5. Network Interface

OS Abstraction for Distributed I/O

Challenges

- Abstract multiple *layers* and multiple *networking protocols*
- Cross-system synchronization and communication primitives
- Extend classical I/O primitives to distributed systems

Open Systems Interconnection (OSI)

Basic Reference Model

Layer 7: Application layer	RPC, FTP, HTTP, NFS
Layer 6: Presentation layer	XDR, SOAP XML, Java socket API
Layer 5: Session layer	*TCP, DNS, DHCP*
Layer 4: Transport layer	*TCP, UDP, RAW*
Layer 3: Network layer	IP
Layer 2: Data Link layer	Ethernet protocol
Layer 1: Physical layer	Ethernet digital signal processing

OS Interface

- Abstract layers 4 and 5 through special files: *sockets*
- Abstract layer 3 in kernel tables (routing, firewall, etc.): `ip`, `route`, `iptables`, `dhclient`
- Abstract layer 2 in kernel network interfaces: `ifconfig`
- Abstract layer 1 in device drivers: `iwconfig`, `hciconfig`

Socket Abstraction

What?

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Networking Domains

- *INET*: Internet Protocol (IP)
- *UNIX*: efficient host-local communication
- And many others (IPv6, X.25, etc.)

- `$ man 7 socket`
- `$ man 7 ip` or `$ man 7 ipv6` (for INET sockets)
- `$ man 7 unix`

Socket Abstraction

What?

- Bidirectional communication channel across systems called *hosts*

Socket Types

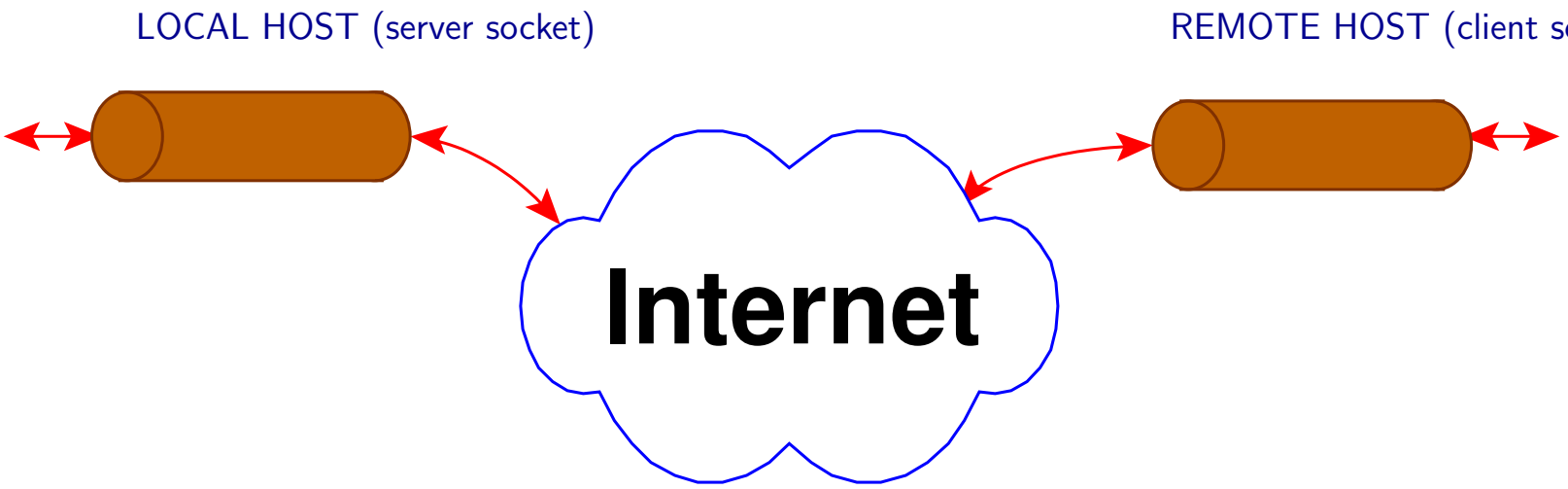
- STREAM: *connected* FIFO streams, reliable (error detection and replay), without message boundaries
- DGRAM: *connection-less*, unreliable (duplication, reorder, loss) exchange of messages of fixed length (datagrams)
- RAW: direct access to the raw, underlying protocol (not for UNIX sockets)
- Mechanism to *address* remote sockets depends on the socket type
  - `$ man 7 tcp` Transmission Control Protocol (TCP): for STREAM sockets
  - `$ man 7 udp` User Datagram Protocol (UDP): for DGRAM sockets
  - `$ man 7 raw` for RAW sockets
- Two classes of INET sockets
  - IPv4: 32-bit address and 16-bit port
  - IPv6: 128-bit address and 16-bit port

Connected (TCP) Scenarios

TCP Abstraction: Creation of a Private Channel

- The *listening server* host
  - Create a *server* socket with `new ServerSocket()`
  - Call `accept()` to wait for an incoming connection, returning a new socket associated with a private channel (or "session") for this connection
- In the *connecting client* host
  - Create and connect a socket: `new Socket(remote_inet,remote_port)`
  - More options possible with the `connect()` method
- The server socket (object of the `ServerSocket` class) can be reused to create more private channels
- Detach a socket connection with `close()`

Establishing a Connection-Based Channel



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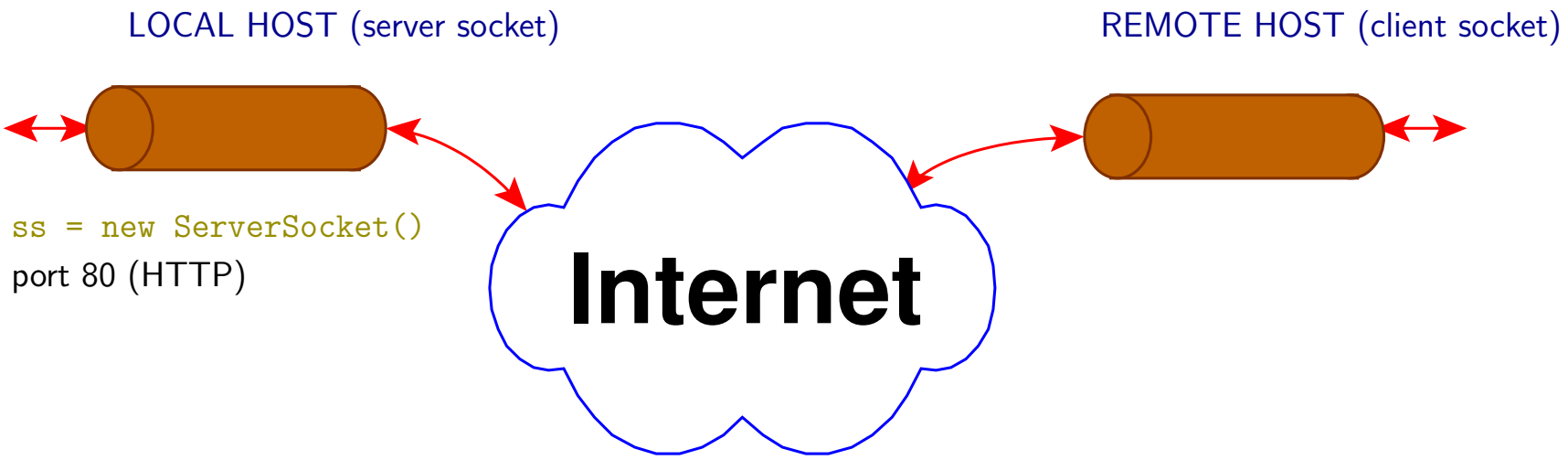

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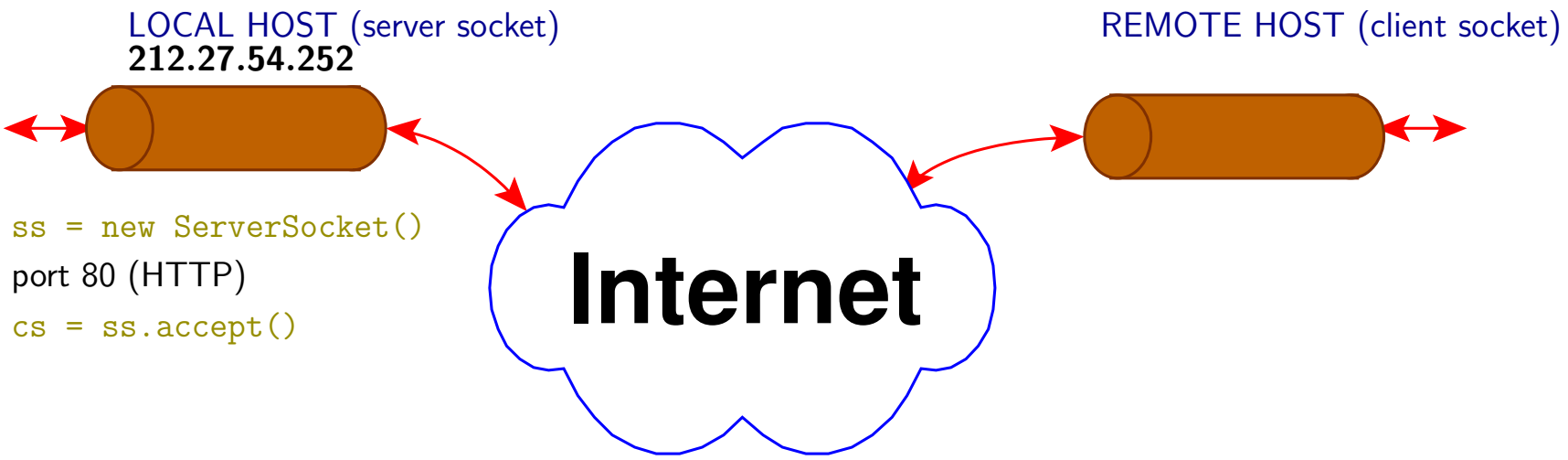

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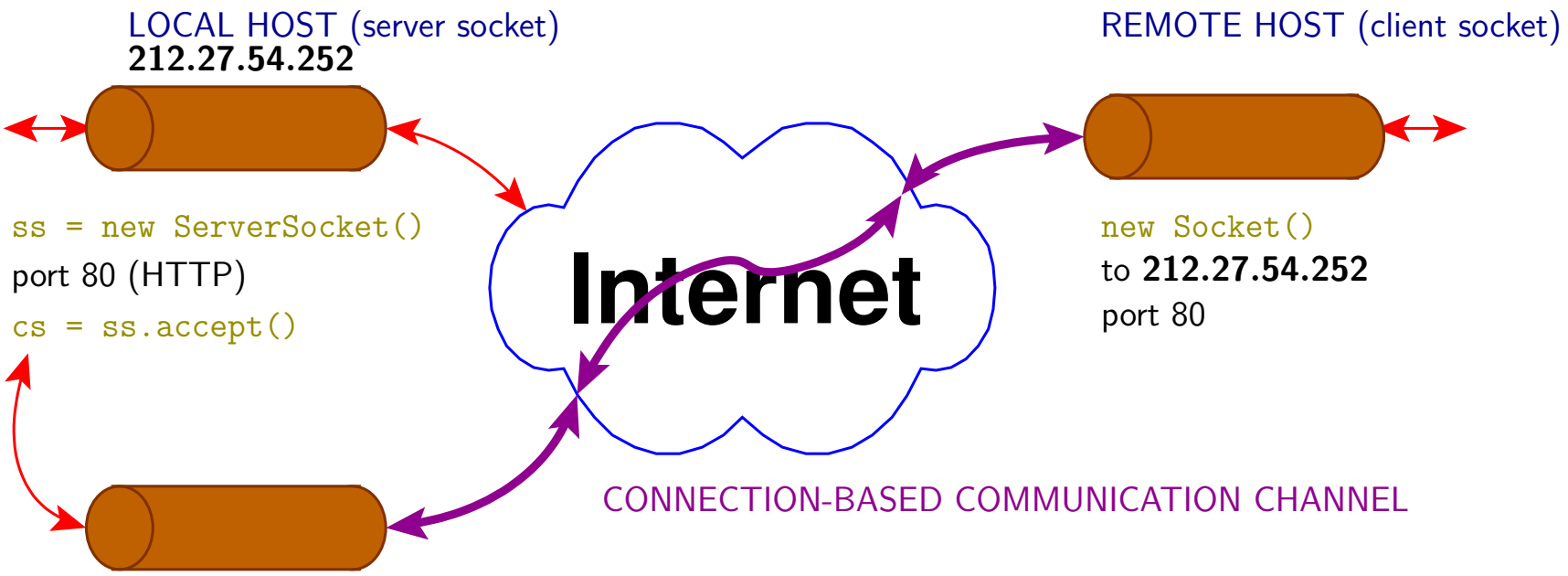

Communicating Through a Pair of Sockets

Connected Socket I/O

- Stream I/O work as usual *on connected sockets only*
- A connected socket without writer simulates *end-of-file*
- Methods (and specific system calls) to control socket-specific I/O (out-of-band, urgency, message structure, etc.)

Application: Threaded Server Model

Dynamic Thread Creation

1. A *main thread* listens for a `connection` request on a *predefined port*
2. After `accepting` the request, the server creates a thread to handle the request and immediately resumes listening for another request
3. The thread performs the request, closes the socket in response to the client's closing and returns

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Worker Pool

1. A *main thread* plays the role of a *producer*
2. A *bounded* number of *worker threads* play the role of *consumers*
3. The main thread listens for `connection` requests and asks the workers to process them (e.g., with a call-back)