Network Thinking

Network Terms

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Outline

- What is network thinking?
- Network terms
- Connectivity
  - Naming
  - Topology
- Protocol stack
  - The Web over TCP/IP stack
  - Web programming
- Network laws
  - Performance metrics
  - Network effect
- Responsible computing

These slides acknowledge sources for additional data not cited in the textbook

1. What is network thinking

- A brief history of computer networks
  - Note the never-stopping changes and evolution of
    - what are connected and what are passed (communicated)

Start Time	Milestone	Main Functions
Late 1800's	Telecommunication networks	Telephony, telegraph
1963	J. C. R. Licklider proposed the concept of Intergalactic Computer Network	A general idea of computer networks
1969	First messages sent over ARPANET (50 Kbps = 50 Kilo bits per second)	Message passing, packet switching, interface HW
1974	TCP/IP	Internetworking (Internet) with telnet, ftp, email applications
1989	World Wide Web	Even more applications enabled by global-scale hypertexting
2000	Network science, grid, cloud computing	Various networks as the object of scientific inquiry, utility computing
2007	Apple iPhone	Mobile Internet
2008	Bitcoin	Blockchain, network of trust

What is network thinking

- A computational process may involve not just one entity, but also a group of interconnected entities
  - Which may refer to or communicate with one another
  - Use naming to refer to entities
  - Use a protocol stack to communicate
- An entity may be an abstract or real entity regarding a computer, a person, or a thing
  - A thing could be a physical thing, a document, an idea, or a concept

- The group of interconnected entities is called a network
  - The entities are called the nodes of the network

What is network thinking

- Network: a group of interconnected entities
  - The total of nodes and interconnections
  - Example: all articles on computing form a network of computer science literature
    - Nodes (articles) are interconnected by citations
    - Note: the nodes may refer to one another, but do not necessarily communicate with one another by sending or receiving messages
- Treat a network as an *object*
  - E.g., study the ranks of articles in the network of computer science literature
- Treat a network as a *subject*
  - E.g., a network of computers (cluster) is used to compute the ranks of all articles by their number of citations
- A new perspective to look at problems and can lead to innovative solutions
  - Network thinking brings new value

Interesting phenomena

- Many interesting phenomena have been observed with network thinking

- E.g., what is your Erdös Number
  - Measuring interdisciplinary nature of modern research
    - https://mathscinet.ams.org/mathscinet/freeTools.html?version=2
  - Paul Erdös is a Hungarian mathematician (1913–1996)
    - "Master of Collaboration"
    - Erdös Number = 3 → Paul Erdös is your coauthor's coauthor's coauthor

    - Zhiwei Xu: Erdös Number = ?
    - Jialin Zhang: Erdös Number = ?

Smart concepts and methods

- Many interesting phenomena have been observed with network thinking
  - E.g., what is your Erdös Number
    - Zhiwei Xu: 4
    - Jialin Zhang: 3
- Many smart concepts and methods have been discovered with network thinking
  - Pageranking
    - An application software example
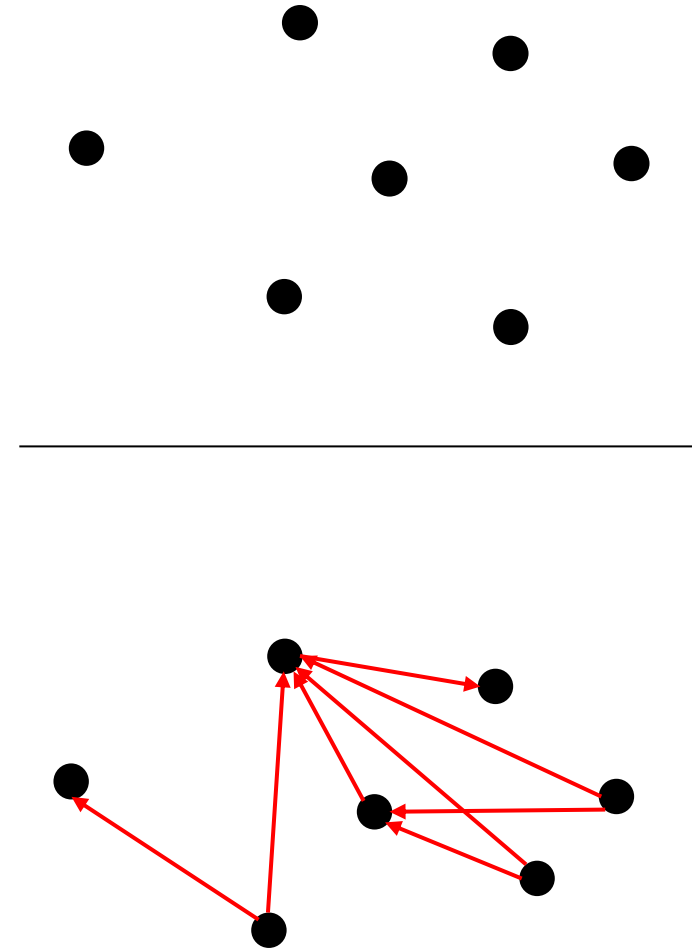 - Exponential backoff
    - A network hardware example

Example: 1G vs. 2G search engines

- 1st generation search engines
  - Computed search results by matching the keywords in search queries to the contents of webpages (*nodes*)
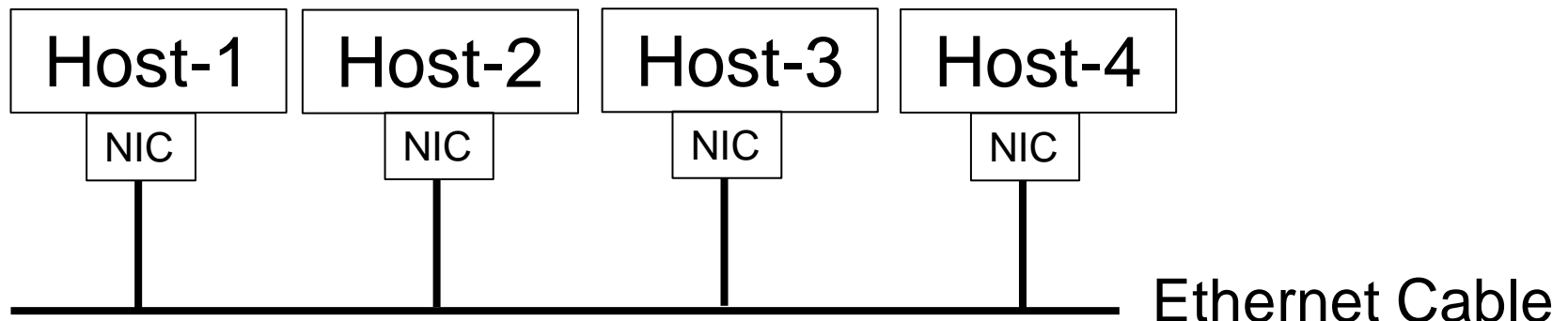 - Only utilized nodes of the network of webpages

- 2nd generation search engines
  - Around 1996, Jon Kleinberg, Robin Li (李彦宏), and Larry Page observed a phenomenon:
    - Web links also significantly influence the relevance of search results
  - Utilized both nodes and interconnections to develop the 2G search engines with better results
    - More fully utilizes network thinking and created Google and Baidu, serving billions of users and generating annual revenue over $100 billion
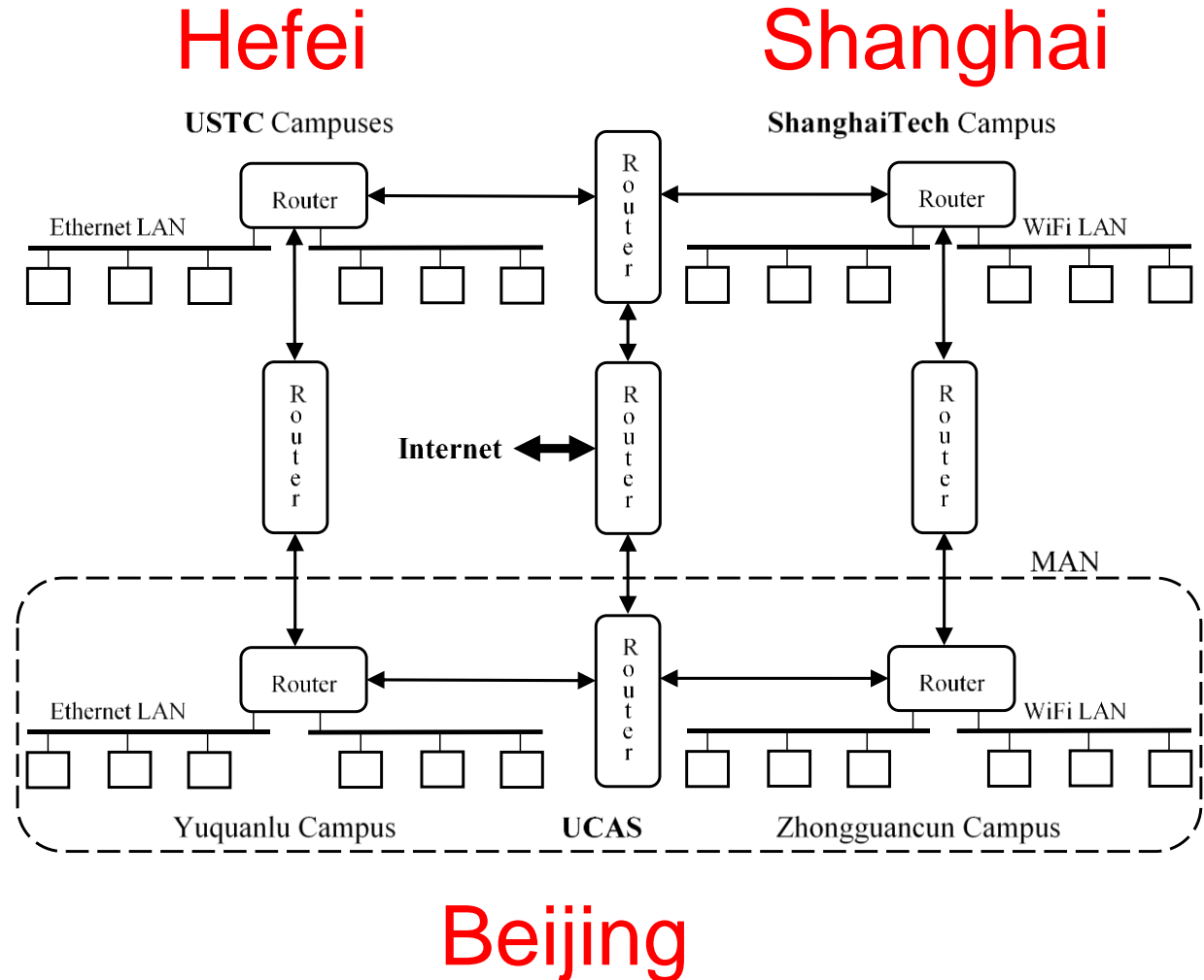
A smart way to resolve conflicts

- Four hosts connected by an Ethernet
  - NIC (network interfacing circuitry) for networking operations
- Conflict example
  - Host-1 tries to send a message to Host-2, while the cable is used by Host-3 communicating with Host-4
- Exponential backoff to resolve conflict
  - When first try fails, Host-1 waits for a random time in [0, T]
  - When second try fails, Host-1 waits for a random time in [0, 2T]
  - When third try fails, Host-1 waits for a random time in [0, 4T]

Host-1	Host-2	Host-3	Host-4
NIC	NIC	NIC	NIC

Ethernet Cable

2. Network terms

- **LAN**
  Local Area
  Network

- **MAN**
  Metropolitan
  Area Network

- **WAN**
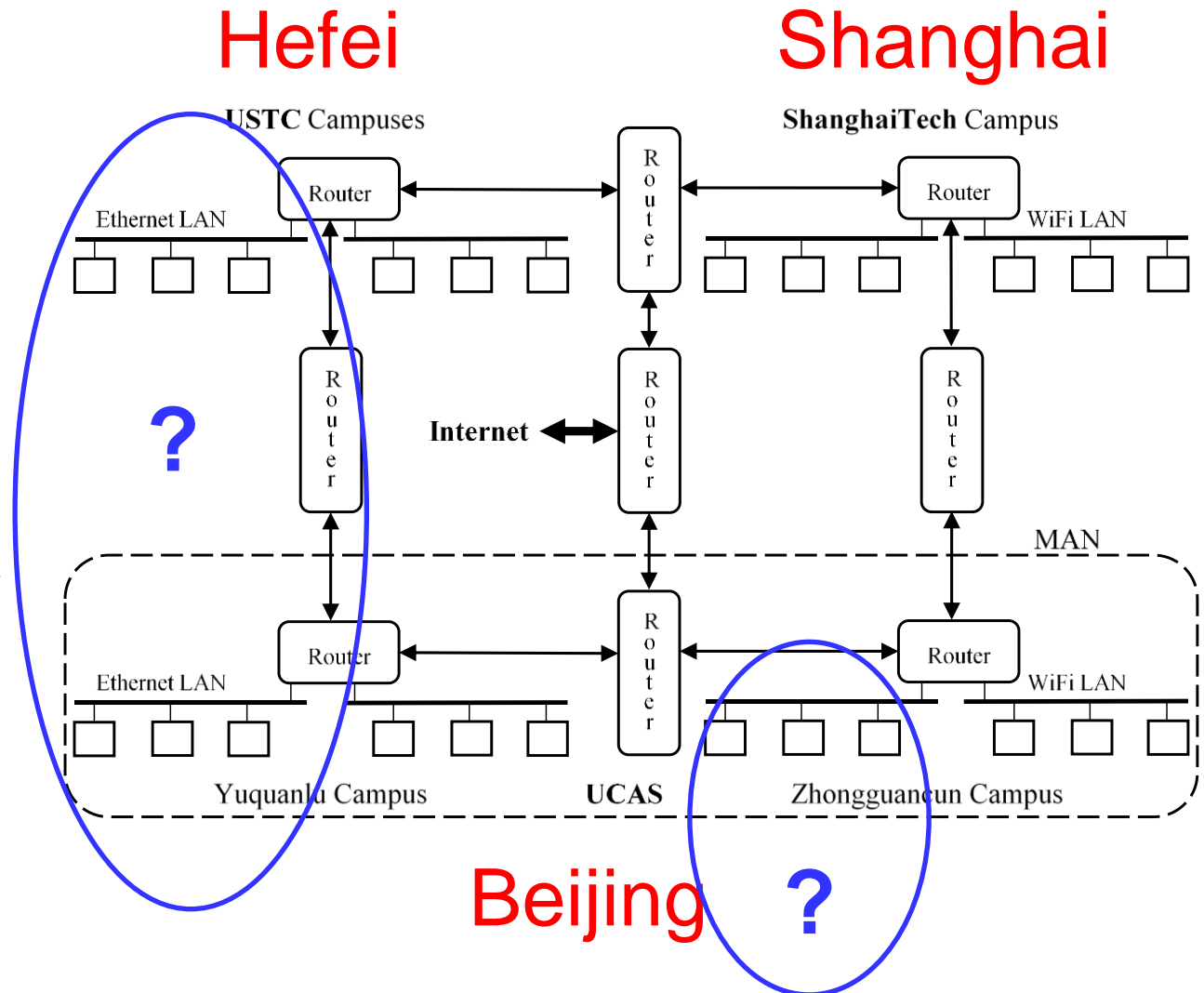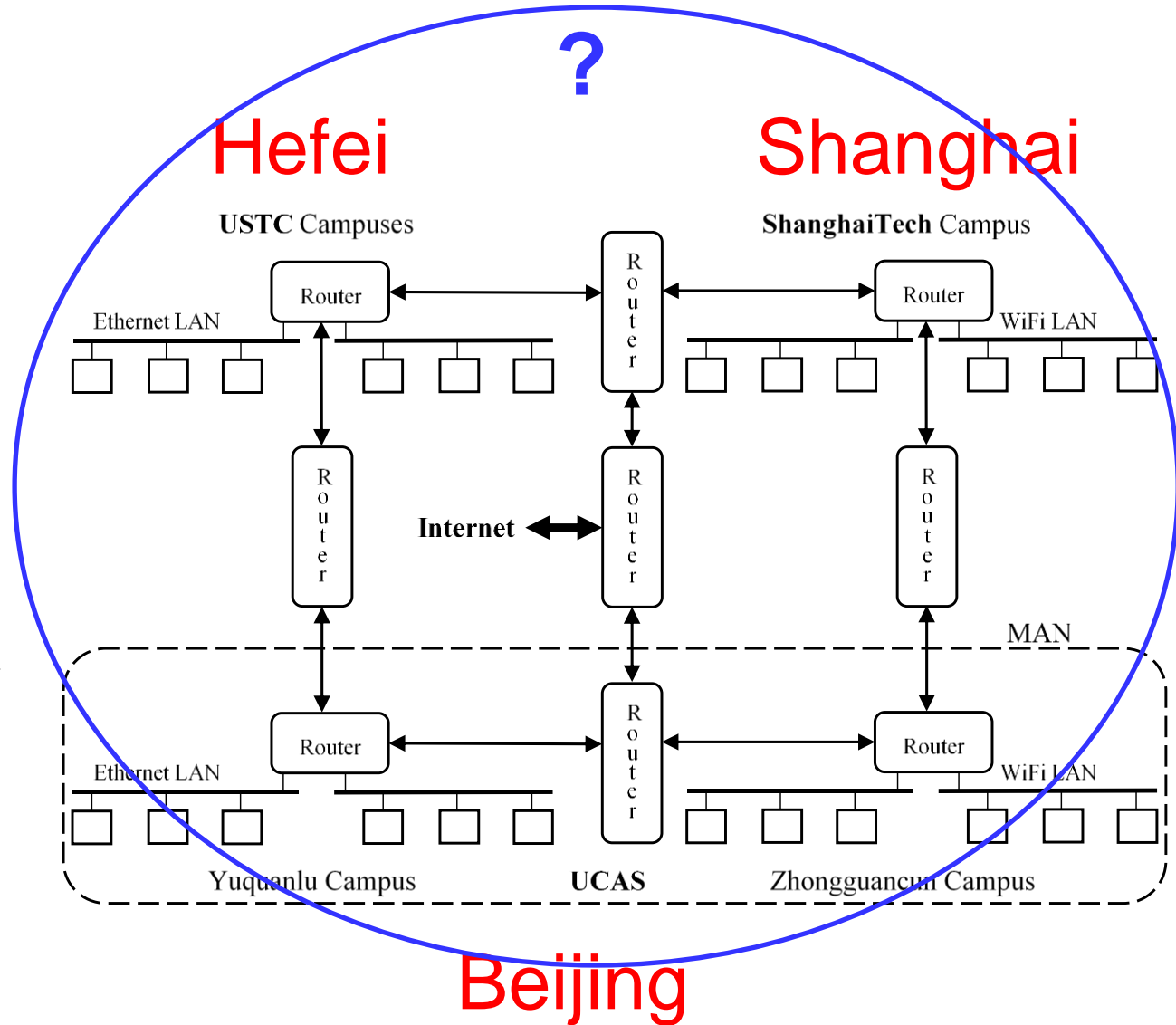 Wide Area
  Network

Hefei   Shanghai

Beijing

Network terms

- **LAN**
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- **WAN**
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Network terms

- **LAN**
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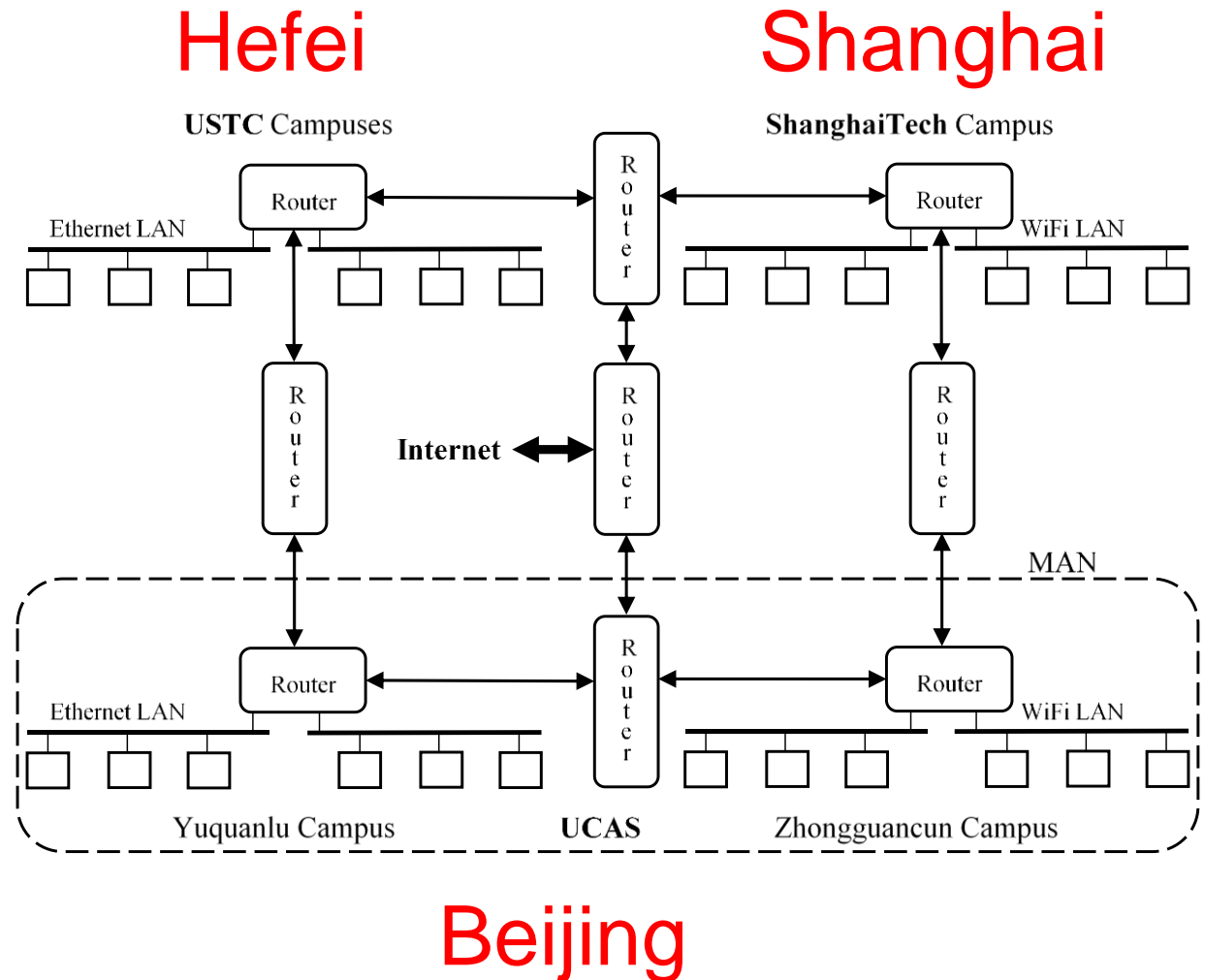 Area Network

- **WAN**
  Wide Area
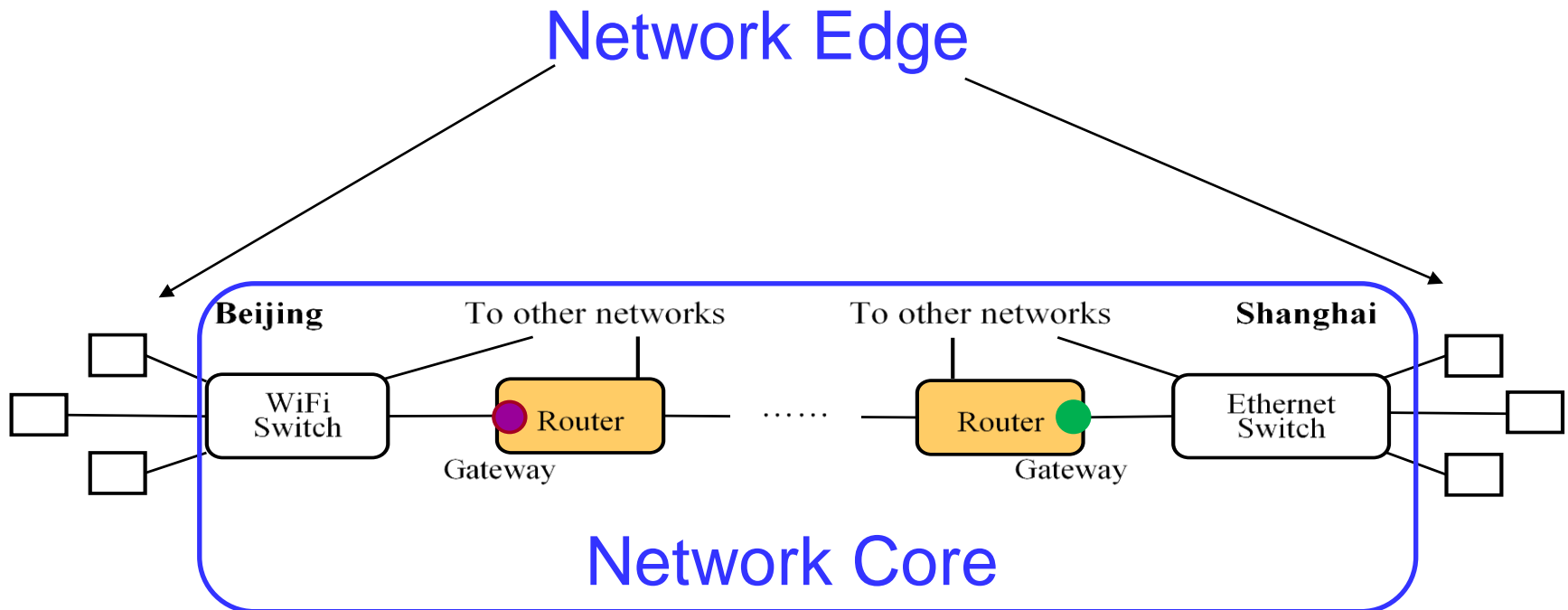 Network

Network terms

- **ISP** Internet Service Provider

  - An institution providing Internet connection services

  - CSTNET for …ac.cn
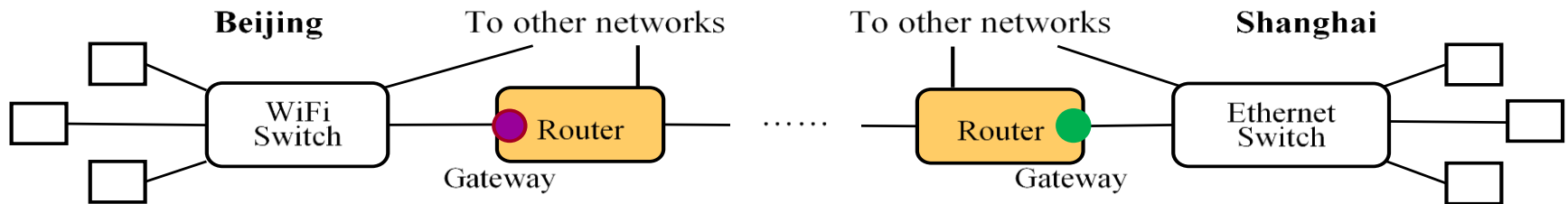 - CERNET for …edu.cn

Hefei

Shanghai

Beijing

Two types of network devices (nodes)

- Hosts: client nodes and server nodes at the network edge
  - 6 edge devices (hosts) are shown
  - Client devices: laptop and desktop computers, smartphones, etc.
  - Server devices: servers, Internet datacenters, supercomputers, etc.

- Networking devices in the core of the network
  - 4 networking devices are shown

Network Edge

Beijing   To other networks   To other networks   Shanghai

WiFi Switch   Router   ......   Router   Ethernet Switch

Gateway   Gateway

Network Core

What devices are used?

- Zhang Lei uses her laptop in Beijing to access a supercomputer in Shanghai
  1. Laptop computer
  2. AP + WiFi switch
  3. Router at Beijing campus
  4. …
  5. Router at Shanghai campus
  6. Ethernet switch connecting the supercomputer
  7. Supercomputer

Internal network and outside network of an organization

- Gateway of network LAN-1 (purple)
  - The router connecting a network to the outside
    - In more detail, the port address of the router
- Gateway of network LAN-2 (green)