CS 521: Systems Programming

Socket Programming

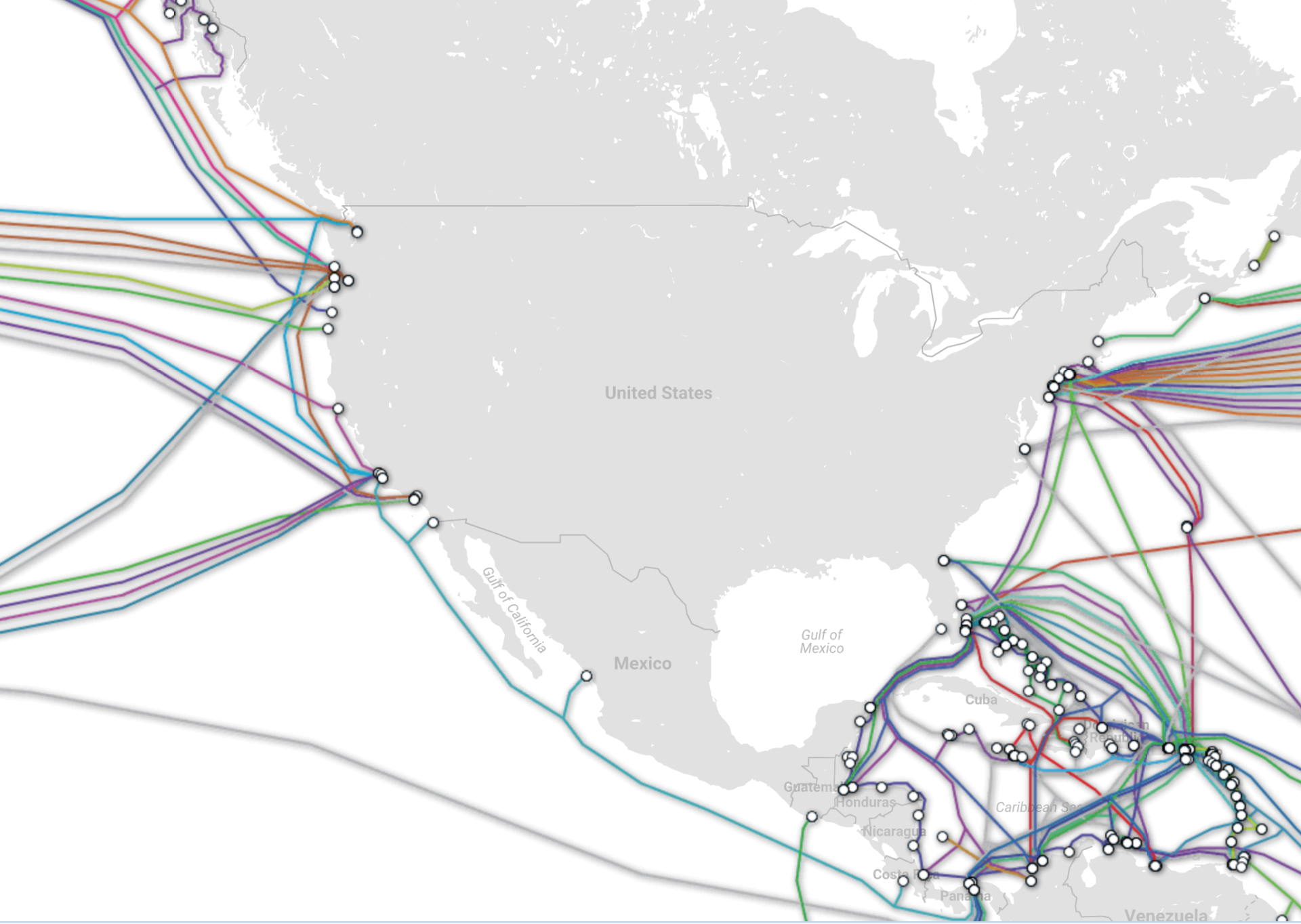
Lecture 22

Networking

- Nowadays, you can't do anything without a network connection
- Like, including using your VMs for class…

Network Terminology

- Host – computer/device connected to a network. Communicate via **packets**
  - How do they connect? https://www.submarinecablemap.com
- Packet – a unit of data, generally represented as a sequence of bytes
- Router – device that forwards packets through the network until they reach their destination host
- Protocol – defines how packets are laid out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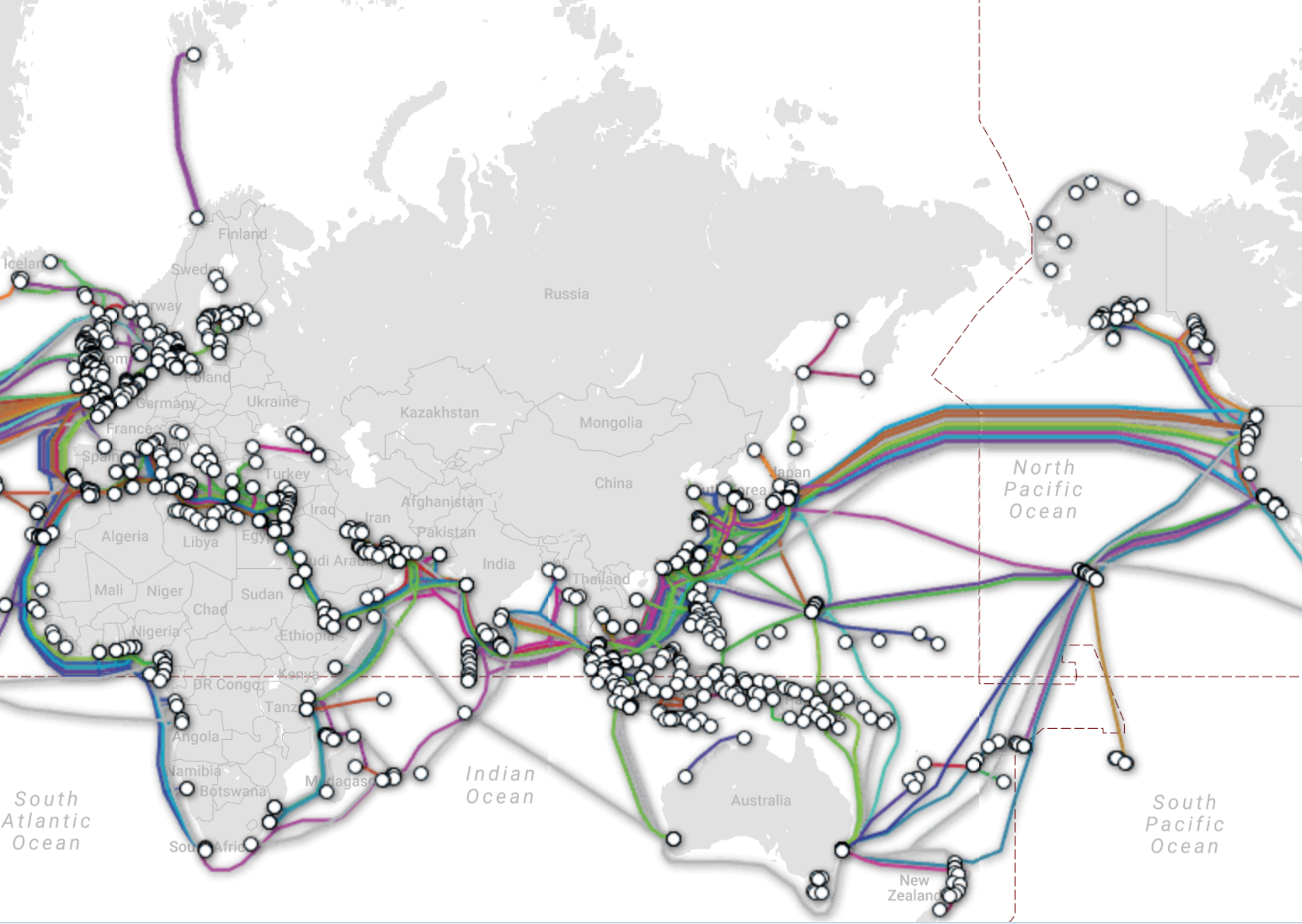
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Namibia
Botswana
Madagascar
South Africa
Australia
New Zealand
North Pacific Ocean
South Pacific Ocean
Indian Ocean
South Atlantic Ocean

TCP

- We use the **Internet Protocol (IP)** Suite for a majority of our communications
- For reliable delivery, we use the **Transmission Control Protocol (TCP)**
  - Modeled as a *stream* of bytes
  - Packets will reach their destination (eventually…) and the contents are verified
    - Retransmit when a failure/corruption occurs
  - Packets are received **in order**

UDP

- **User Datagram Protocol (UDP)** on the other hand, is *connectionless*
  - Rather than a stream of bytes, we deal with discrete messages
- No acknowledgment or retransmission
- Ordering is not guaranteed
- Used for games, video streaming, and other applications where delivery needn't be guaranteed

Sockets

- The standard API for network communication is **sockets**
  - Introduced in 1983, 4.2 BSD UNIX
- Sockets follow the Unix philosophy
  - everything is a file!
- When we open a connection, we get a file descriptor that we can `read()` and `write()` from
  - Just like a file… or pipe

Ports

- Each outgoing and incoming socket connection is assigned a **port number**
  - 16-bit unsigned integer (max: 65535)
- Want to talk to a web server via (HTTP)? Port 80!
- How about SSH? Port 22!
- Processes **bind** to these ports and listen on them
- When initiating an outgoing connection (e.g., from your browser) you can assign any available port

Clients and Servers

- Clients connect to a remote host for some type of service
  - ssh, http, etc.
- A server listens for these incoming connections and responds to them

Basic Server Workflow

1. Create a socket
2. Bind to a port
3. Listen for connections
4. Accept incoming connections:
   - This wraps a usual Unix file descriptor internally
     - Note: TCP is bidirectional: you can send and receive from the same FD

Basic Client Workflow

1. Create a socket
2. Connect to the remote host
3. Write/read data to/from the socket
   - Again, TCP is bidirectional: you can send and receive from the same connection

TCP Weirdness

- The first unintuitive thing about (TCP) sockets is there is no concept of a "message"
- Instead, everything gets read/written as byte arrays (streams of bytes)
  - Not all the bytes will come in at the same time, although order is guaranteed with TCP
- We generally need to use fixed-size messages or prefix them with a length to know what to expect

Simple Messaging [1/2]

- A common message format:
  - `[ MESSAGE SIZE ][ MESSAGE PAYLOAD ]`
- Once you've unpacked the message payload, it can contain more fields
  - For example: message **type**, version number, flags, etc.
- This allows for a layered approach:
  - Network code
  - Message creation code
  - Pass through a chain of handlers

Simple Messaging [2/2]

- If you don't need advanced features, size-prefixed messages work well
- Exceptions:
  - You'd like to avoid reading the entire message before you start processing it
  - You don't even need to process the whole message (perhaps you are forwarding it somewhere else)
- Network **wire formats** have a huge range of features and complexity

Serialization

- **Serialization** transforms an object, structure, or application state into a format for transmission
  - (and often storage to disk)
- Most common: **binary** formats
  - Better performance
- When you receive a serialized message, transforming it back into its original representation is called **deserialization**

Trying it out

- Let's build a simple chat program…