CSCE 463/612
Networks and Distributed Processing
Spring 2024

Introduction II

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Multi-Threading

- Quiz next time (entire class)
  - My programming tutorial (pointers, bits ops, debugging, Windows datatypes)
- Threads execute concurrently as part of a process
- Benefits:
  - Allows for parallelism in a multiprocessor/multicore system
  - If a blocking call is made in one thread, other threads can continue executing
- Issues:
  - Memory is shared between threads, concurrent access requires proper synchronization
  - Order of execution of threads is non-deterministic

Multi-Threading 2

- Reasons for using multiple threads in hw #1
  - Web servers respond slowly (1-10 seconds/request)
  - While a thread is suspended waiting for connect() and recv(), other threads should be allowed to work
- Multiple threads achieve significant speed-up
  - You could run thousands of threads, but limit your testing to ~10 until you know it works correctly
- Common synchronization mechanisms
  - Mutex (mutual exclusion): allows only one thread access to critical section; others must wait
  - Semaphore: allows up to N concurrent threads
  - Event: binary (i.e., ON or OFF) signal

Multi-Threading 3

- Mutex usage
  - Any data structure (e.g., queue) or resource (e.g., screen or disk) modified by parallel threads needs to be protected
  - If not, inconsistencies (data corruption) may result

```
CRITICIAL_SECTION cs;
InitializeCriticalSection (&cs);

EnterCriticalSection (&cs);   // lock
// critical section here ...
LeaveCriticalSection (&cs);   // unlock
```

- Events
  - CreateEvent, WaitForSingleObject, CloseHandle
- Homework note: pass shared parameters to threads using a dedicated class instead of using global variables (see 463-sample.zip on course site)

Multi-Threading 4

- A semaphore has a numerical value `s` attached to it
- Wait on semaphore (operation P)
  - If `s == 0`, the semaphore suspends the calling thread
  - If `s > 0`, the thread is allowed access and `s` is set to `s-1`
- Release semaphore (operation V)
  - If threads are waiting, unblock one of them and run it
  - Otherwise, increment `s = s + 1`

```
HANDLE sema = CreateSemaphore (...);
DWORD ret = WaitForSingleObject(sema, INFINITE);            // wait
if (ret != WAIT_OBJECT_0)
    // report error

// critical section...

if (ReleaseSemaphore (sema, ...) == FALSE)                  // release
    // report error
```

Chapter 1: Roadmap

1.1 What *is* the Internet?

1.2 Network edge

1.3 Network core

1.4 Network access and physical media

1.5 Internet structure and ISPs

1.6 Delay & loss in packet-switched networks

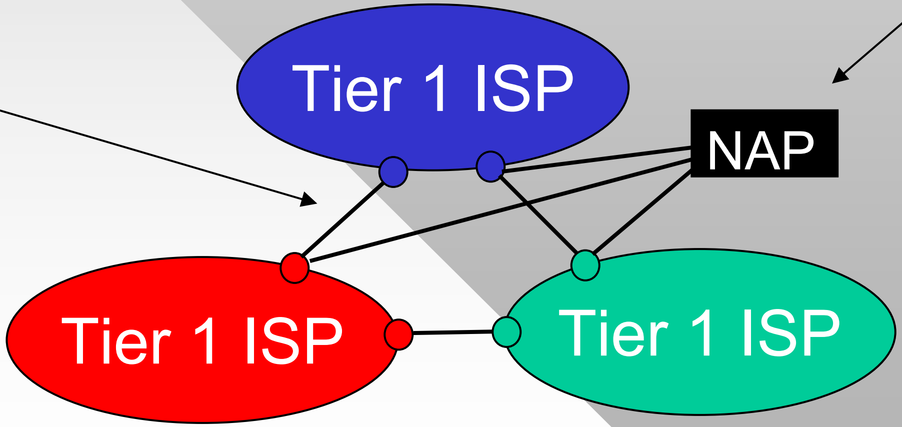
1.7 Protocol layers, service models

1.8 History

Internet: Network of Networks

- Roughly hierarchical
  - In the center: “tier-1” ISPs (e.g., Sprint, AT&T, Verizon), national/international coverage
  - Treat each other as equals, do not pay for upsteam bandwidth
  - Form the backbone of the Internet

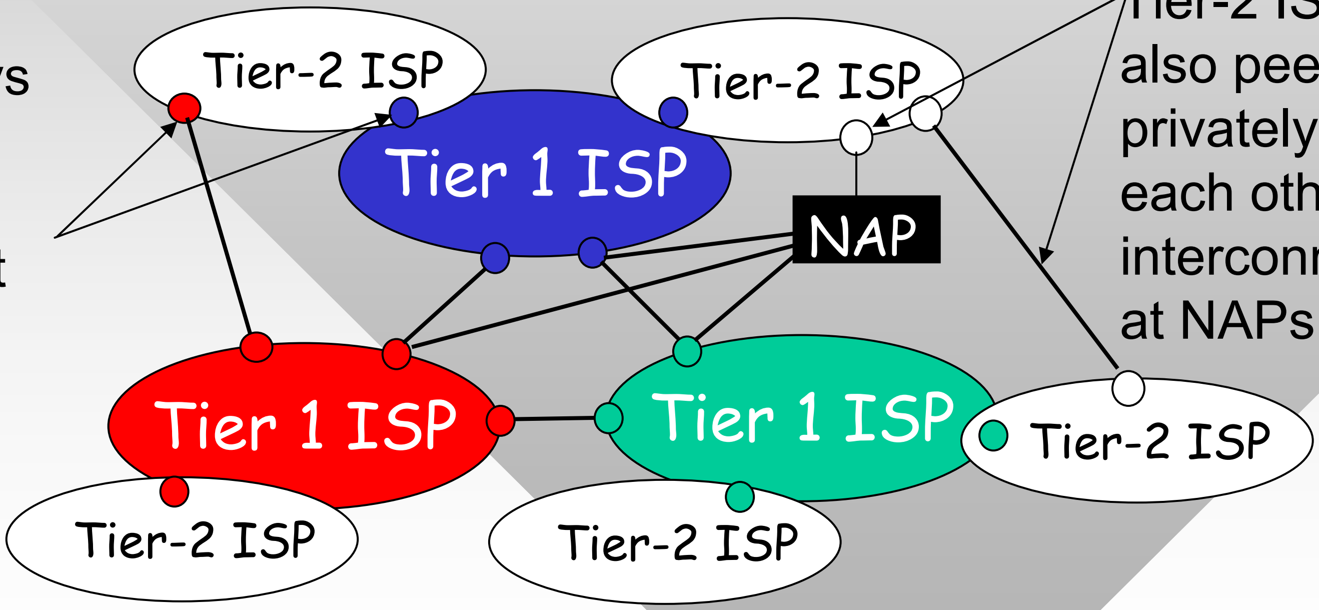
Tier-1 providers interconnect (peer) privately



Tier-1 providers also interconnect at public *network access points* (NAPs)

Internet: Network of Networks

- "Tier-2" ISPs: smaller (often regional) ISPs
  - Connect to one or more tier-1 ISPs, possibly other tier-2 ISPs



Tier-2 ISP pays tier-1 ISP for connectivity to rest of Internet

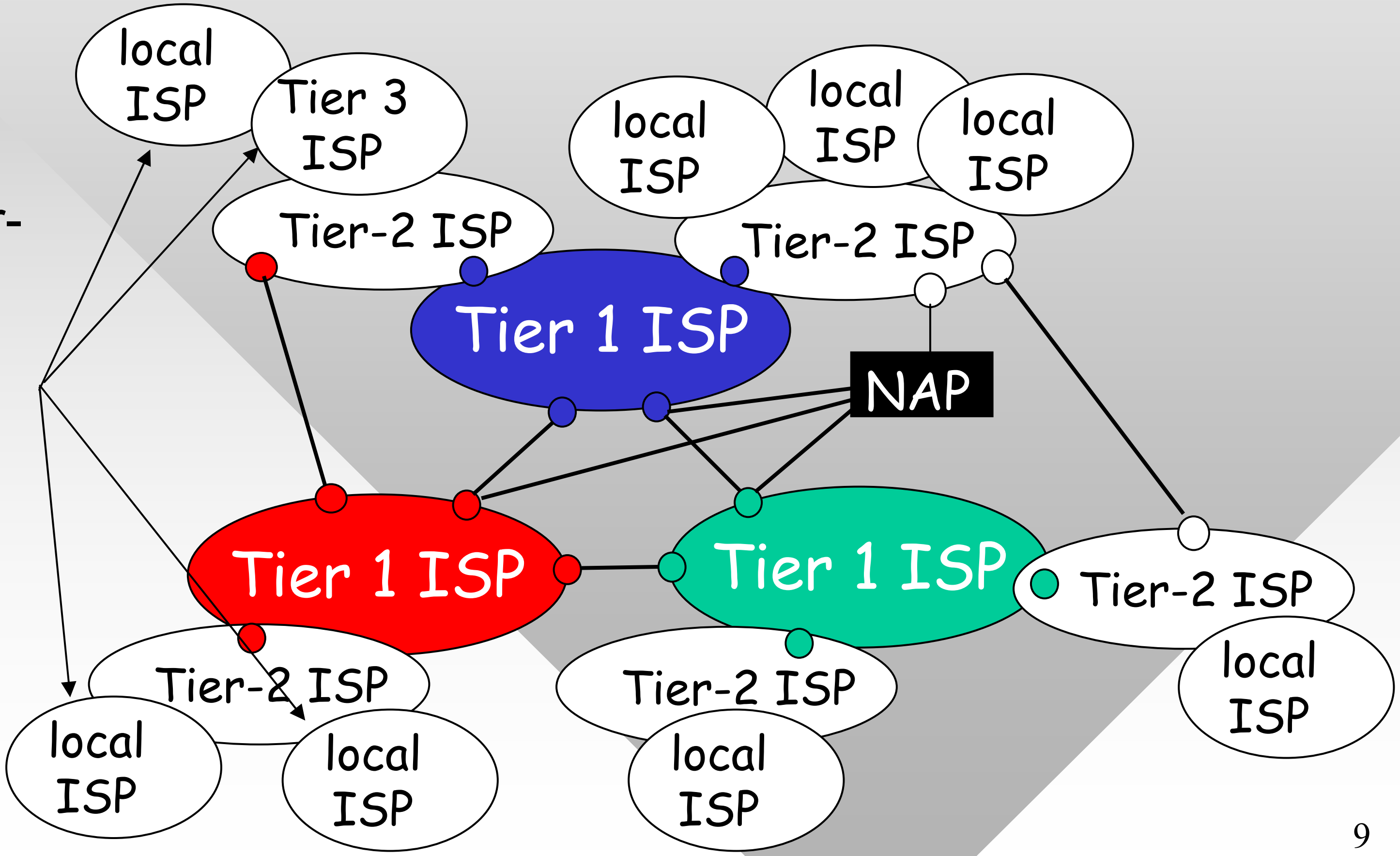
Tier-2 ISP is *customer* of tier-1 *provider*

Tier-2 ISPs also peer privately with each other, or interconnect at NAPs

Internet Structure: Network of Networks

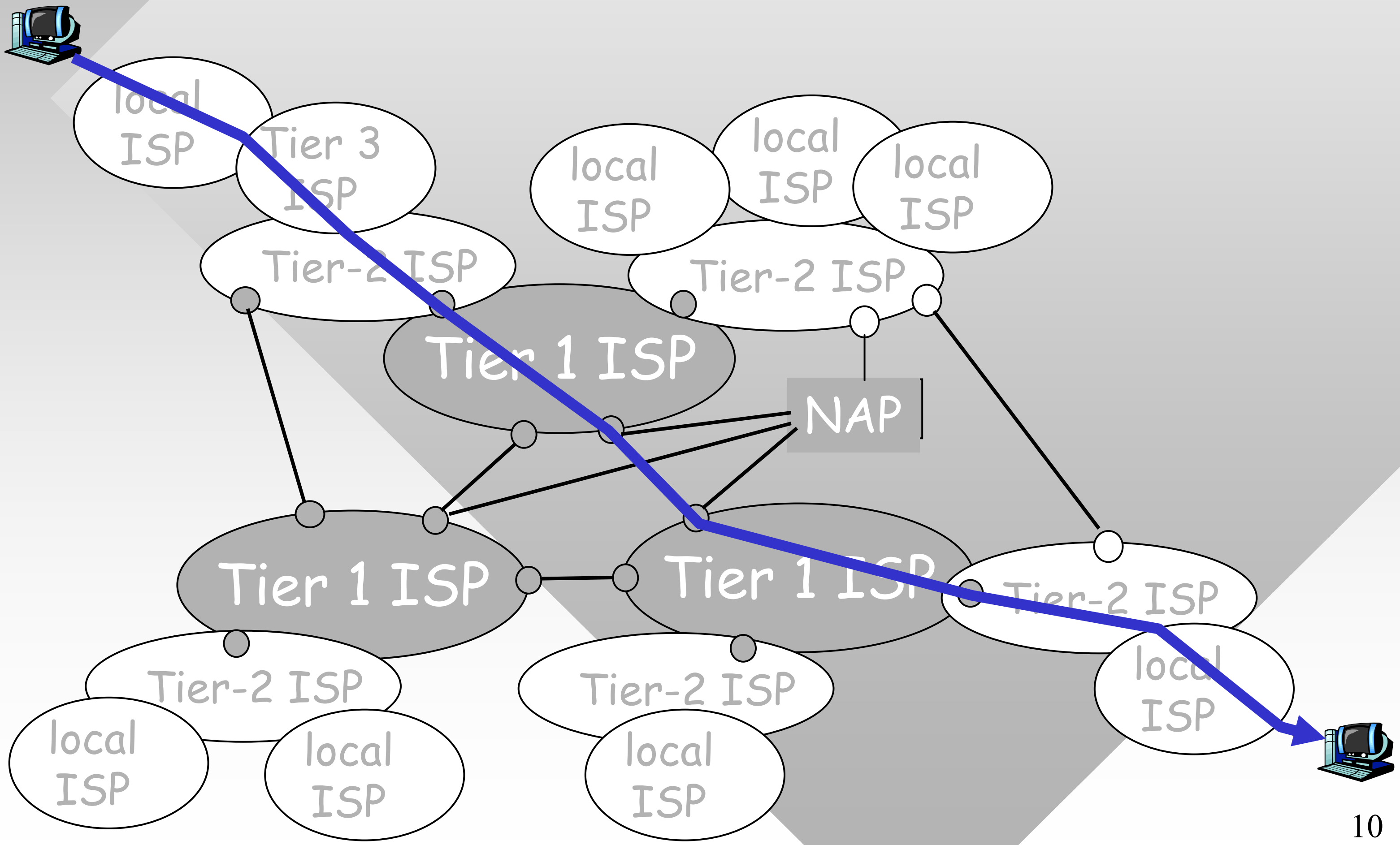
- "Tier-3" ISPs and local ISPs
  - Last hop ("access") network (closest to end systems)

Local and tier-3 ISPs are *customers* of higher tier ISPs connecting them to rest of Internet



Internet Structure: Network of Networks

- A packet passes through many networks!


local ISP
Tier 3 ISP
Tier-2 ISP
local ISP
local ISP
local ISP
Tier-2 ISP
Tier 1 ISP
NAP
Tier 1 ISP
Tier 1 ISP
Tier-2 ISP
local ISP
Tier-2 ISP
Tier-2 ISP
local ISP
local ISP
local ISP