Computer Networks
ICS 651

- Data Link layer
- Wireless Medium: Broadcast
- Aloha
- 802.11
- Ad-Hoc Wireless networks
- Mobile Ad-Hoc networks (MANets)
- Wireless sensor networks

Data Link Layer

- layer 2: the layer below IP
- the layer above the physical layer
- concerned with issues such as
  - framing: combining bits into packets
  - access control: for shared media, orderly sharing of the shared medium
  - error checking/correcting, using CRCs
- usually originally designed for only a single hop, though in practice often multihop

Common Data Link Layers

- Ethernet
- 802.11
- wireless mobile (cellular) Internet
- modems with PPP or SLIP
- amateur packet radio
- parts of ATM (Asynchronous Transfer Mode – the rest may be classified as the network layer, or as the data link layer, or as not fitting the layer model very well)
- SONET, Frame Relay
- many older technologies, including FDDI, Token Ring, ...

Wireless Radio Communications

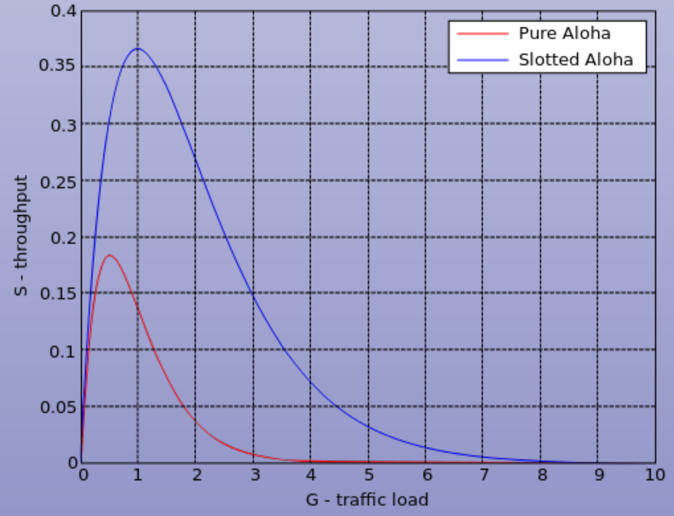
- broadcast medium: many/all can hear each sender
  - unless using directional antennas
  - multiple antennas can be used as a single directional antenna
- collision: two senders sending at the same time, receiver can't tell what the message was (collision is detected by a receiver receiving a packet with a bad checksum/CRC)
- send and receive power are very different, so sender cannot detect collision
  - this may be changing as technology improves
- no central clock, often limited power

Aloha

- remote transmitters send on frequency f_0 (could collide with each other), receive on frequency f_1
- hub sends on frequency f_1 (no collisions), receives on frequency f_0
- hub rebroadcasts everything it receives, so all stations know whether a given transmission was successful
- if a transmission fails, the originator must retransmit
- now used with ground stations and satellites
- all collisions are on the uplink to the satellite

Aloha – Efficiency

- when nobody sends, network utilization is low
- when everybody sends, lots of collision, so network utilization is low
- optimum is when the network is about 18% utilized
- improvement: have everyone start transmission at a given time (the hub can transmit a clock signal). This decreases the chances of collision – slotted Aloha
- further improvement: using Aloha, everyone who needs to send, sends their address, then the base station reports the winning address and only that station sends its data -- why is this an improvement?



Wireless Radio Communication Networks

- can the Internet protocol be used over wireless links?
- hidden sender problem: A sends to B, C does not know A is sending and might send to B at the same time
- because of the chance of collision and other interference, wireless networks can have high error rates
- wirelessness is important for mobility, but how to do addressing and routing, especially when (as in IP) addressing is tied to location?
- cellular: each system has a "home", identifies itself to the local base station (strongest radio signal), which tells the home how to reach me
- cellular: as I move, my connection must be handed off to another base station
- WiMax is a form of cellular communication
- cellular: not peer-to-peer networking

802.11 Data Link Layer WiFi

- if Alice and Bob are both in range of Charlie, but not in range of each other, then Bob is a hidden terminal for Alice, and vice-versa
- hidden terminal problem solved by
  - sender sends a very short packet (Request to Send, RTS) reserving the medium for the time needed for the actual data
  - receiver responds with a very short packet (Clear to Send, CTS) reserving the medium
  - anyone within range of either the sender or the receiver must now keep quiet
  - collision avoidance: most collisions are on the RTS/CTS, not the data packet
  - a final ack confirms that the receiver has received the data
- synchronous data (e.g. voice) has higher priority
- broadcast is best-effort, unicast is reliable

802.11 Network Topologies

- Managed mode:
  - Access Point (AP) is in range of all the end stations, forwards data to and from the Internet (bridging)
  - ideally, APs can communicate with each other over a wired (or wireless) network, creating a cellular wireless network: a mesh network
- Ad-Hoc mode:
  - all nodes are equivalent and communicate directly with one another

Ad-Hoc Wireless Networks

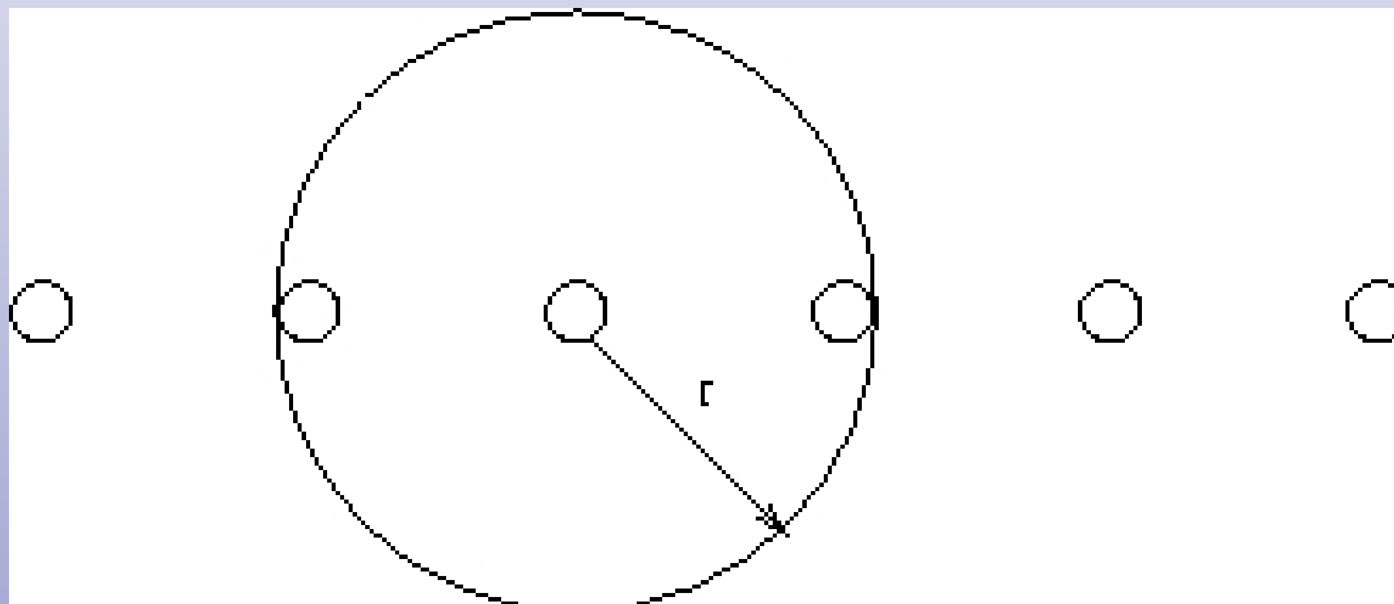
- in an Ad-Hoc Network, everyone agrees to forward everyone else's packets
- who do we forward to? How do we locate the default router? Is this "routing" on the data-link layer? What happens when wireless units move?
- types:
  - Mobile Ad-hoc NETwork, MANET (for vehicle communications, VANET)
  - Wireless Sensor Networks
  - Mesh Networks
- P2P: every node is a router, every node is a host

Ad-Hoc Wireless Networks and IP

- IP assumes that:
  - if A can talk to B on B's interface i, and
  - C can talk to B on B's same interface i, then
  - A should be able to directly communicate with C
- this is not the case in wireless ad-hoc networks
- two solutions: modify IP (hard), or run the entire ad-hoc network as a single IP (sub)network (easier)
- the second solution requires an underlying, data-link-layer routing protocol

Ad-Hoc Wireless Networks: Performance

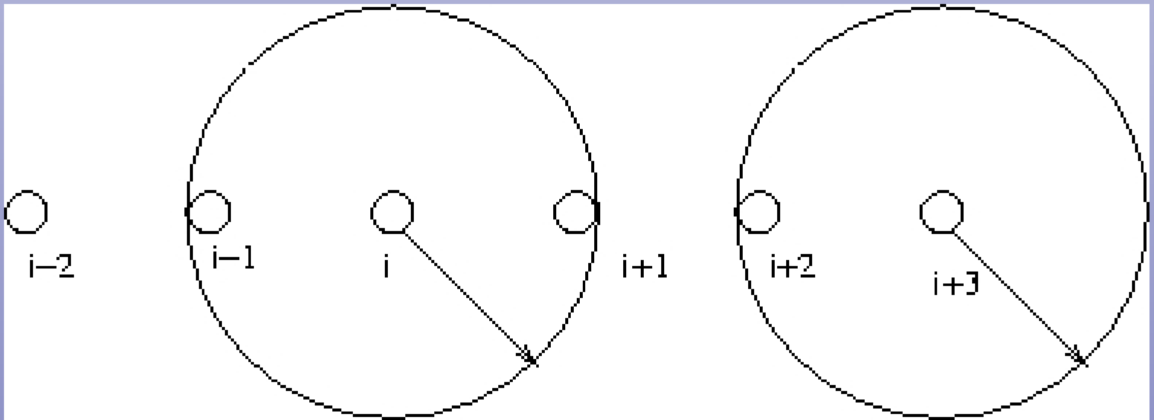
- assume a number of nodes in an ad-hoc wireless network
- the nodes are deployed in a straight line, each node in range of only the node before it and the node after



- the link bandwidth is B bits/second
- how many bits per second can the first node send to the last?

Ad-Hoc Wireless Networks: Performance

- if node i transmits to node i+1, node i+1 cannot be transmitting to node i+2
- if node i transmits to node i+1, node i-1 cannot be transmitting to node i
- if node i transmits to node i+1, node i-2 cannot be transmitting to node i-1
- so with one-directional transmission, at most 1/3 of the links can be active at any given time.
- so the maximum data rate in such a configuration is B/3
- this is the best possible case, and is hard to achieve in practice



Mobile Ad-hoc wireless NETworks: MANets

- nodes in a defined space move around at random speeds and directions
- new random speed and direction selected when a boundary is reached
- high mobility requires very agile routing protocols: it is normal for routes to go down
- broadcast always works, but can we do better?

MANet routing protocols

- broadcast always works, but can we do better?
- DSR (Dynamic Source Routing): sender builds a route, includes it in every packet. Routing tables are small, but packets are big or routes are short
- AODV (Ad-Hoc On-Demand Distance Vector): similar to distance vector, but routes are built on demand only, by broadcasting.
  - Distance vector is very efficient with information exchange, but does not do well when links fail
- OLSR (Optimized Link-State Routing) is proactive (not on-demand) and uses flooding to distribute each node's link-state database

Wireless Sensor Networks

- low mobility (though sometimes units disappear), low power, low data rates, often many nodes (mesh of nodes), high reliability needed
- restricted application-dependent communication, e.g. merge all the data towards a base station
- multi-hop ad-hoc networks (assumed in most research) can use diffusion: requests (queries) and data messages (events) move at random through the network until their paths intersect each other
- much discussion of the Internet of Things (IoT) assumes 1-hop (or low-hop) networks connected to the Internet through a gateway

Wireless Sensor Network: more general data forwarding

- some applications may require general communication, e.g. communication in the local area, transmit images and sound, debugging and reconfiguration
- geographic routing: move the packet in the direction of the destination. Often fails. Many workarounds, including Geometric Routing, which keeps track of overall network topology.
- gradient routing: source or destination sends a broadcast, everyone keeps track of distance. Grad, Lusus.
- sender can send a broadcast, which builds a reverse route back to the sender. Receiver uses this route to reply, building a route back to itself. Multipath On-Demand Routing (MOR).
- keeping multiple paths (MOR) lets you dynamically load balance (each node may have multiple next hops) and try to avoid congestion (if one transmission fails, try transmitting to a different next hop).

Wireless Sensor Networks Physical Layers

- wanted: long range and low power
- directional focus: lasers, infrared, phased array antennas, directional antennas. All require aiming, but some could be automatic
- omnidirectional: no focus needed, but more power needed for same range
- if antenna is high off the ground, power ~= r^2 x distance
- if antenna is near the ground, power ~= r^4 x distance

ISM Bands

- Industrial, Scientific, Medical (ISM) bands are generally free from licensing restrictions
- ISM bands are available in the 800-900MHz range (but different frequencies e.g. for US and Europe), 2.4GHz range (worldwide, same frequency as microwave ovens, resonant frequency of water), and other ranges e.g. 5GHz
- good selection of radios: systems, circuits, chips, antennas
- maximum power level usually determined by regulation, e.g. FCC in the US
- serial radios, 802.11, Bluetooth, Zigbee, and many other standards all use ISM bands