



Network Thinking

Connectivity: Naming and Topology

连通性：网络的名字空间与拓扑

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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

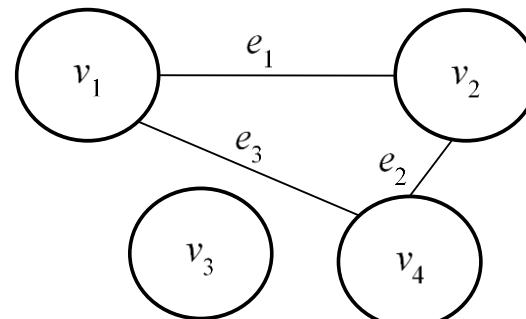
These slides acknowledge sources for additional data not cited in the textbook

3. Connectivity (互联互通, 连通性)

- Connectivity refers to the structure of a network
 - Often expressed as a graph $G = \langle V, E \rangle$ of two sets
 - Set of nodes (vertices): $V = \{v_1, v_2, \dots, v_n\}$
 - Set of edges (links): $E = \{e_1, e_2, \dots, e_m\}$
- Connectivity studies *naming* and *topology* problems
 - Naming: How to name the nodes of a network? How to find a specific node? How to refer to a specific node? 如何命名网络的节点、发现节点、指向节点?
 - How are the nodes interconnected? Does the network structure change over time?

• Undirected

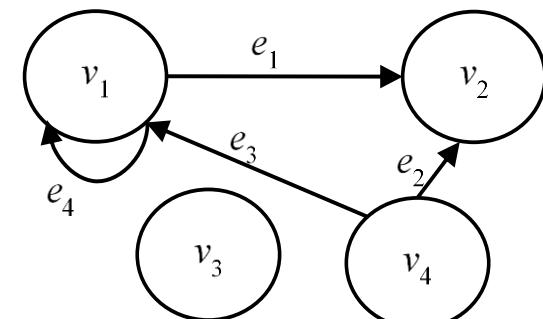
- $V = \{v_1, v_2, v_3, v_4\}$
- $E = \{e_1, e_2, e_3\}$



undirected graph

• Directed

- $V = \{v_1, v_2, v_3, v_4\}$
- $E = \{e_1, e_2, e_3, e_4\}$



directed graph

3.1 Naming

- Every network has a **namespace**
 - Consists of all names specified by a naming scheme
 - Naming scheme: a function assigning (mapping) a legitimate string to a node or an edge
 - Specified by a standards body 名字空间与命名方法由志愿者社区标准确定
 - Institute of Electrical and Electronics Engineers (IEEE) 国际电气与电子工程师协会
 - Internet Engineering Task Force (IETF) 国际互联网工程任务组
 - World Wide Web Consortium (W3C) 万维网联盟

Namespace	Instance	Remark on naming schemes
Personal name	Joan Smith	Personal names in a country
WeChat user	ZhongguanVillager	Any legitimate string per WeChat standard
URL	cs101.ucas.edu.cn/	Universal Resource Locator of a webpage
Internet site	www.ict.ac.cn	Any domain name by IETF standards
Email address	zxu@ict.ac.cn	userName@domainName
IP address	159.226.97.84	Internet Protocol address per IETF standards
Phone number	189-6666-8888	11 decimal digits by Telcom provider standards
MAC address	00-1E-C9-43-24-42	12 hexadecimal digits per IEEE standards

Naming issues and considerations

- *Uniqueness.* Does a name map to a unique node? 唯一性
 - The email address namespace enjoys uniqueness, but the namespace of personal names of a country's population does not have uniqueness. There may be multiple persons named Joan Smith, causing *name conflicts*, which in turn may lead to wrong connections.

Namespace	Name (a legitimate string)	Uniqueness
Personal name	Joan Smith	?
WeChat user	ZhongguanVillager	?
URL	cs101.ucas.edu.cn/	?
Internet site	www.ict.ac.cn	?
Email address	zxu@ict.ac.cn	?
IP address	159.226.97.84	?
Phone number	189-6666-8888	?
MAC address	00-1E-C9-43-24-42	?

Naming issues and considerations

- *Uniqueness.* Does a name map to a unique node?
 - The email address namespace enjoys uniqueness, but the namespace of personal names of a country's population does not have uniqueness. There may be multiple persons named Joan Smith, causing *name conflicts*, which in turn may lead to wrong connections.

Namespace	Name (a legitimate string)	Uniqueness
Personal name	Joan Smith	No
WeChat user	ZhongguanVillager	No
URL	cs101.ucas.edu.cn/	Yes
Internet site	www.ict.ac.cn	Yes
Email address	zxu@ict.ac.cn	Yes
IP address	159.226.97.84	Yes
Phone number	189-6666-8888	Yes
MAC address	00-1E-C9-43-24-42	Yes

Naming issues and considerations

- *Autonomy*. Can a user create or change a name on his own? **自主性**
 - Autonomy has the advantage of convenience, but may lead to chaos
 - One may change a URL, but Web links to the old URL become invalid
 - Creating or modifying a name may need to go through a centralized process
 - Involving an authority of name registry

Namespace	Name (a legitimate string)	Autonomy
Personal name	Joan Smith	?
WeChat user	ZhongguanVillager	?
URL	cs101.ucas.edu.cn/	?
Internet site	www.ict.ac.cn	?
Email address	zxu@ict.ac.cn	?
IP address	159.226.97.84	?
Phone number	189-6666-8888	?
MAC address	00-1E-C9-43-24-42	?

Naming issues and considerations

- *Autonomy.* Can a user create or change a name on his own?
 - Autonomy has the advantage of convenience, but may lead to chaos
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Namespace	Name (a legitimate string)	Autonomy
Personal name	Joan Smith	Yes
WeChat user	ZhongguanVillager	Mostly Yes
URL	cs101.ucas.edu.cn/	Hierarchically Centralized
Internet site	www.ict.ac.cn	Hierarchically Centralized
Email address	zxu@ict.ac.cn	Hierarchically Centralized
IP address	159.226.97.84	Hierarchically Centralized
Phone number	189-6666-8888	Choose from a centralized pool
MAC address	00-1E-C9-43-24-42	Hierarchically Centralized

Naming issues and considerations

- *Friendliness.* Are the names user-friendly, i.e., understandable by humans?

用户友好性：是否对人（用户）友好，便于用户理解？

- The eight name schemes in Table have roughly decreasing user friendliness
- "Joan Smith" is much more understandable than "00-1E-C9-43-24-42", which is the name of the network interface circuitry in a computer, also called MAC address

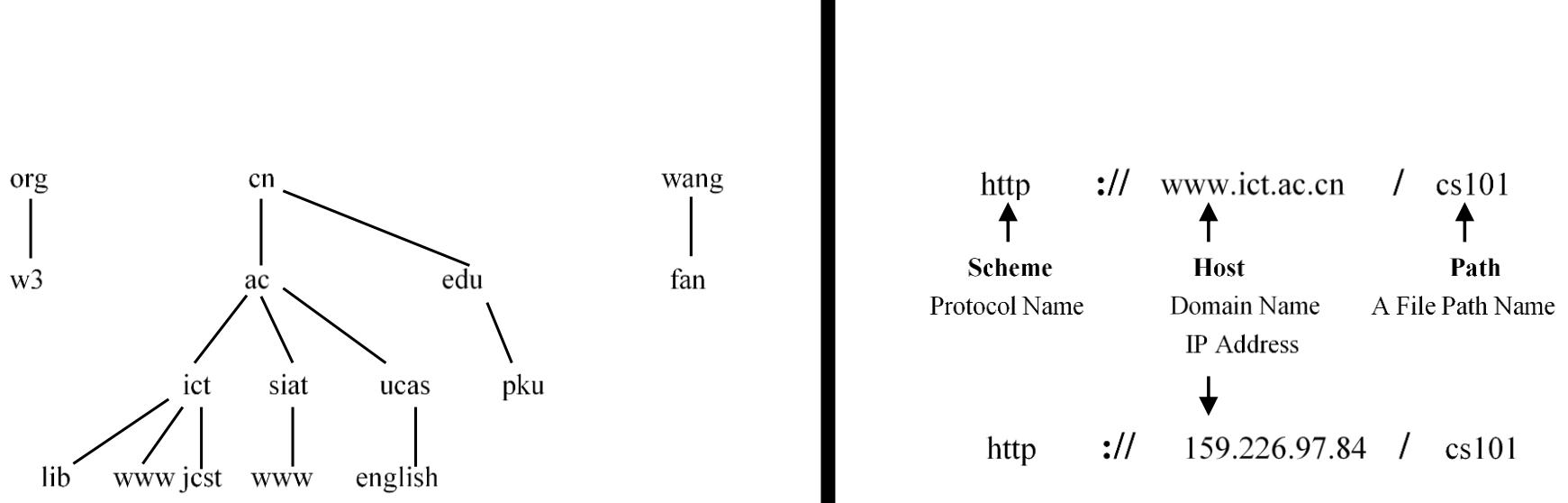
Namespace	Name (a legitimate string)	User Friendliness
Personal name	Joan Smith	Yes
WeChat user	ZhongguanVillager 中关村民	Mostly Yes
URL	cs101.ucas.edu.cn/	Somewhat friendly
Internet site	www.ict.ac.cn	Somewhat friendly
Email address	zxu@ict.ac.cn	Somewhat friendly
IP address	159.226.97.84	No
Phone number	189-6666-8888	No
MAC address	00-1E-C9-43-24-42	No

Naming issues and considerations

- *Name conversion.* An entity can have two namespaces.
 - The Internet site with domain name www.ict.ac.cn has an IP address 159.226.97.84
 - The Domain Name System (**DNS**) converts a domain name to its IP address
DNS将互联网域名转换为IP地址
 - **http://www.ict.ac.cn → http://159.226.97.84**
 - Addresses are a special form of names, and can be used to access entities directly
- Two types of IP addresses are used today **两类IP地址**
 - **IPv4 addresses** use **32 bits** and can generate 2^{32} different IP addresses
 - Each IPv4 address is organized as a 4-field format xxx.xxx.xxx.xxx such as 159.226.97.84 **IP地址通常写成“.”区分开的4个字段**
 - Each field is a decimal number from 0 to 255 **159.266.97.84是非法的**
 - **IPv6 addresses** use **128 bits** and can generate 2^{128} different IP addresses
 - *** Each IPv6 address is an 8-field format xxxx.xxxx.xxxx.xxxx.xxxx.xxxx.xxxx.xxxx such as 2001:0db8:85a3:0000:0000:8a2e:0370:7334
- IPv4 addresses exhaustion occurred as of November 2019
 - There are $2^{128-32} = 2^{96}$ times as many IPv6 addresses as IPv4 addresses **2019年11月，全球IPv4地址已穷尽**

Domain name hierarchy and URL

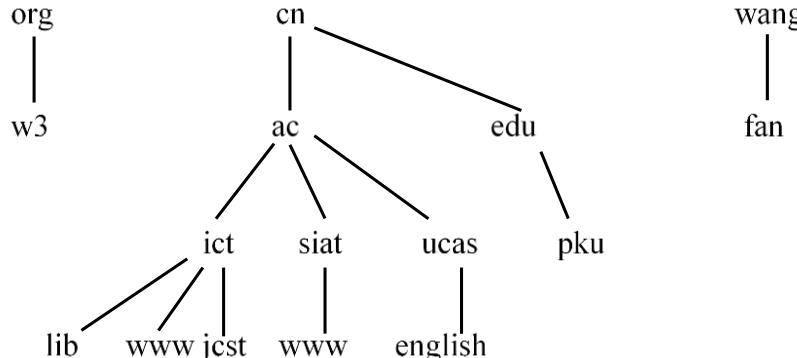
- What is the URL of the homepage of the following institutions?
 - Fan Wang
 - Journal of Computer Science and Technology
 - Peking University
 - Shenzhen Institute of Advanced Technology
 - The World Wide Web Consortium
 - University of Chinese Academy of Sciences
- Check your answers by accessing the URLs



Domain name hierarchy and URL

- What is the URL of the homepage of each of the following institutions? What is the top-level domain?

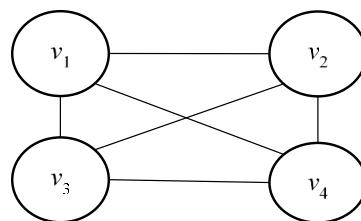
- http://fan.wang/ wang
- http://jcst.ict.ac.cn/ cn
- http://pku.edu.cn/ cn
- http://www.siat.ac.cn/ cn
- http://w3.org/ org
- http://English.ucas.ac.cn cn



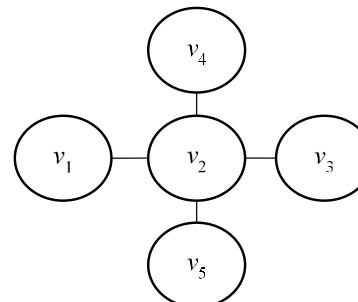
http :// 159.226.97.84 / cs101

3.2 Topology

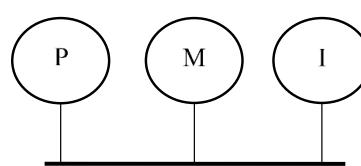
- Three types of networks 静态网络、动态网络、演化网络
 - A **static network** does not change nodes and edges
 - A **dynamic network** does not change nodes; may change edges
 - At one moment, the bus connects the processor (P) and the memory (M)
 - At the next moment, the bus connects the memory (M) and an input device (I)
 - The bus supports a *shared-media network*, while the crossbar supports a *switching network*
- An **Evolutionary network** change both nodes and edges over time
 - Internet, WWW



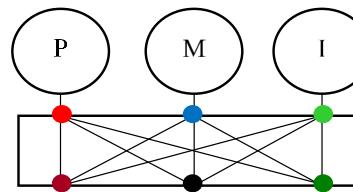
(a) A fully connected graph



(b) A star network



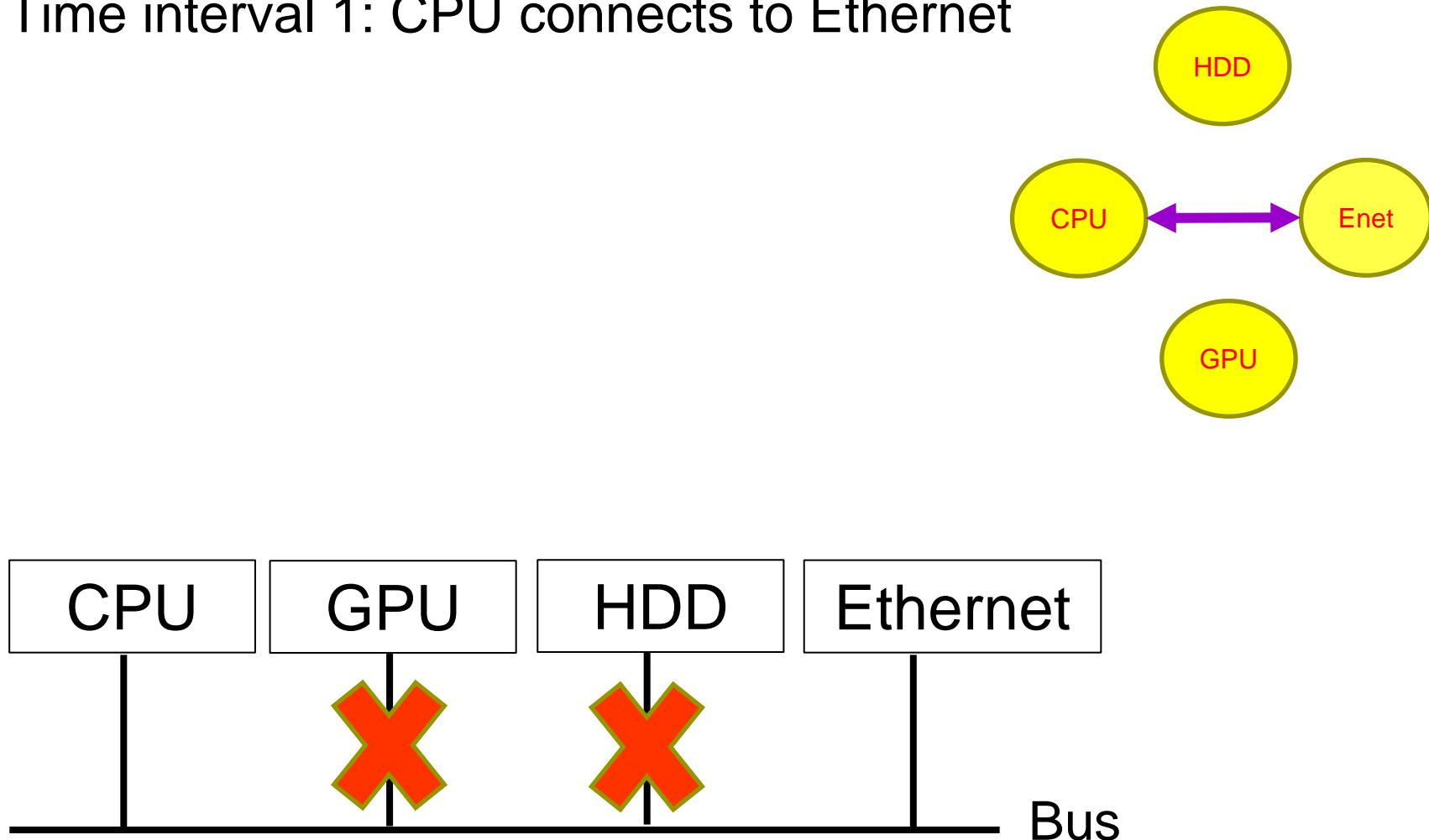
Nodes connected by (c) a bus



(d) a crossbar switch

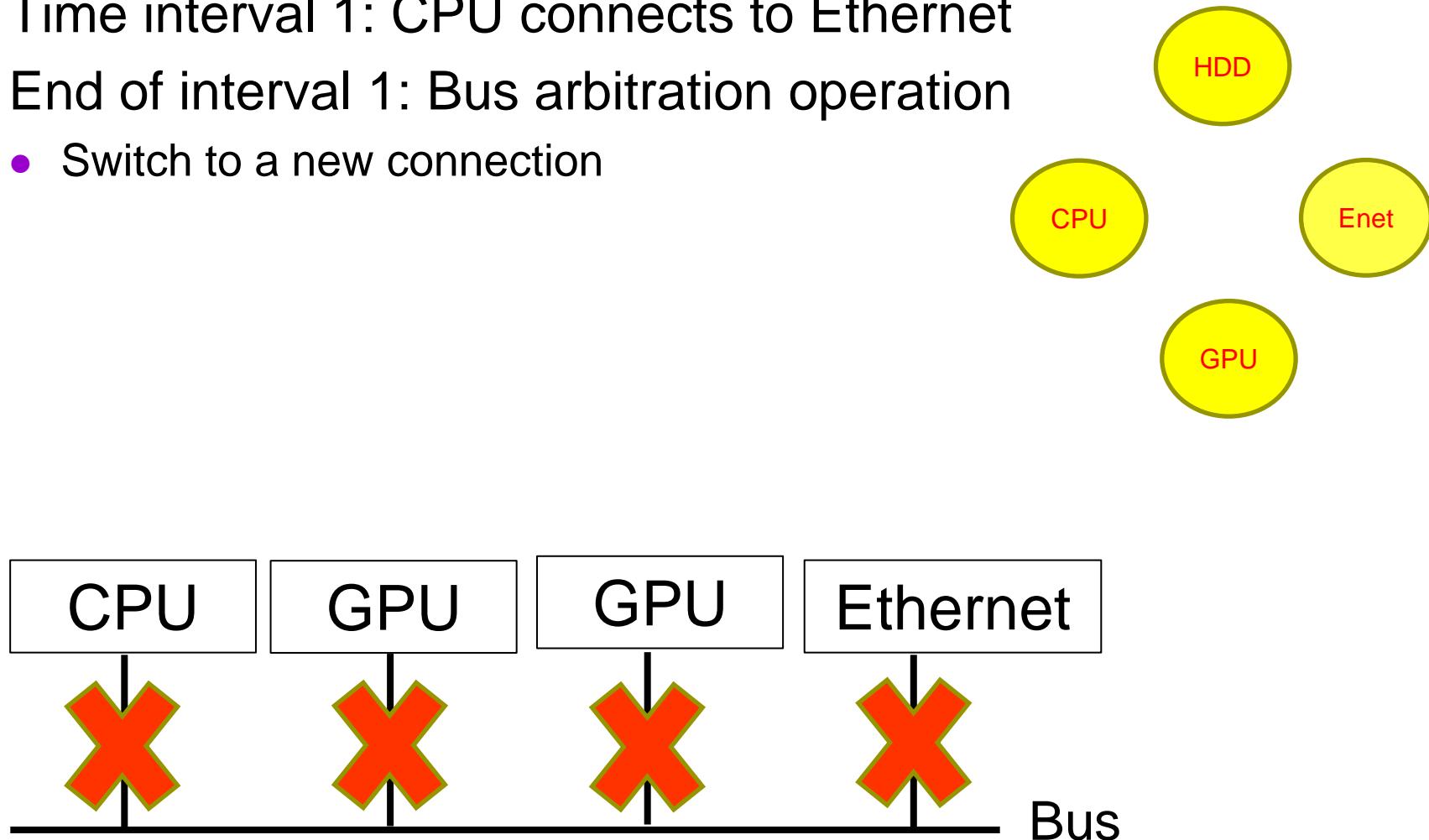
How does a dynamic network work?

- Bus arbitration 总线仲裁例子
 - Time interval 1: CPU connects to Ethernet



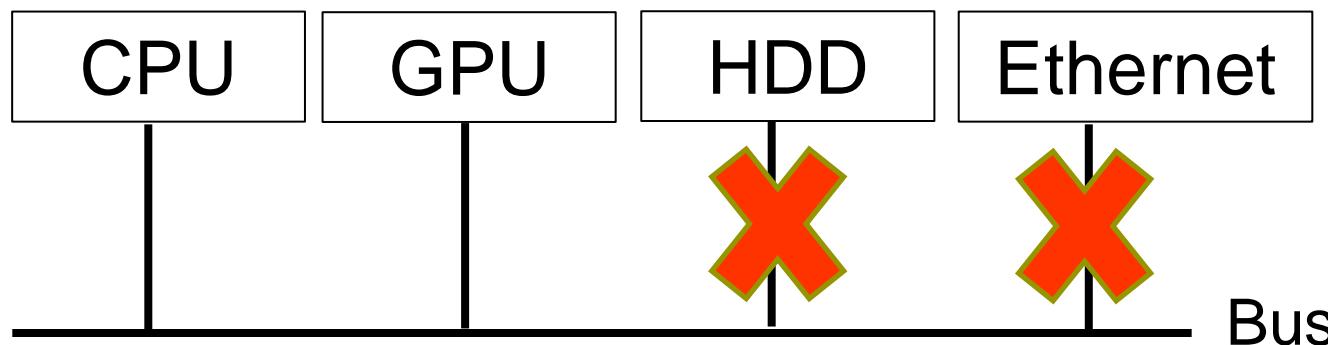
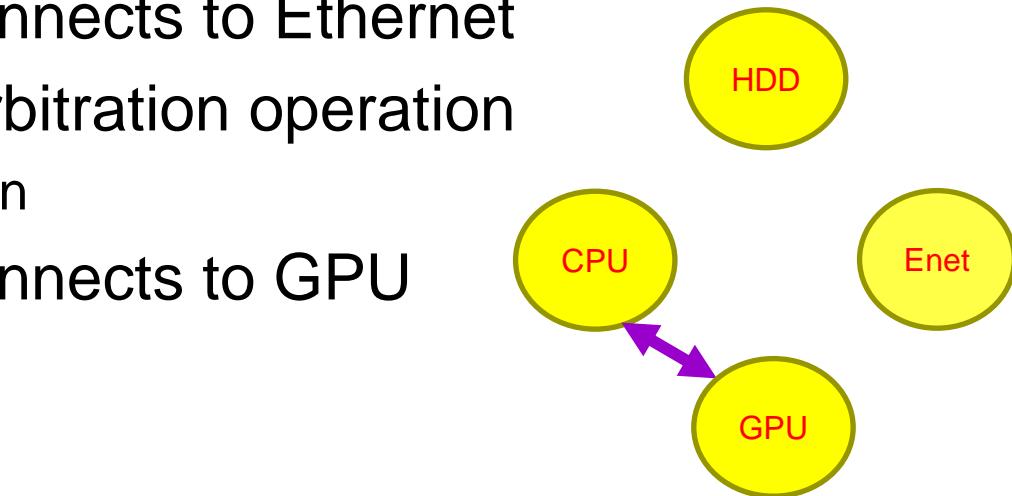
How does a dynamic network work?

- Bus arbitration
 - Time interval 1: CPU connects to Ethernet
 - End of interval 1: Bus arbitration operation
 - Switch to a new connection



How does a dynamic network work?

- Bus arbitration
 - Time interval 1: CPU connects to Ethernet
 - End of interval 1: Bus arbitration operation
 - Switch to a new connection
 - Time interval 2: CPU connects to GPU



Switch

- All nodes of the network are dynamically connected
 - Switch = dynamic fully-connected network
- Can be configured to realize any connection
 - Interval 1: Permutation, {P→M, M→I, I→P}
 - Interval 2: Broadcast, {P→P, P→M, P→I}
 - Interval 3: Point-to-point, {P→M}

