**Internet** A global system of interconnected computer networks linking billions of computing devices throughout the world; hosts: end systems running network applications, communication links: the media by which data travel (twisted pair copper wire/fiber optic cable); routers and switches: switching devices that end systems are connected to for forwarding data from one host to another; A network of networks, a communication infrastructure; **Network Protocol** defines format, order of messages sent and received between network entities & actions taken upon message transmission/receipt **Layer** a collection of conceptual similar functions that provide services to the layer above it and receives services from the layer below it; Application (supporting network applications), Transport (process-to-process data transfer), Network (data routing from source host to destination host), Link (data transfer between neighboring network devices), Physical (bit transfer on the transmission medium); At each layer, the data packet can be divided into header and data/payload; Encapsulation: the data packet from the upper layer is encapsulated in data part of a packet in this layer, and header is added over the data for control information; Decapsulation: remove header of this layer & extract data part for passing to the upper layer; **Components of the Internet** Network edge: servers & clients; Access networks: links connecting hosts to edge routers/switches; Residential access networks: digital subscriber line (use existing telephone line to central office DSL

access multiplexer, a few Mbps upstream & tens of Mbps downstream), cable network (use hybrid fiber coaxial cables to connect to ISP router, tens to hundreds of Mbps upstream, tens of Mbps to a few Gbps downstream), fiber to the x (use optical fiber to provide all/ part of the last-mile telecommunication network for connecting user homes/premises to the ISP’s router, x = node, curb, building, home, …, to the home: a few Gbps upstream and downstream); Institutional access networks (school/company): Ethernet, Mobile access networks (Wi-Fi, 4G/5G); Network core: Inter-connected routers, many communication sessions share the same network, circuit-switching: frequency/time division multiplexing or packet-switching: store & forward, statistical multiplexing; **Delay** nodal processing delay = queueing delay (time waiting at output link for transmission) + transmission delay (packet length/link bandwidth) + propagation delay (length of physical link/propagation speed in medium) **Throughput** Rate at which data are transferred end-to-end from sending host to receiving host