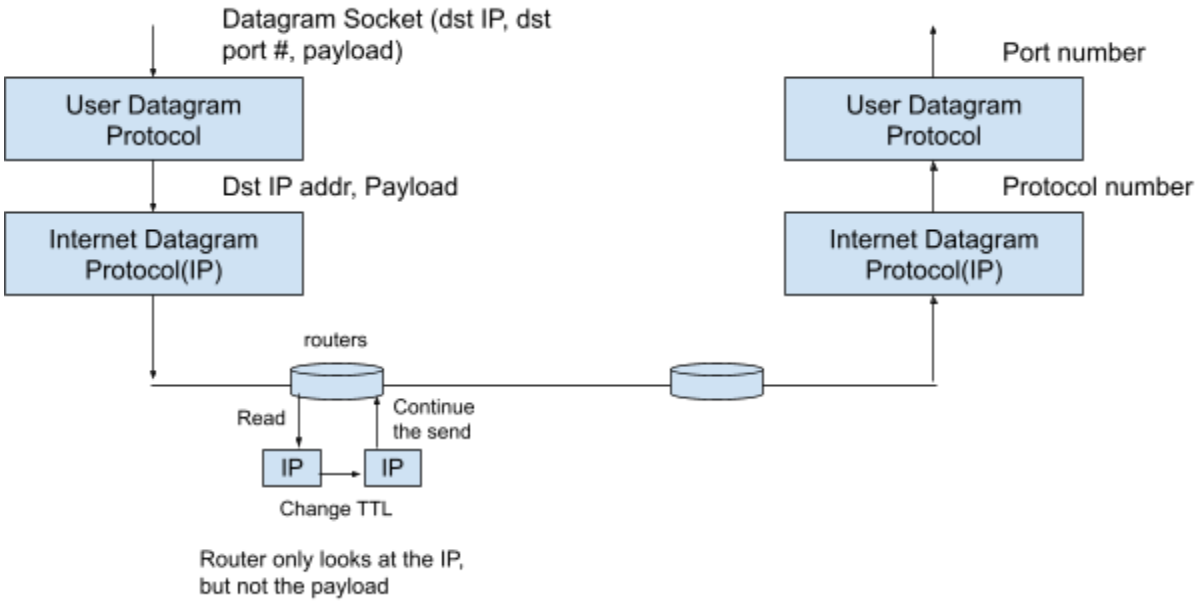
- Last week: best effort datagram - IP implementation
    - IP impl: (destination IP address, payload) -> Internet datagram {src IP address, dst address, TTL, payload, protocol}
    - Best-effort delivery
        - Delivered once
        - Never delivered
        - Delivered n > 1 times
        - Delivered with altered or truncated payload
        - Delivered to wrong destination
        - Delivered after another datagram that was sent later
    - User datagram protocol impl: (dst IP address, dst port #, payload) (`UDPSocket::sendto(...)`-> User datagram {contains src port, dst port, payload} (becomes payload of IP impl input)
    - Both provides best-effort delivery of datagrams (“unreliable”)
        - The fundamental difference between UDP and IP is that UDP is port-to-port (between unprivileged user programs) and IP is host-to-host/computer-to-computer (entities have internet addresses).
        - UDP and IP are in the OS kernel, but whatever that is on the top of UDP can be in user-space. Unprivileged user programs would not affect each other if the OS assigns a different port address to each user programs.
    - Q: what if datagrams are altered during transmission?
      A: UDP and IP have light checksum field for detecting alteration, and delivery to a wrong destination is something that could happen under “best-effort”.
    - Q: how does Firefox know which dst port to send UDP to?
      A: This is the same as how Firefox knows the dst IP address. (this question is deferred to later lecture)
      (/etc/protocols: protocol index, /etc/services: port number)
    - Q: how does Firefox know its own port number?
      A: The OS kernel assigns a src port to Firefox that won’t conflict with any other user program.
    - Q: how does Firefox know the source address of incoming datagrams?
      A: `UDPSocket::recv`: (src address &, payload &)
    - Q: Do I have to listen to the port as specified by /etc/services?
      A: It is possible to run a service not on a well-assigned port number.
- The protocol stack is a sequence of modules where each module only communicates with the layer 1-level upper and lower from it through service abstraction.



-
- What can be built on top of UDP?
    - Unreliable text messaging
    - Voice over UDP (VoIP)
    - IP over UDP (VPN: Virtual Private Network)
      Netflix -> UDP -> IP -> VPN Software -> UDP -> IP
      Some machine in France: VPN Software <- UDP <- IP, and send the upper-layer IP datagram over the Internet.
      When Netflix receives the datagram, it sees the src address as from France
- What if we want something more than “unreliable”? What if we want a “reliable retrievable short piece of data”?
    - Asker: request -> response can be built on top of UDP. Asker keeps sending until it gets an answer. Asker would eventually returns a response, and is “reliable”
    - `host cs144.keithw.org` is built as a user-program on top of UDP, and provides asker’s reliability (either returns or time-out)
    - For certain kind of requests, it is ok to make the request more than one time, but this is not the case for all requests.
    - What is the difference between reliable retrieval (“host cs144.keithw.org”) and reliable action (“Fire a torpedo”)? The kind of reliability that the service provides dictates how we design the service.