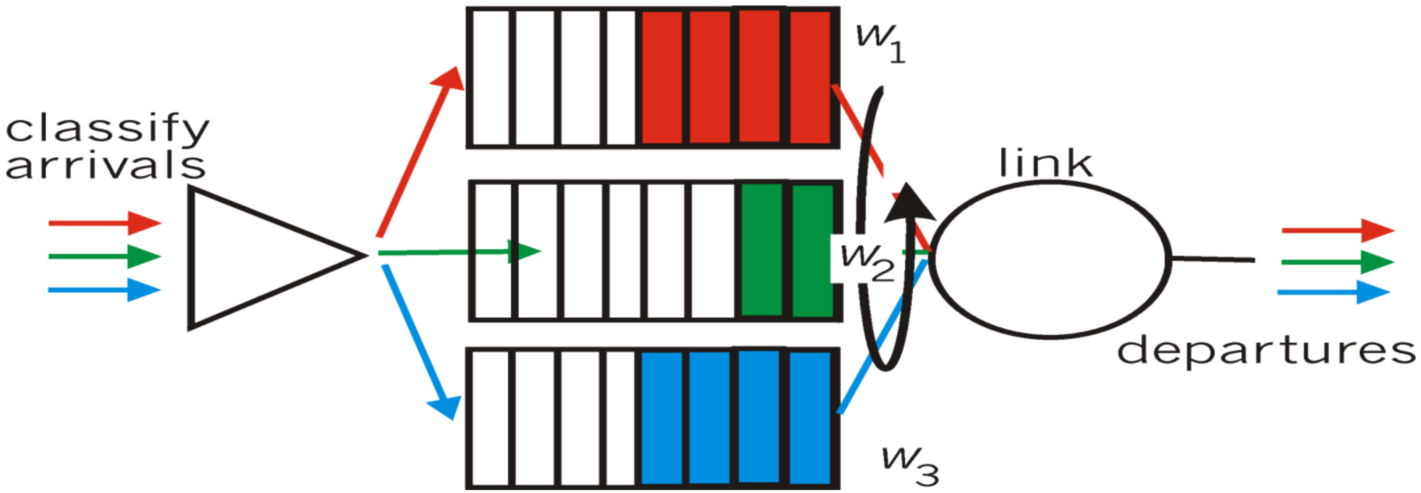
- Expedited Forwarding: pkt departure rate of a class equals or exceeds specified rate
  - logical link with a minimum guaranteed rate
- Assured Forwarding: 4 classes of traffic
  - each guaranteed minimum amount of bandwidth
  - each with three drop preference partitions

5. Write the mechanisms of scheduling and policies

Scheduling Policies: still more

Weighted Fair Queuing:

- generalized Round Robin
- each class gets weighted amount of service in each cycle
- real-world example?



Policing Mechanisms

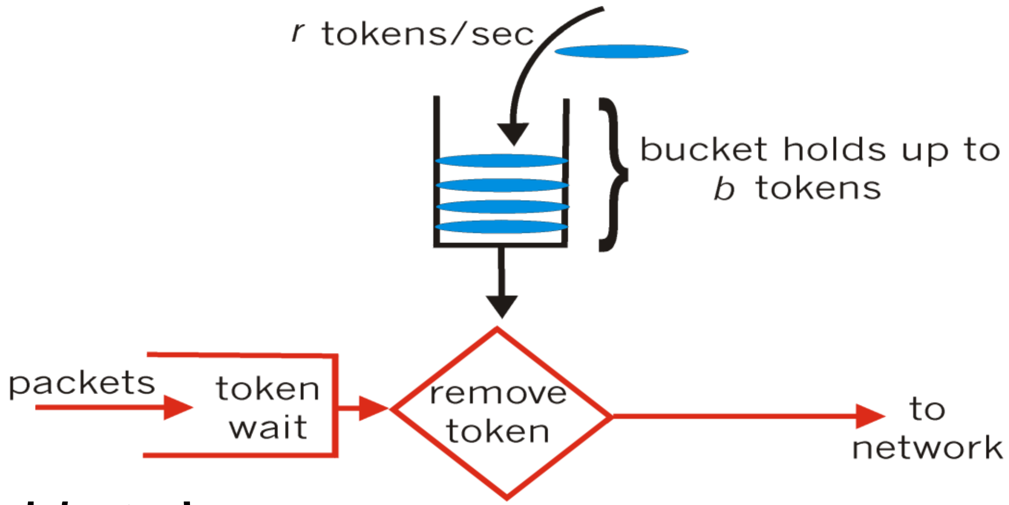
Goal: limit traffic to not exceed declared parameters

Three common-used criteria:

- *(Long term) Average Rate:* how many pkts can be sent per unit time (in the long run)
  - crucial question: what is the interval length: 100 packets per sec or 6000 packets per min have same average!
- *Peak Rate:* e.g., 6000 pkts per min. (ppm) avg.; 1500 ppm peak rate
- *(Max.) Burst Size:* max. number of pkts sent consecutively (with no intervening idle)

Policing Mechanisms

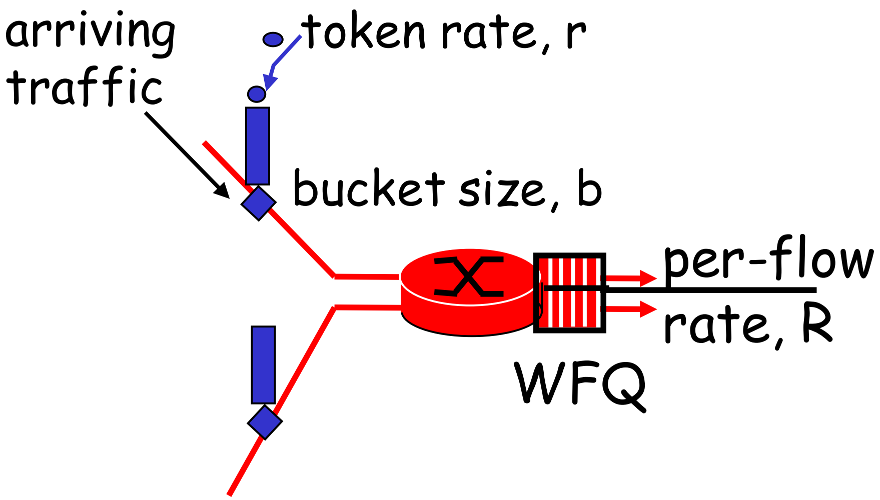
Token Bucket: limit input to specified Burst Size and Average Rate.



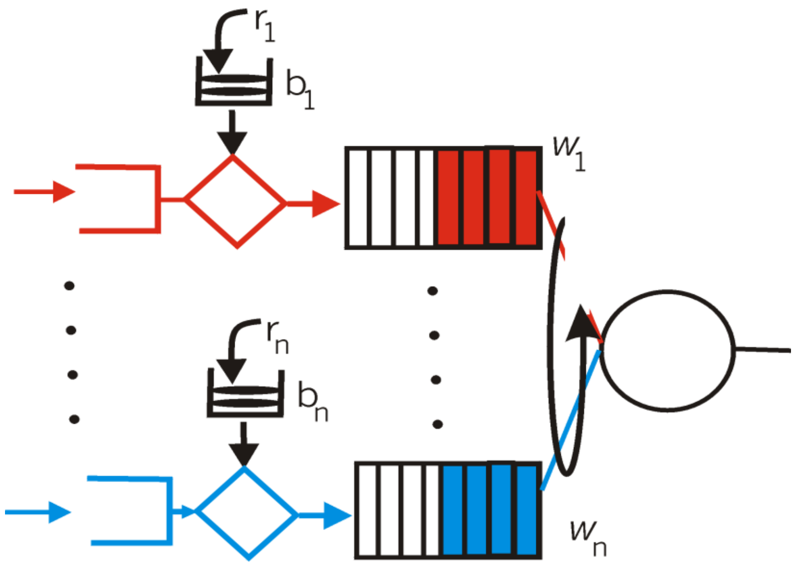
- bucket can hold b tokens
- tokens generated at rate *r token/sec* unless bucket full
- *over interval of length t: number of packets admitted less than or equal to (r t + b).*

Policing Mechanisms (more)

- token bucket, WFQ combine to provide guaranteed upper bound on delay, i.e., *QoS guarantee*!



$D_{max} = b/R$



5. Write about RSVP and its operations

RSVP Design Goals

1. accommodate heterogeneous receivers (different bandwidth along paths)
2. accommodate different applications with different resource requirements
3. make multicast a first class service, with adaptation to multicast group membership
4. leverage existing multicast/unicast routing, with adaptation to changes in underlying unicast, multicast routes
5. control protocol overhead to grow (at worst) linear in # receivers
6. modular design for heterogeneous underlying technologies

RSVP: does not…

- specify how resources are to be reserved
  - rather: a mechanism for communicating needs
- determine routes packets will take
  - that's the job of routing protocols
  - signaling decoupled from routing
- interact with forwarding of packets
  - separation of control (signaling) and data (forwarding) planes

RSVP: overview of operation

- senders, receiver join a multicast group
  - done outside of RSVP
  - senders need not join group
- sender-to-network signaling
  - *path message:* make sender presence known to routers
  - path teardown: delete sender's path state from routers
- receiver-to-network signaling
  - *reservation message:* reserve resources from sender(s) to receiver
  - reservation teardown: remove receiver reservations
- network-to-end-system signaling
  - path error
  - reservation error

THE END