ECE 257A
Modern Communication Networks

Lecture 01. Introduction and Overview

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Today's agenda

- Course logistics
- Why take this course?
- How to get an A?
- Modern network architecture and work flow

Course logistics

Administrative information

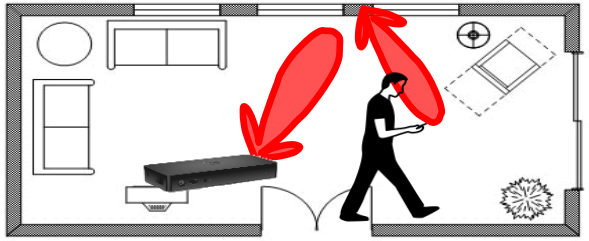
- Lecture schedule
  - 12:30pm-1:50pm, Tue. Thu.
  - We also reserved 2pm-2:50pm Wed. for a few make-up lectures (2-3)
- Instructor: Prof. Xinyu Zhang
  - Instructor office hours:
    1:50pm-2:50pm, Tue. Thu.; Atkinson Hall 4314
    OR email appointment
- TA: Xiao Sai (xsai@eng.ucsd.edu)
  - TA office hours:
    Monday, Thursday; Atkinson Hall 4th floor (map posted on TritonEd)
    OR email appointment

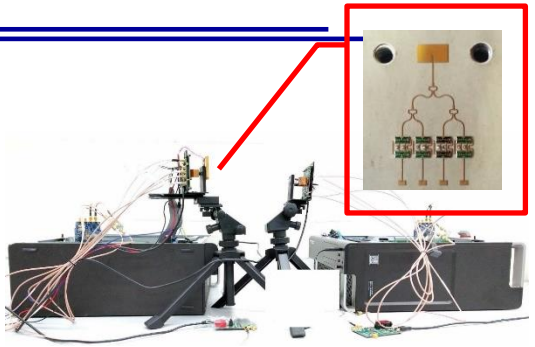
Administrative information

- Course website:
  - Public: http://xyzhang.ucsd.edu/ece257a
  - Internal: TritonEd
- More about me – research themes
  - Wireless systems and networking
  - Mobile and ubiquitous computing

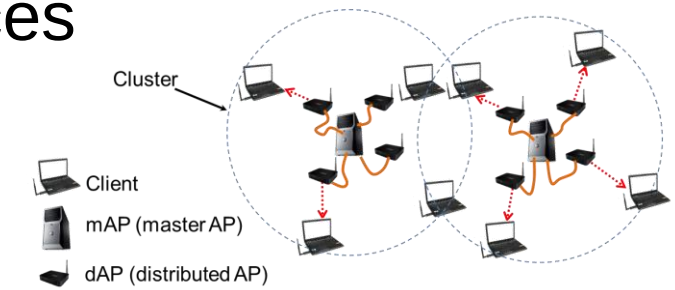
Research in wireless systems and networking

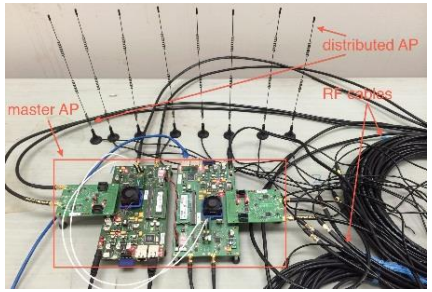
- Ubiquitous Gbps wireless networking through mmWave radio beams



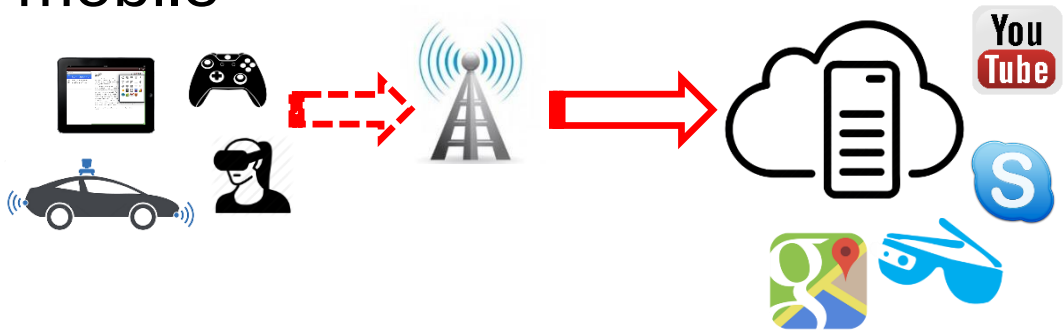


- Eliminating wireless interferences through distributed antennas





- High performance mobile applications

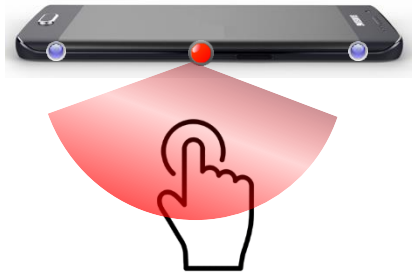


Research in mobile and ubiquitous computing

- 3D localization for smartphones and IoT
  - e.g., LiTell

- Sensing human interaction with batteryless “things”
  - e.g., Tagyro

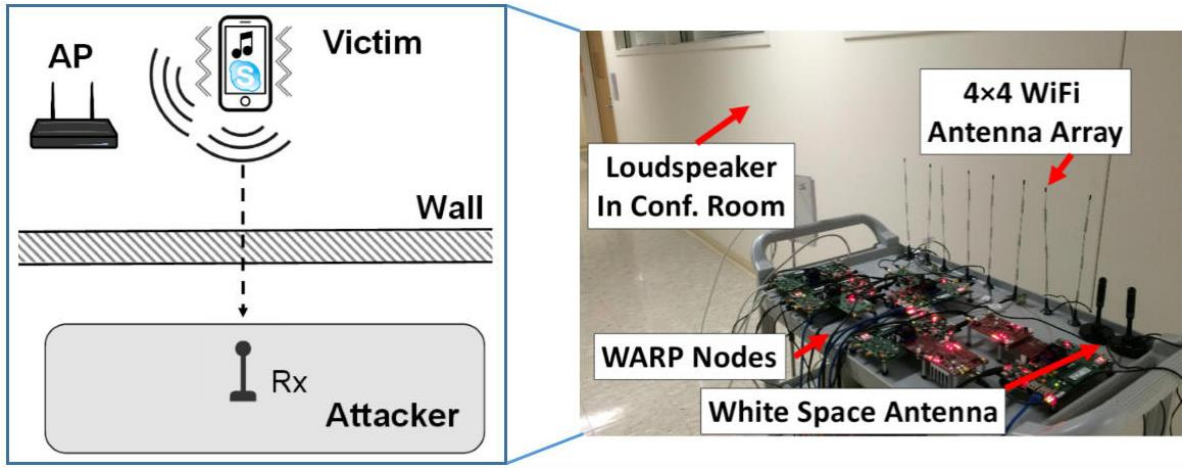
- Sensing human interaction with small mobile devices
  - e.g., UbiK, Okuli

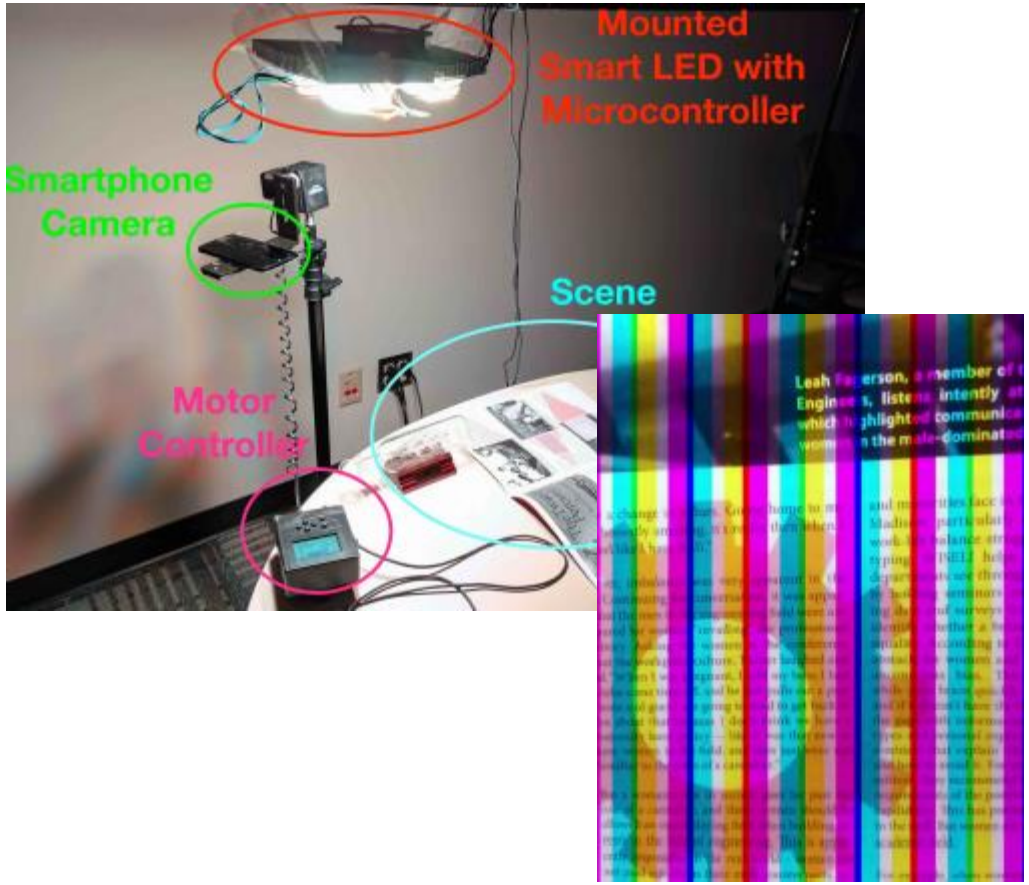


* See Youtube demos via Google: “Xinyu Zhang”

Research in mobile and ubiquitous computing

- Security for IoT
  - e.g., Vibrometry, LiShield





* See Youtube demos via Google: “Xinyu Zhang”

Why take this course?

What is this course about?

- All about modern communication networks
  - What are there?
  - How do they work?
  - Why do they work that way?
- Some new features
  - Interdisciplinary: communication engineering + network system design
  - Full-stack: from PHY layer packet processing to application-layer software

What is this course about? (longer version)

- Network architecture:
  - Building blocks of the modern wireless Internet
  - Work flow of end-to-end data delivery (Web request as an example)

- Packet and signal processing at the lower layer
  - Channel models and fundamental capacity theorems
  - Modulation, demodulation, packetization
  - Multi-antenna communication&networking technologies
  - Millimeter-wave networking (core 5G technology)

What is this course about? (longer version)

- Network protocols and operations at the higher layer
  - MAC layer protocols and stochastic models
  - Routing protocols and optimization formulation; mobile IP
  - TCP and its optimization formulation; TCP over wireless

- Mobile applications
  - Video streaming, video chat, virtual reality
  - Energy efficiency issues

Learning objectives

- Understand the big pictures
- Understand the end-to-end work flows
- Acquire basic network modeling skills (stochastic processes, linear/non-linear optimization)
- Prepare for future study, research, and career

Learning objectives (longer version)

- Understand the big pictures
  - Describe the modern wireless Internet architectures and workflows so that a person with general engineering background can understand
- Understand the fundamental modules in modern wireless technologies
  - Being able to express the packet/symbol level processing in simplified models, and to implement the algorithms
  - Understand the asymptotic capacity scaling mechanisms for wireless communication technologies

Learning objectives (longer version)

- Learn the performance modeling techniques for network protocols
  - Stochastic models for MAC
  - Optimization models of routing and TCP
- Prepare yourself for future
  - Research skills: surf the reference sea; writing and presenting reports
  - Background knowledge for other courses
  - Research in networking, wireless communications, and mobile computing
  - Jobs in IT companies

How to get an A?

Prerequisite

- Basic understanding of computer networks
- Low level course in communication systems

Elements of the course

- Homework assignment (20%)
- Course project (40%): Proposal: 5%, Final Report: 30%, Final presentation: 5%
- Final exam (35%)
- Course participation (5%)

Homework assignments

- 4 assignments, each involving 4-6 problems.
- Typical problems: Q&A, algorithms, modeling, simulation, and small programming assignments (Matlab, Python)
- Certain assignments allow group work

Course project: 3 options

- System measurement and design
  - Measurement and analysis of protocol/application behavior
  - Design and validation of new network algorithms/protocols
  - Reproducing results from an existing paper (you can reuse their code)
- Theoretical modeling
  - Modeling and performance evaluation of emerging protocols/applications, e.g., millimeter-wave networking, low-power IoT
- Topic survey
  - Pick a specific topic and write a 10-page survey paper, e.g., software-defined mobile networks, millimeter-wave networking, backscatter communications, low-power wide-area IoT networking, AI-driven networking

Course project

- Group projects are strongly recommended
  - Up to 3 people are allowed for the first 2 options; up to 2 people are allowed for the area survey option
  - Must get instructor approval if you want to work alone
- Project proposal due by 10/11/2018; Guidelines for project proposal will be provided through a separate email
- A list of suggested topics will be provided by next Monday
- Final presentation: week 12/03.

Final exam

- Date: 11:30am-2:29pm,12/14/2018

- If you are familiar with the lecture content and homework, you'll do well.

- Learning and reviewing course materials
  - No textbook (mostly outdated). But reference papers and book chapters will be provided
  - Polish your reference reading capability (only read the parts that are relevant to lectures)

Course participation

- Attend lectures regularly (let instructor know you)
- Participate in discussion
- Don’t be afraid to ask “layman” questions
  - Look at problems from different perspectives; use your domain knowledge
  - Innovations often come from simple insights

Today's lecture:
Modern Network Architecture

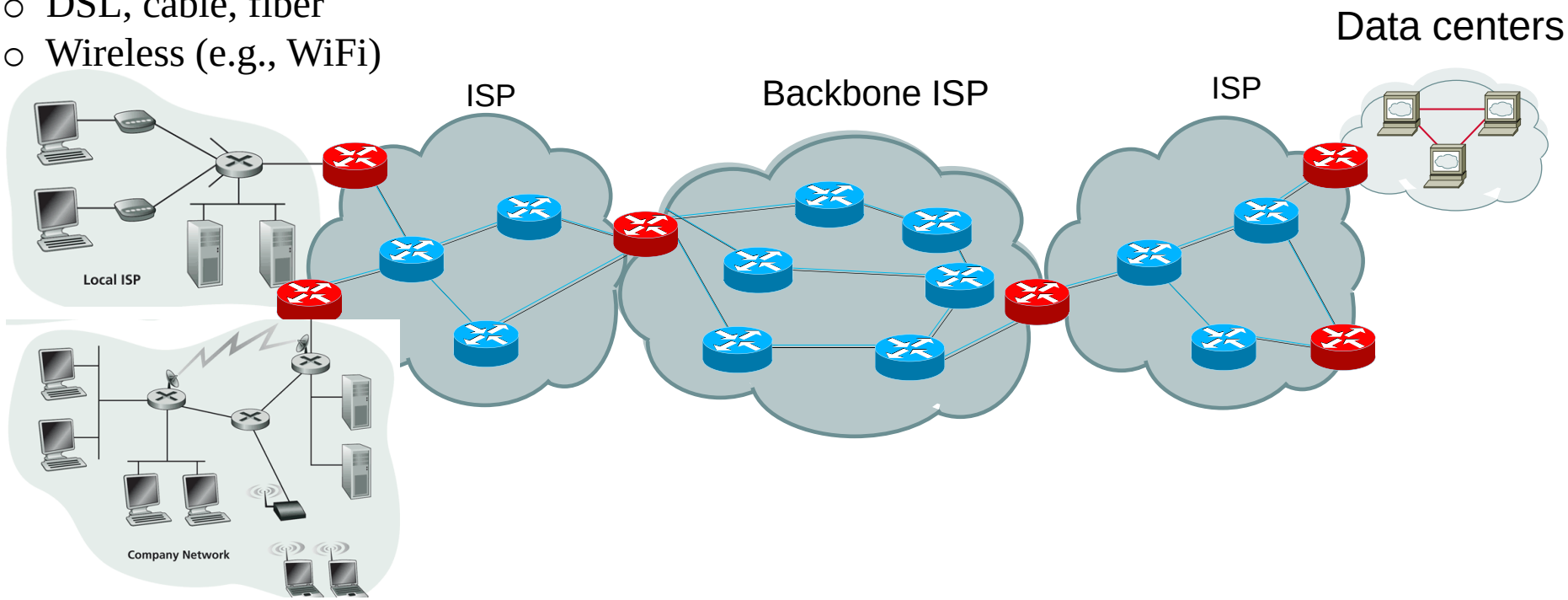
Evolution of modern Internet

- Internet connects human being
  - Emails, online forums, social networks…
- Internet connects mobile computing devices
  - Smartphones, wearable devices, gaming devices, …
- Internet connects sensors and “things”
  - Smart meters, smart furniture, smart appliances, …

Always-connected, context aware computing and communication

Modern Internet topology: simplified view

Residential access:
- DSL, cable, fiber
- Wireless (e.g., WiFi)



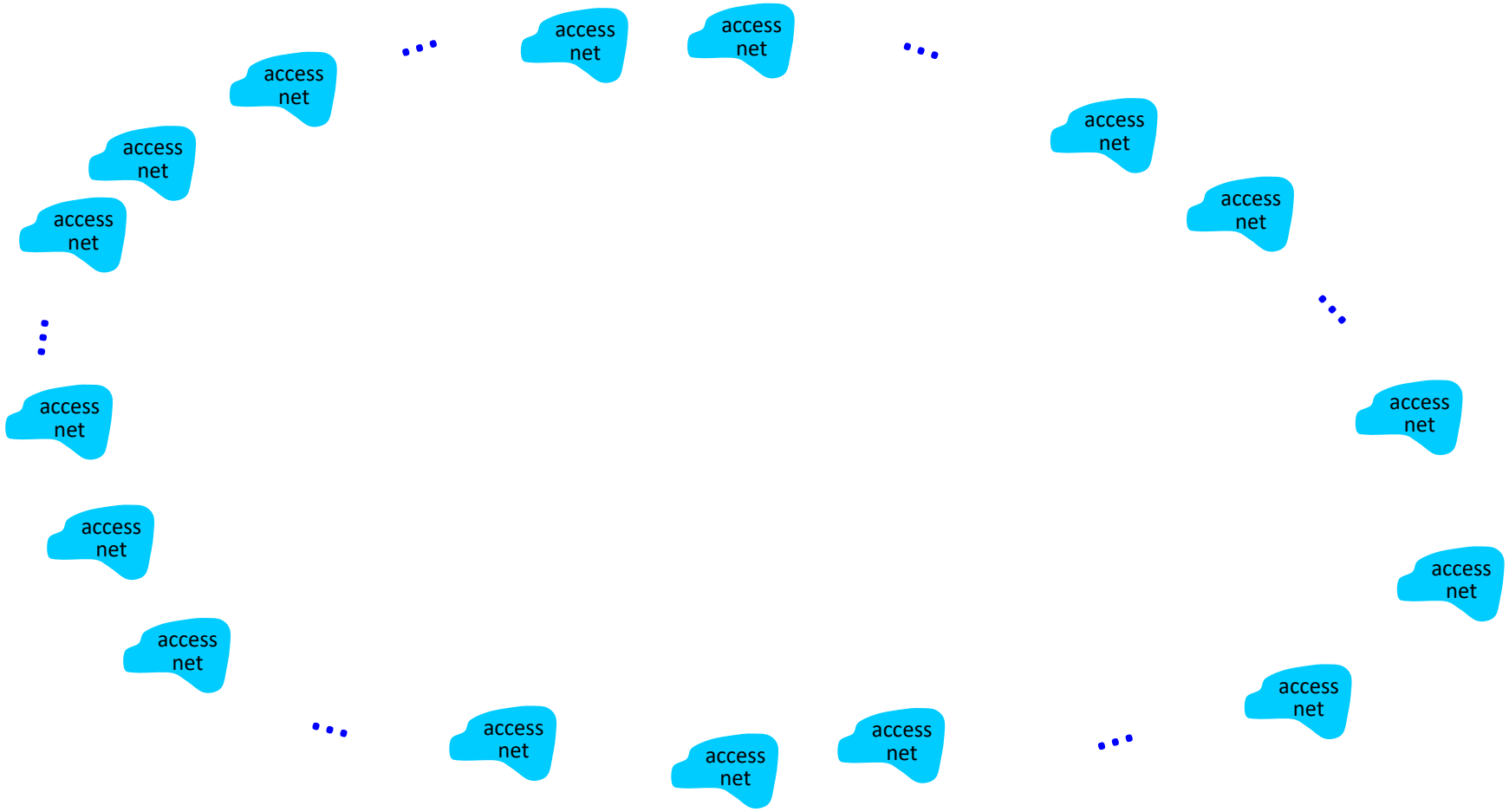
Campus/enterprise access:
- Ethernet
- Wireless (e.g., WiFi)

Modern Internet topology: Network of Networks

- End systems connect to Internet via access ISPs (Internet Service Providers)
  - Residential, company and university ISPs
- Access ISPs in turn must be interconnected
  - So that any two hosts can send packets to each other
- Resulting network of networks is very complex
  - Evolution was driven by economics and national policies

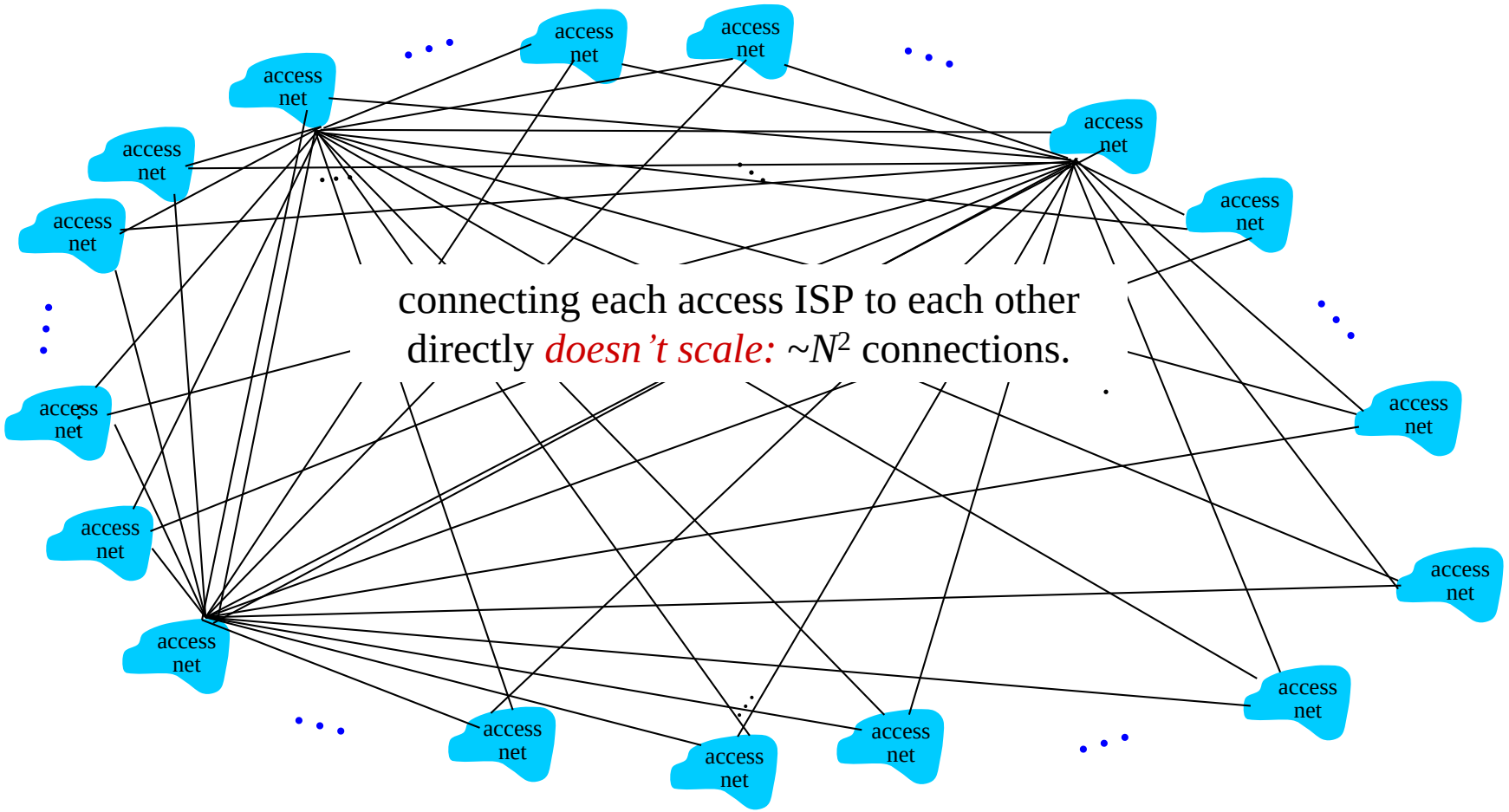
Modern Internet topology: Network of Networks

Question: given *millions* of access ISPs, how to connect them together?



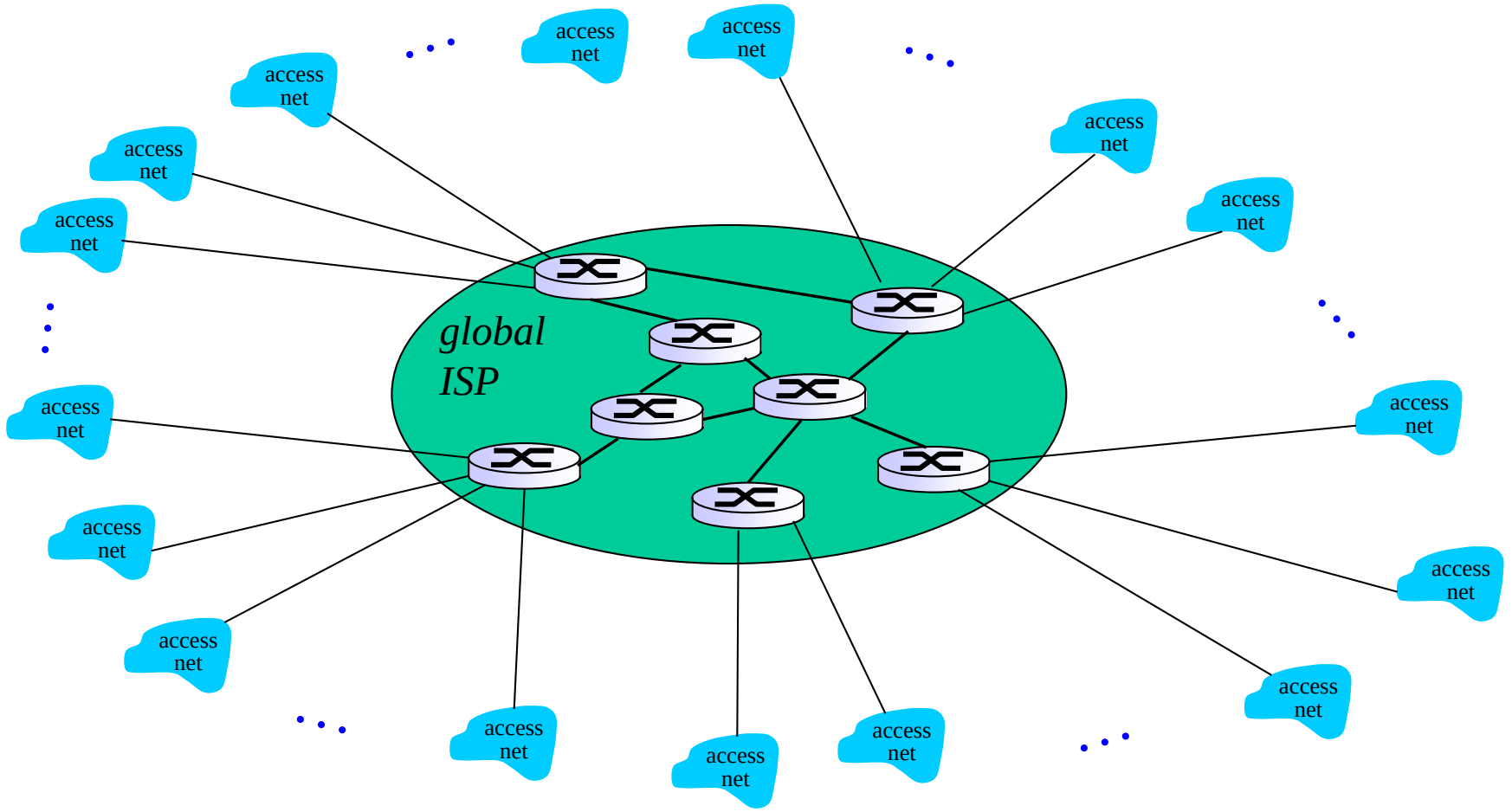
Modern Internet topology: Network of Networks

Option: connect each access ISP to every other access ISP?



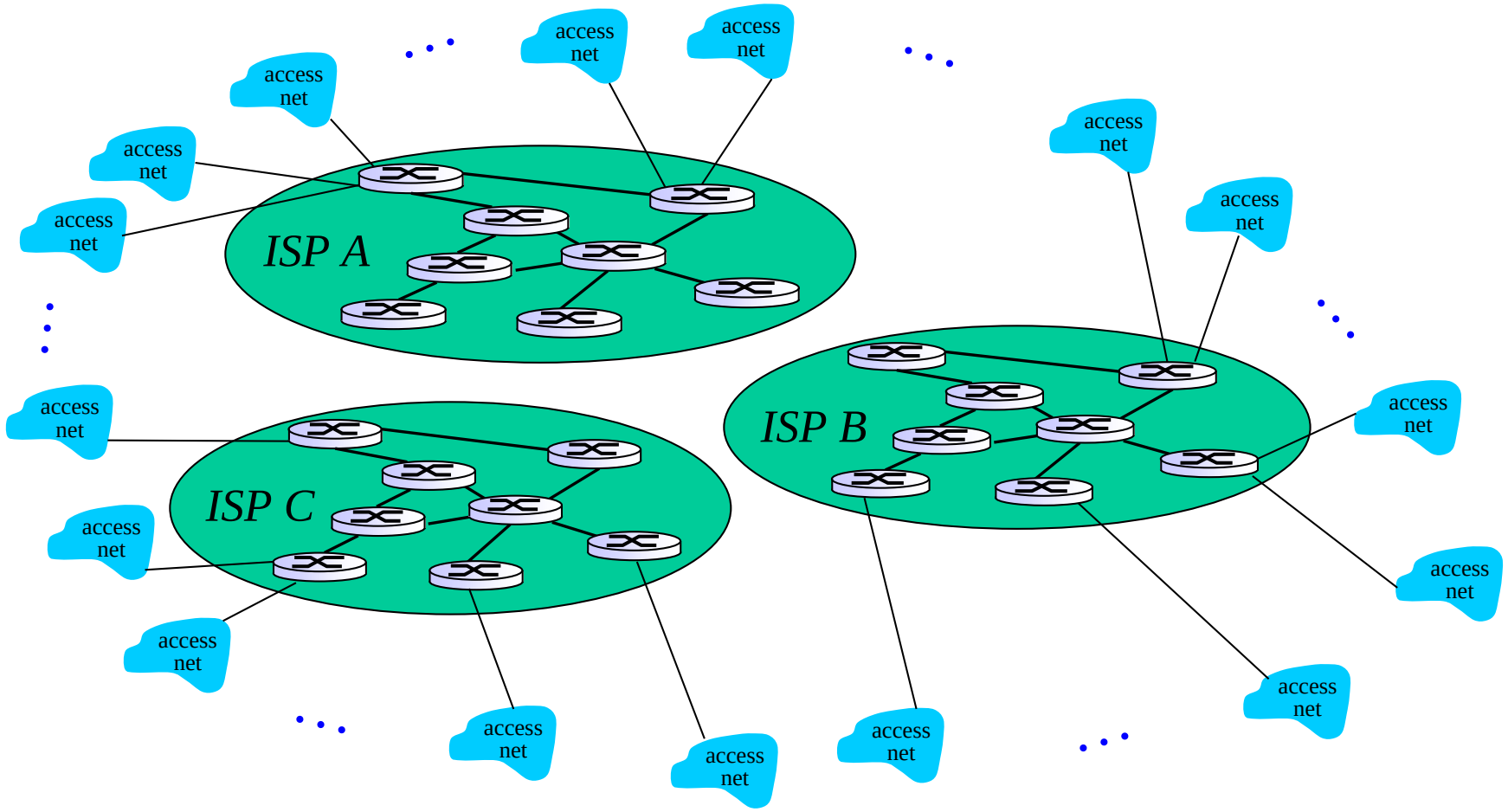
Modern Internet topology: Network of Networks

Option: connect each access ISP to a global transit ISP? Customer and provider ISPs have economic agreement.



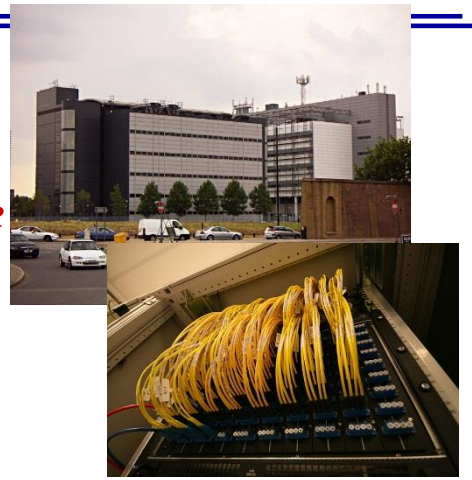
Modern Internet topology: Network of Networks

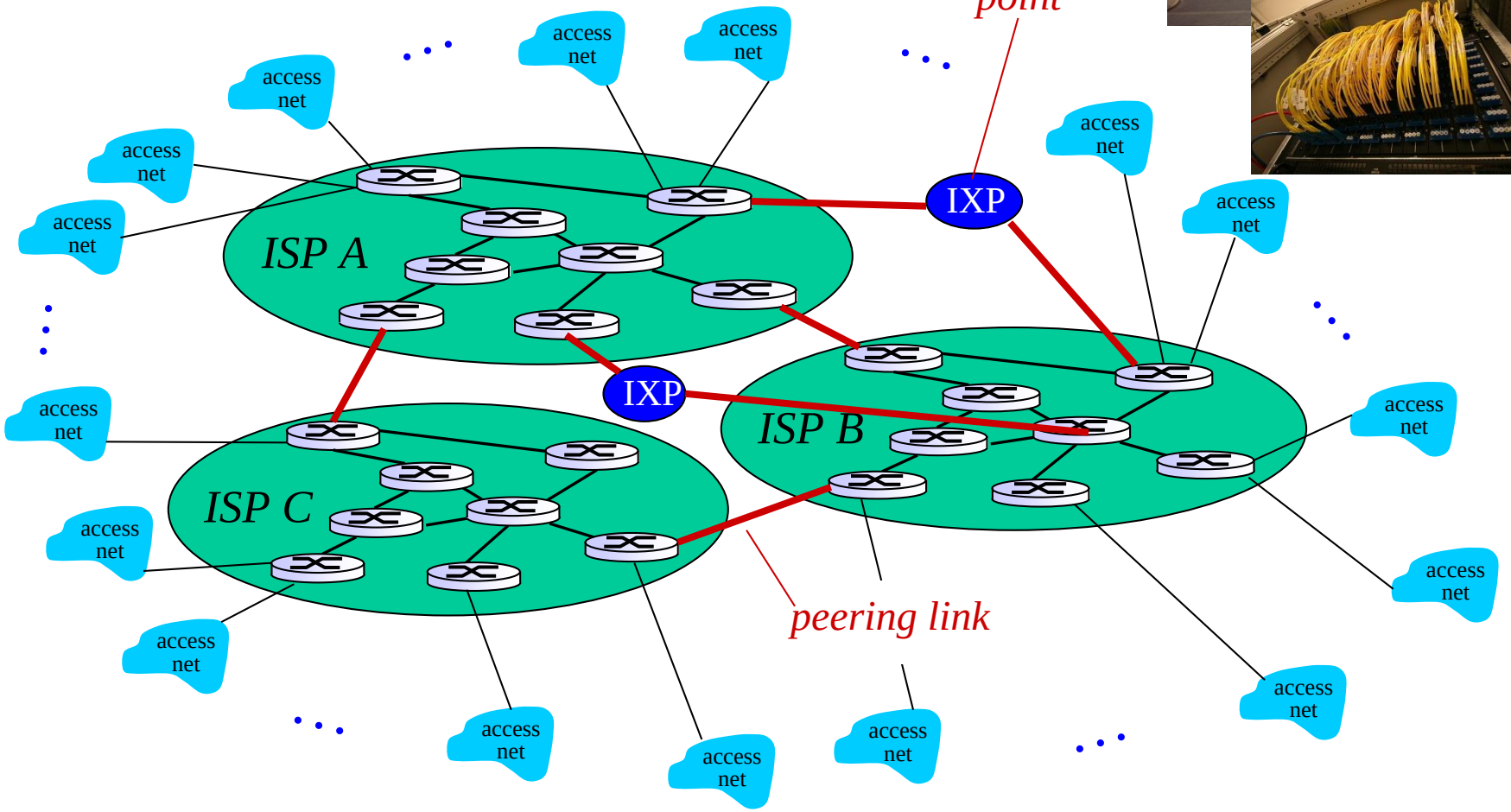
But if one global ISP is viable business, there will be competitors ….



Modern Internet topology: Network of Networks

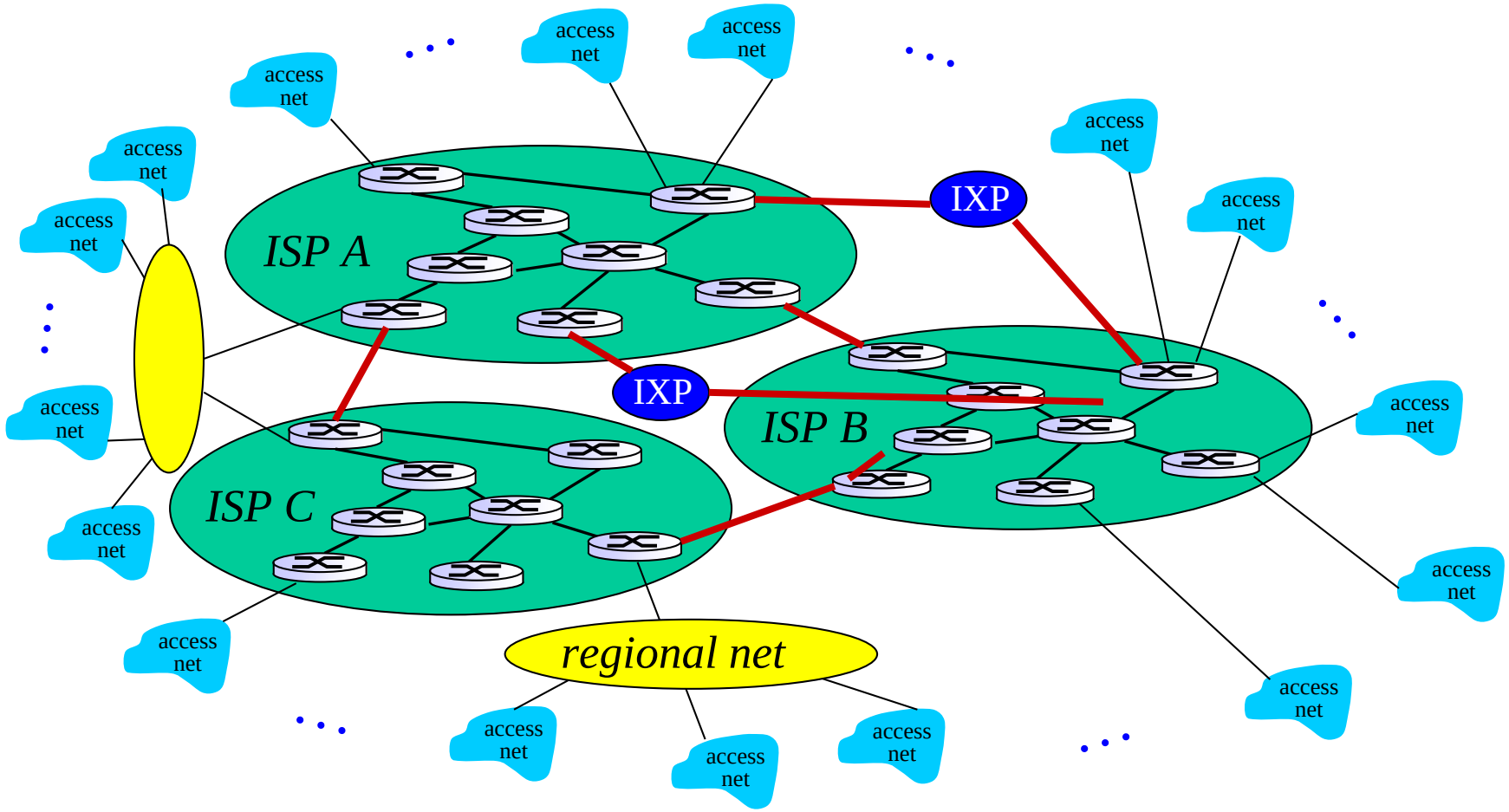
But if one global ISP is viable business, there will be competitors …. which must be interconnected





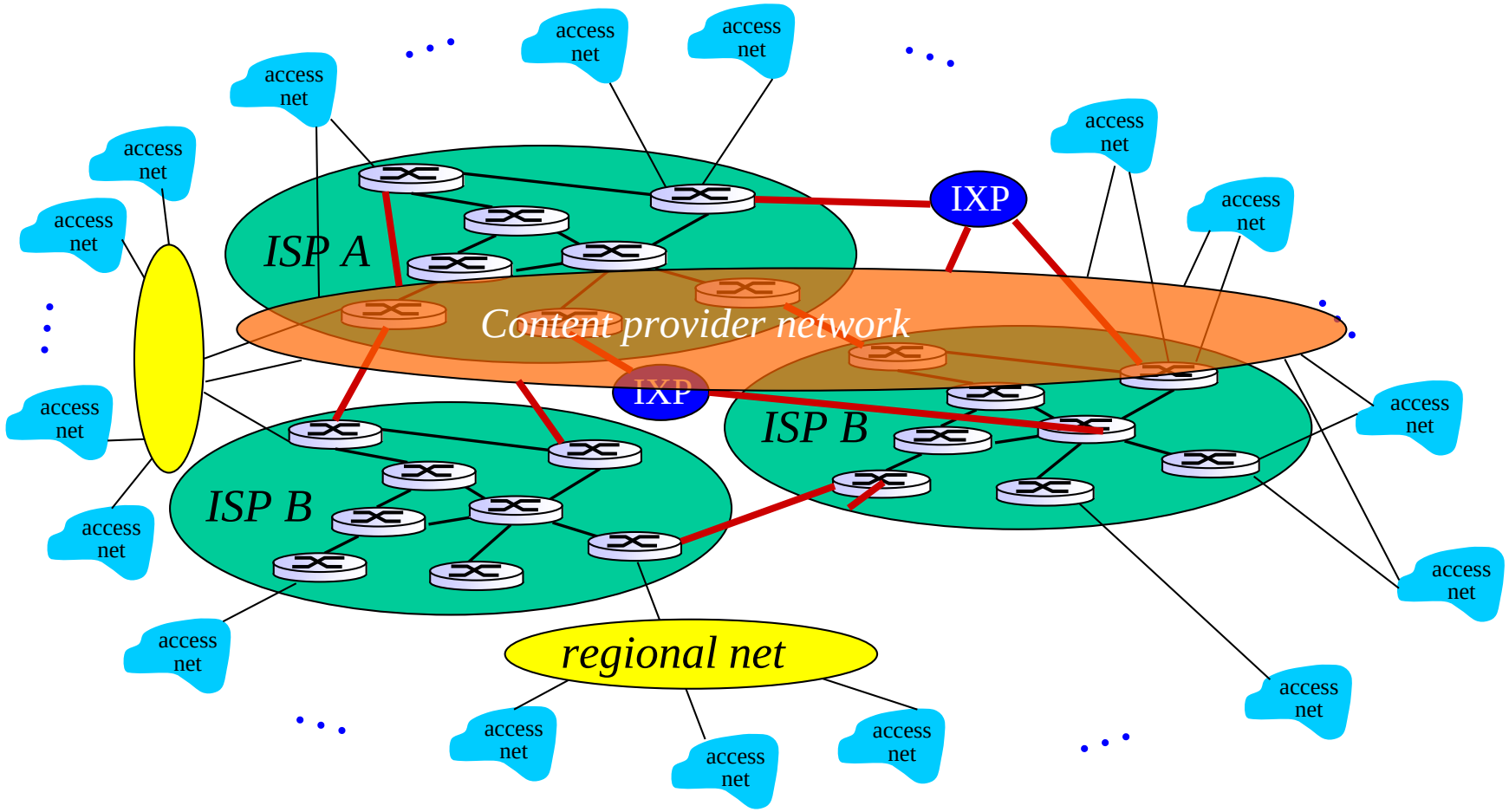
Modern Internet topology: Network of Networks

… and regional networks may arise to connect access nets to ISPs

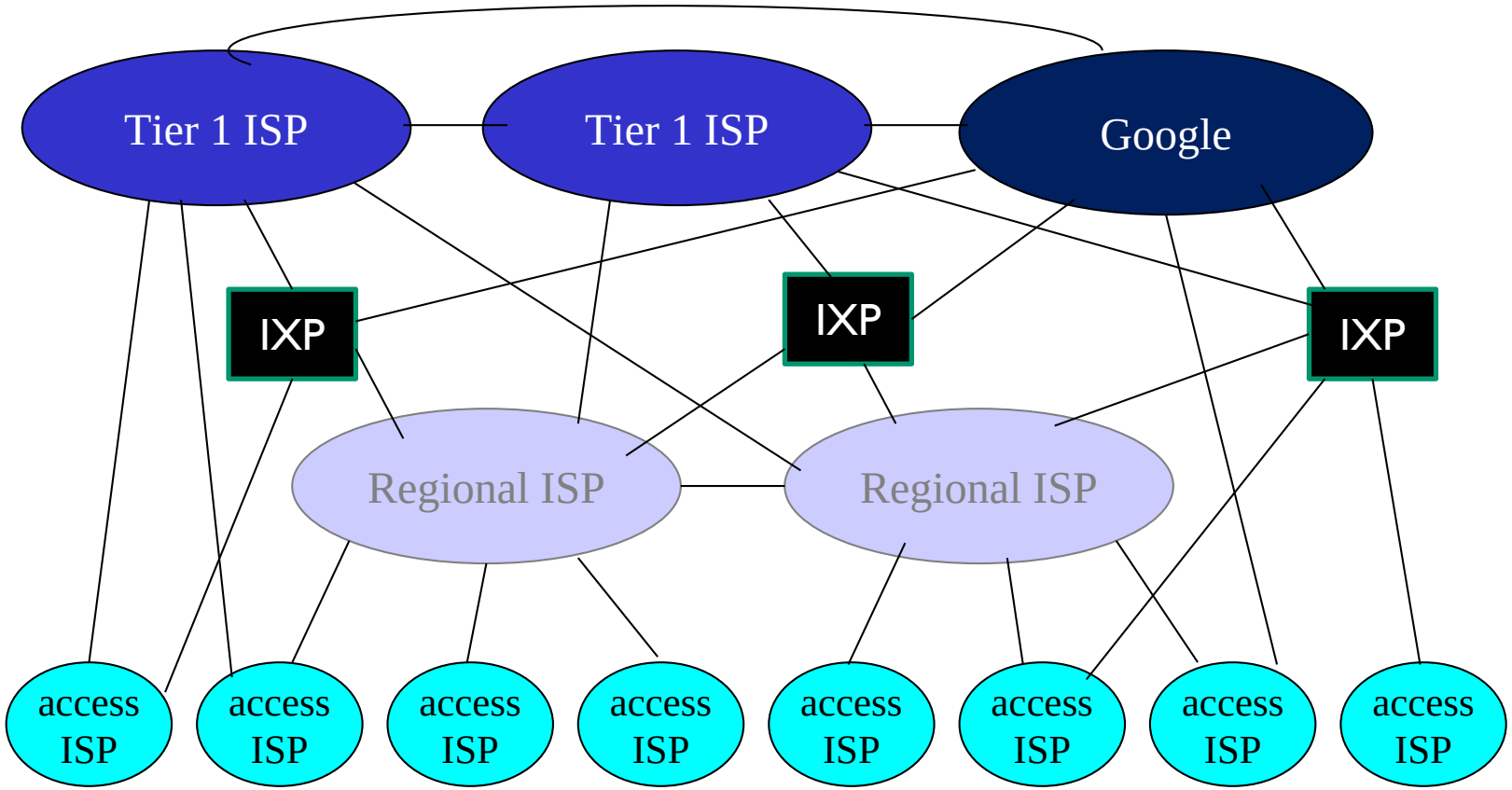


Modern Internet topology: Network of Networks

… and content provider networks (e.g., Google, Microsoft, Akamai) may run their own network, to bring services, content close to end users



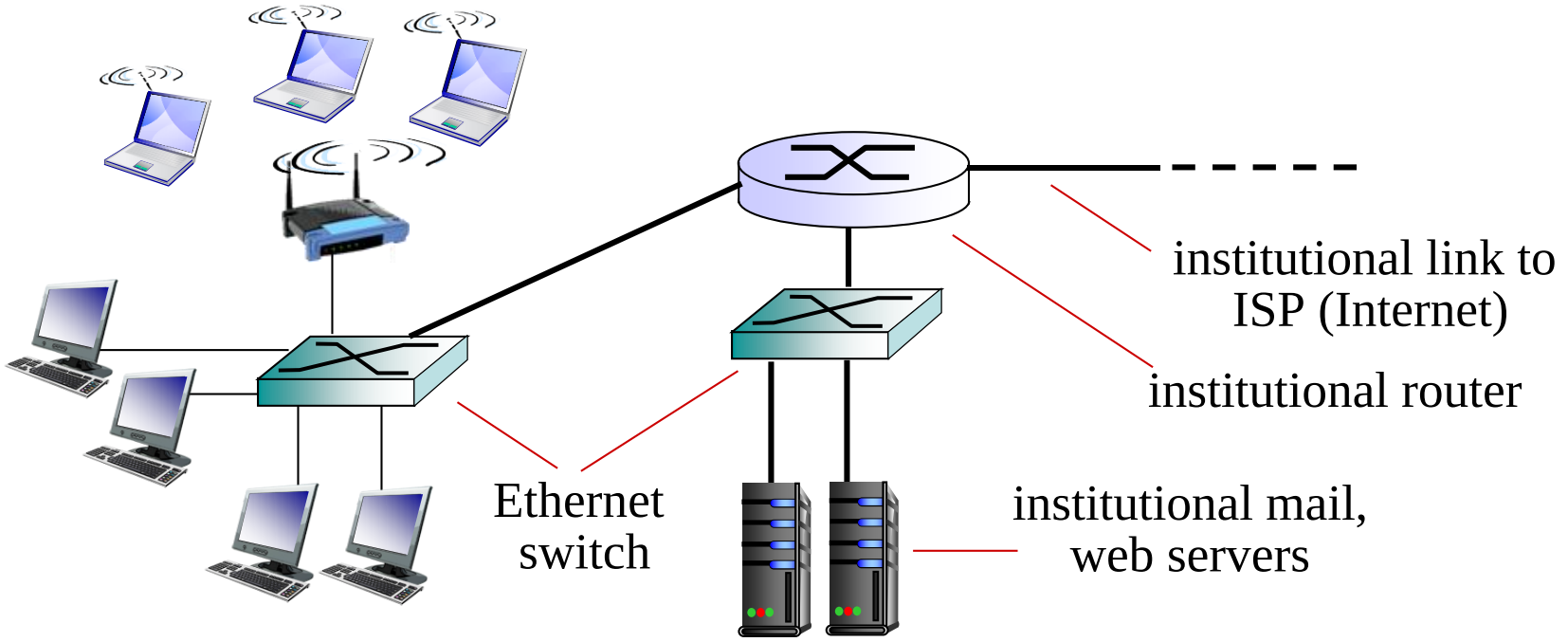
Modern Internet topology: Network of Networks



- at center: small # of well-connected large networks
  - "tier-1" commercial ISPs (e.g., T-Mobile, AT&T), national & international coverage
  - content provider network (e.g, Google): private network that connects it data centers to Internet, often bypassing tier-1, regional ISPs

Access network: the last-hop, the bottleneck

- Enterprise network (companies, organizations, campus)

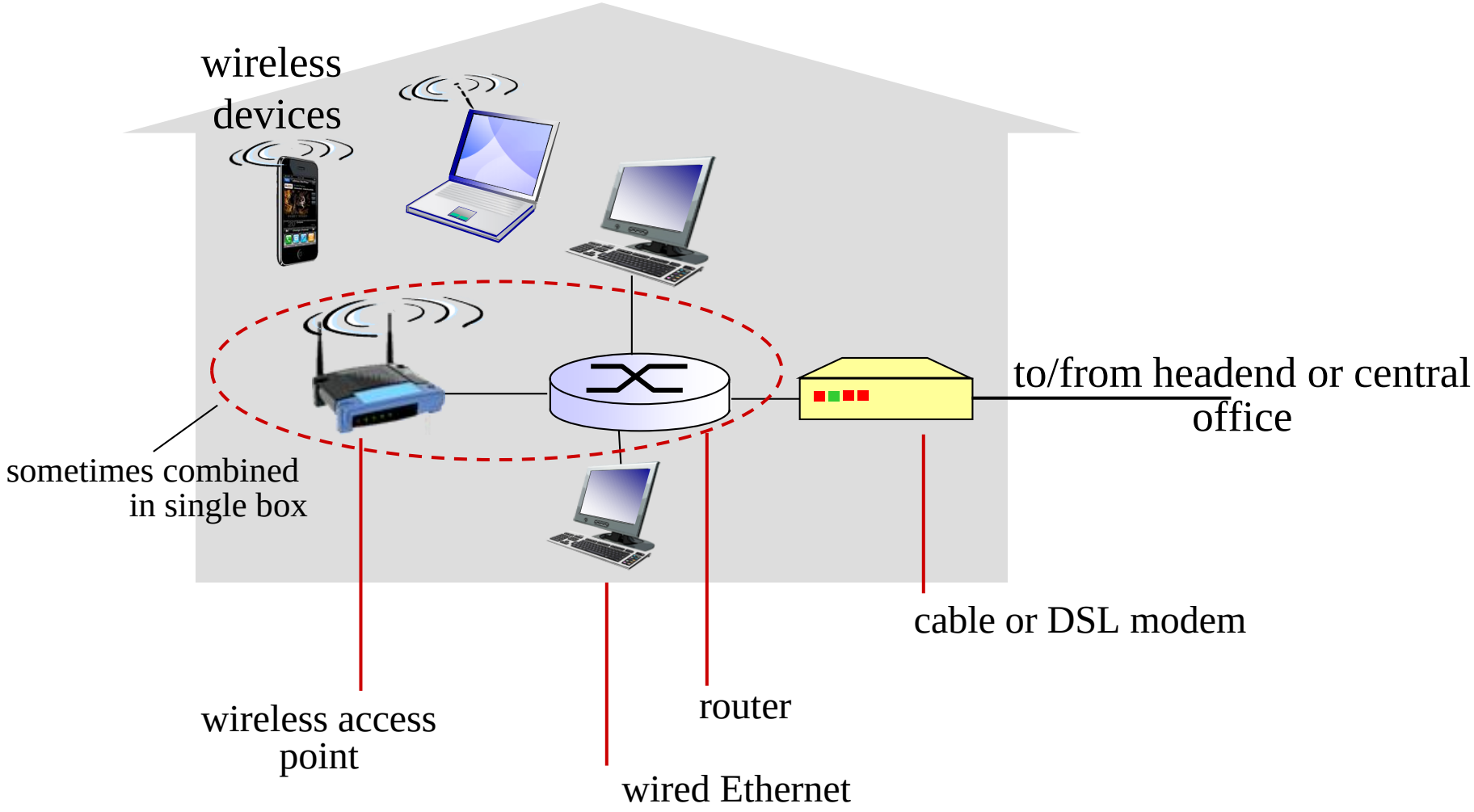


typically used in companies, universities, etc

- 10 Mbps, 100Mbps, 1Gbps, 10Gbps transmission rates
- today, end systems typically connect into Ethernet switch

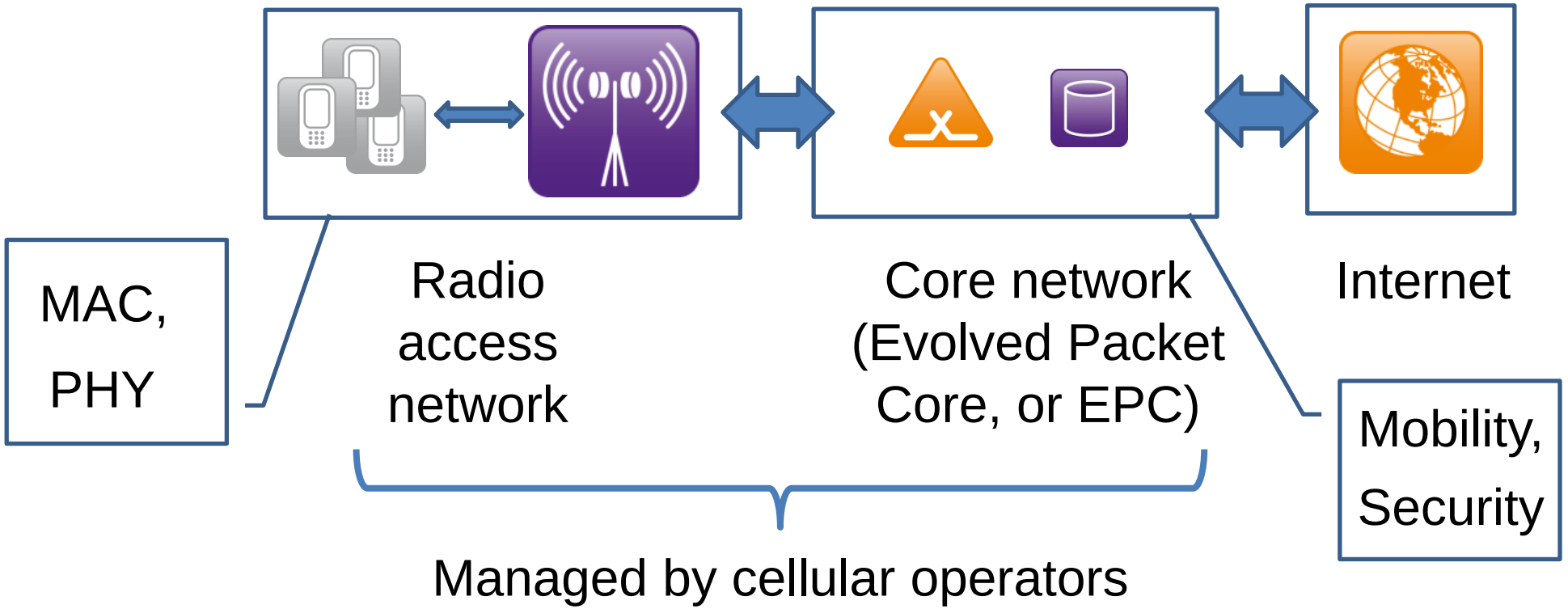
Access network: the last-hop, the bottleneck

- Home network

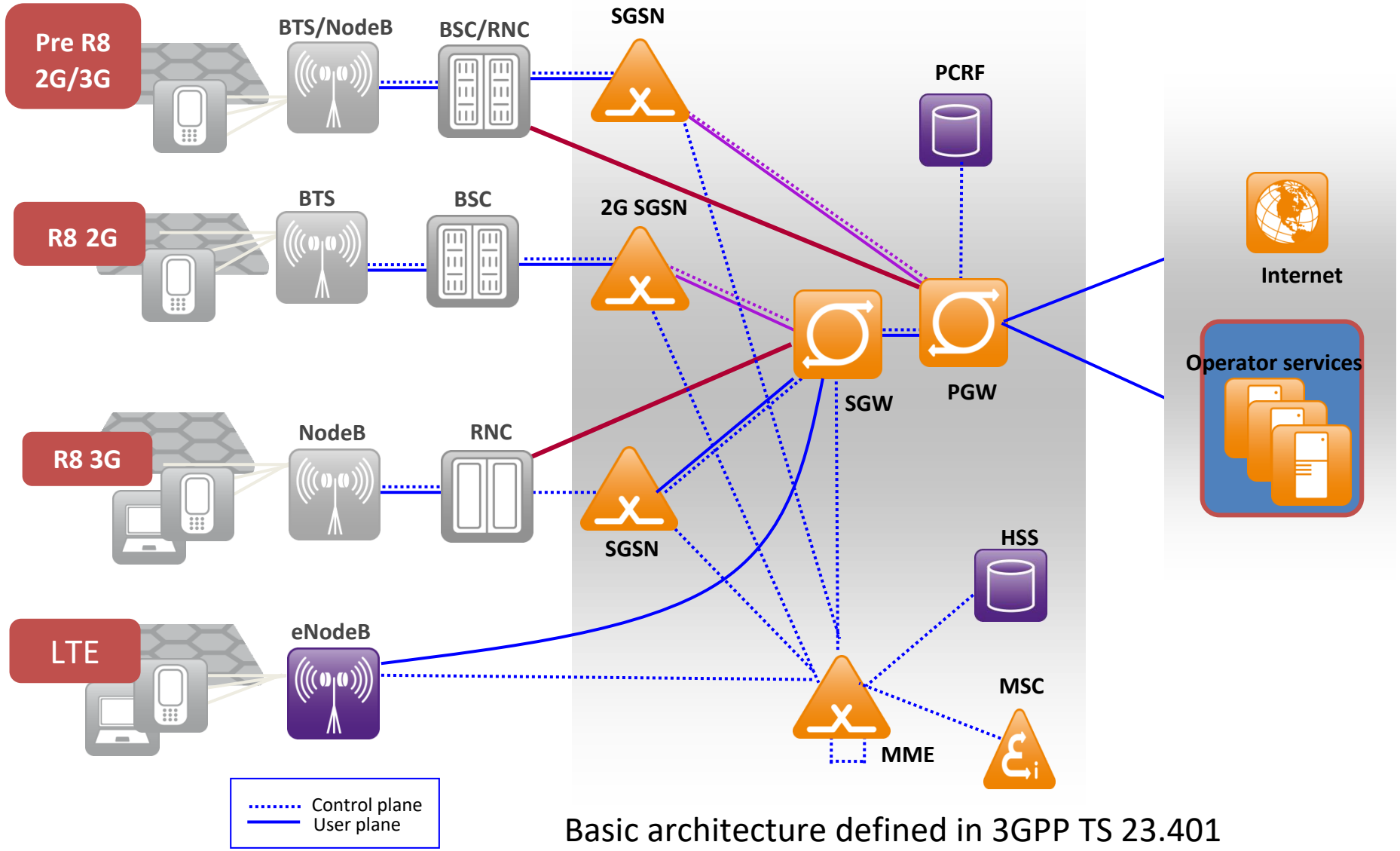


Access network: the last-hop, the bottleneck

- 4G cellular mobile broadband (simplified view)



4G LTE: architectural details



Basic architecture defined in 3GPP TS 23.401

Cellular mobile broadband: 4G LTE

- Elements

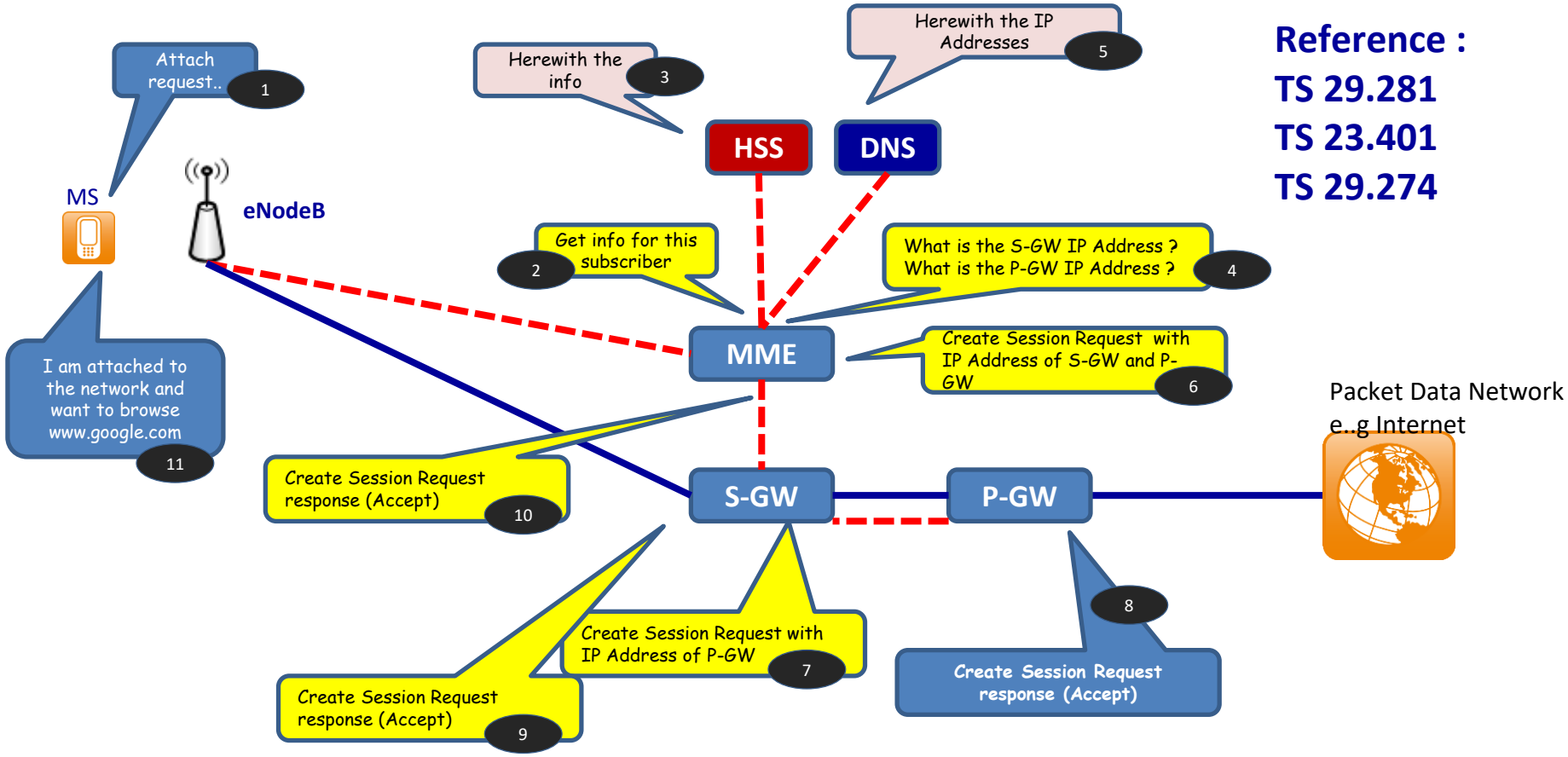
Acronym	Full name	Function
E-NodeB		Air interface toward 4G mobile users
MME	Mobility Management Entity	Mobility Management for 4G Control Plane only
S-GW	Serving Gateway	Mobility Management for 4G User Plane, Handover anchoring.
P-GW	Packet Data Network Gateway	Routing to Packet Data Network, Session Management, IP address Allocation.
HSS	Home Subscriber Server	Manage Permanent 4G subscriber data.

Cellular mobile broadband: 4G LTE

- User plane vs. control plane
  - User plane: user traffic that contains the conversation between 2 or more user peers
    - ✓ Carried over the core network as a "bearer", or flow
    - ✓ User's voice call or data traffic
  - Control plane: signaling communication used to control the bearer traffic.
    - ✓ Involving sending and receiving messages between 2 nodes
    - ✓ e.g., communication between MME and HSS

Cellular mobile broadband: 4G LTE

- A simplified packet switched call flow in LTE

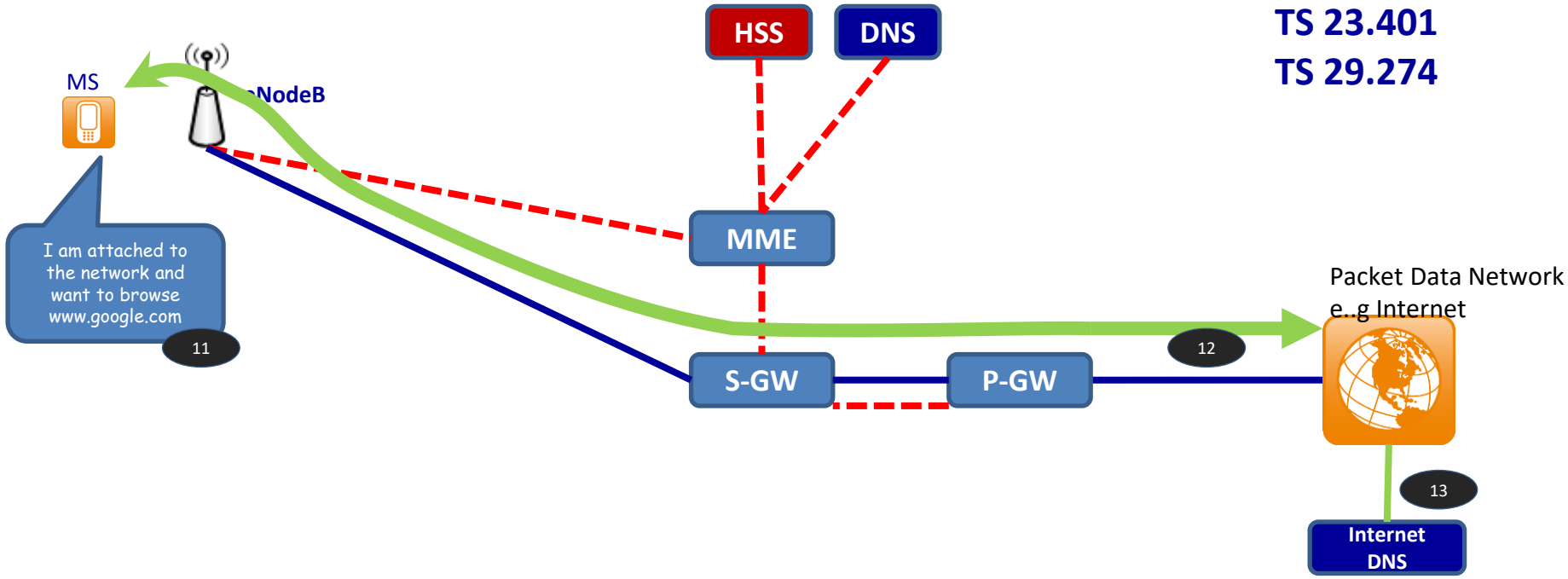


Reference :
TS 29.281
TS 23.401
TS 29.274

Cellular mobile broadband: 4G LTE

- A simplified packet switched call flow in LTE (Cont'd)

Reference :
TS 29.281
TS 23.401
TS 29.274



Pros and Cons of the current LTE architecture

- Pros
  - Backward compatibility
  - Completeness: handle all possible situations to maintain performance
- Cons
  - High complexity and high cost, esp. in for core network
  - Inflexible, hard to upgrade, esp. for the core network
  - Highly centralized core network, prone to failure and bottleneck effects (PGW and SGW are usually the bottlenecks)
  - Two many cascades + a few bottlenecks ➔ long queuing latency

More are expected for next-generation architecture

- Current LTE: Mbps throughput, 100 ms latency
- Need high throughput
  - Gbps throughput
  - Applications: anywhere, anytime HD video streaming, VR teleportation, context sharing among autonomous vehicles, etc.
  - Solution: new wireless comm technologies to solve the last-mile bottleneck
- Need low latency
  - 10 ms latency: remote surgery, immersive virtual reality, etc.
  - 1ms latency: safety-critical communication for autonomous vehicles
  - Solution: new network architecture to flatten the topology

Architectural innovations for future mobile network

- Mobile software defined networking (mobile SDN)
  - Split the control and data plane for bottleneck entities (SGW and PGW)
  - Control plane should have low latency
  - A distributed set of SGWs and PGWs: flatten topology, higher throughput, lower latency
  - Virtualize PGW, SGW and other core network entities, for higher flexibility, better scalability, and lower cost
- Mobile edge computing
  - Deploy application servers at the mobile core network instead of on the Internet; closer to users → lower latency
  - Virtualize server resources for flexibility and scalability

References

- ✓ Section 1.3.3 of “Computer networking : a top-down approach”, James F. Kurose, Keith W. Ross.
- ✓ “The LTE Network Architecture - A comprehensive tutorial”, Alcatel Lucent whitepaper, available at: http://www.cse.unt.edu/~rdantu/FALL_2013_WIRELESS_NETWORKS/LTE_Alcatel_White_Paper.pdf
- ✓ Section I and II of “SDN/NFV-Based Mobile Packet Core Network Architectures: A Survey”, IEEE Communications Surveys & Tutorials (Volume: 19, Issue: 3, 2017)