IN4181 – Lecture 2

Ad-hoc and Sensor Networks

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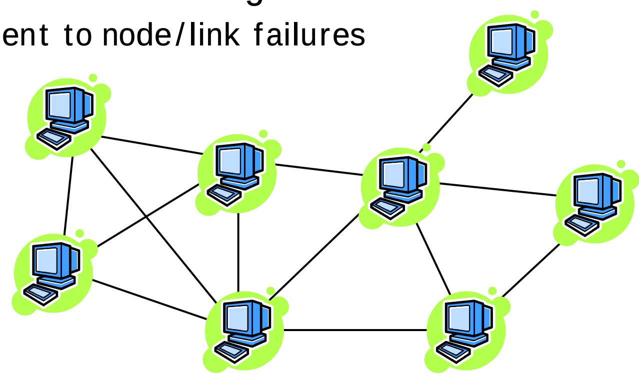
Outline: discuss impact of wireless

- Ad-hoc networks
  - link layer: medium access control
  - network layer: routing
  - transport layer: TCP/IP
- Sensor networks
  - localization
  - data processing
  - deployments

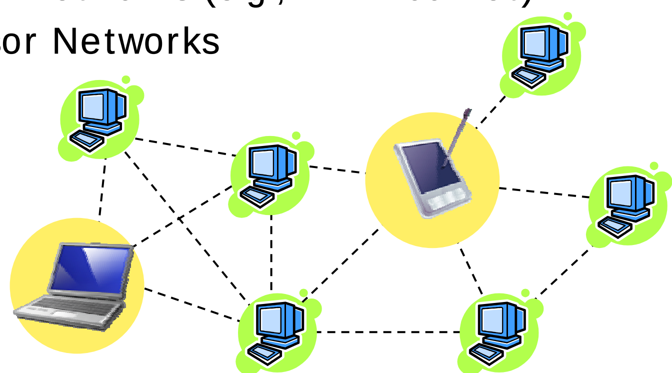
Ad-hoc networks

- Each node is willing to forward data
- NO dedicated routing hardware
  - resilient to node/link failures



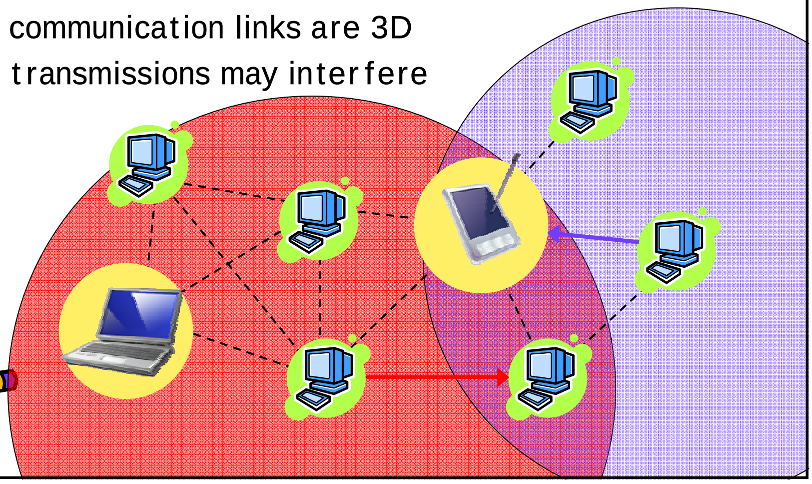
Wireless ad-hoc networks

- Mobile Ad-Hoc Networks (MANETS)
- Mesh Networks (e.g., MIT roofnet)
- Sensor Networks



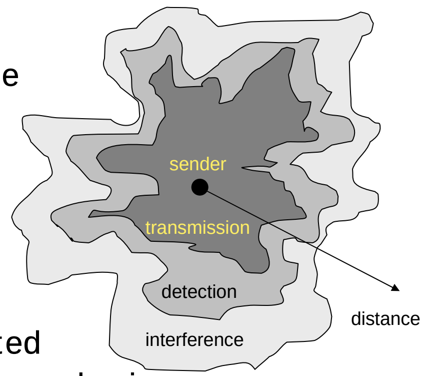
Wireless is a broadcast medium

- Pictures are misleading
  - communication links are 3D
  - transmissions may interfere



Signal propagation ranges

- Transmission range
  - communication is possible
  - low error rate
- Detection range
  - detection of the signal
  - no communication
- Interference range
  - signal may not be detected
  - signal adds to the background noise



From bits to packets

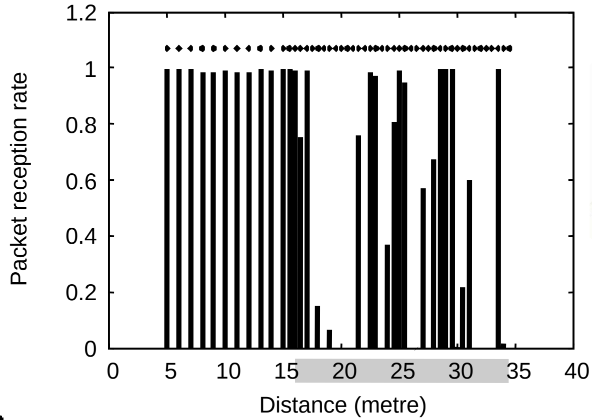
- Physical layer
  - coded, modulated bitstream
  - BER: Bit-Error-Rate
  - RSSI: Received Signal Strength Indicator

CC1000/TinyOS/B-MAC

preamble	start	len	MAC hdr	data payload	CRC
8	2	1	4	up to 29	2

- Link layer
  - packets: header + data payload + CRC
  - PER: Packet-Error-Rate

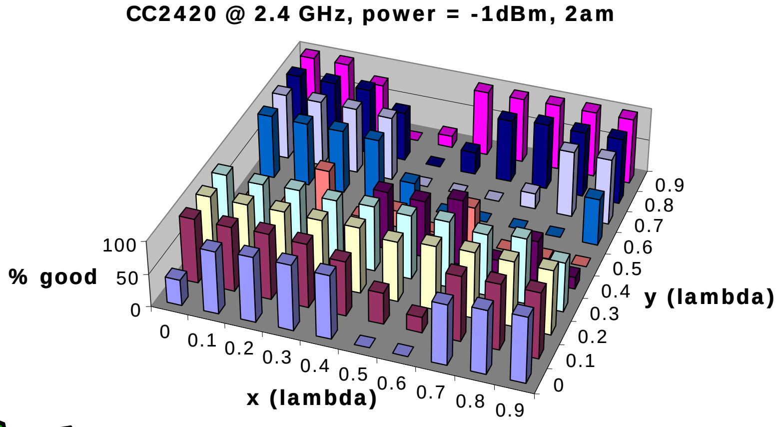
Link-layer propagation ranges



EYES node

Gray area effect [Zhao:2003]

Link-layer & multipath fading



[Robert Poor, Ember corp.]

Medium Access Control

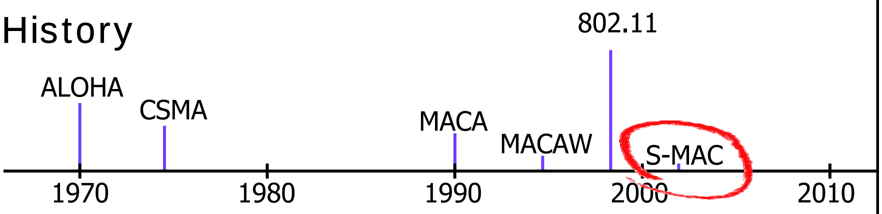
background

Medium Access Control

Control access to the shared radio channel

- avoid interference between transmissions
- mitigate effects of collisions (retransmit)

History



Medium Access Control

Control access to the shared radio channel

- avoid interference between transmissions
- mitigate effects of collisions (retransmit)

Approaches

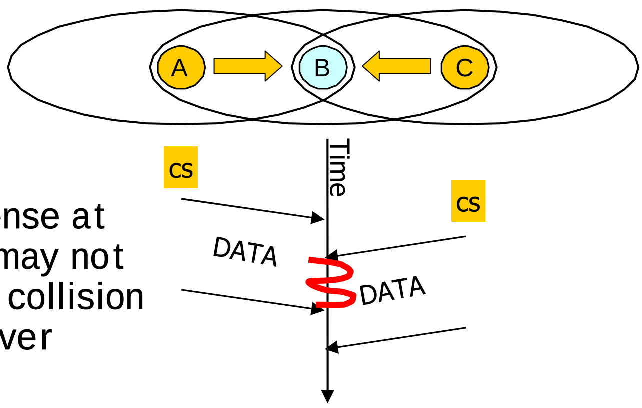
- contention-based: no coordination
- schedule-based: central authority (access pt)

Collision-based MAC protocols

ALOHA :
- packet radio networks
- send when ready
- 18-35% channel utilization

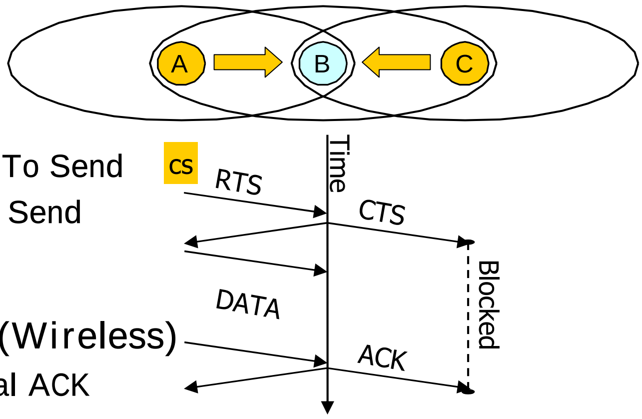
CSMA (Carrier Sense Multiple Access):
- "listen before talk"
- 50-80% channel utilization

Hidden terminal problemc



Carrier sense at sender may not prevent collision at receiver

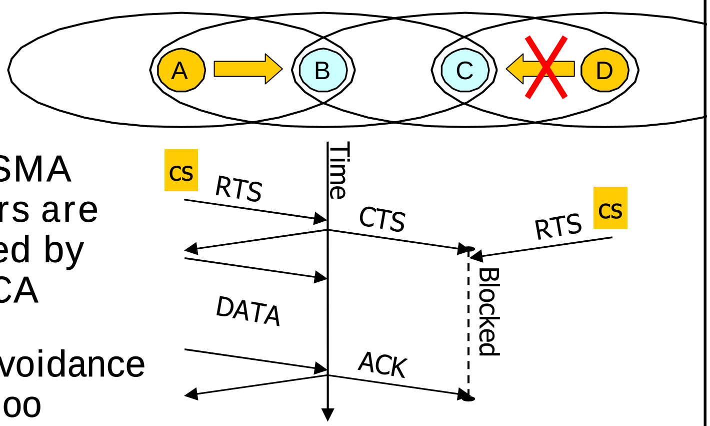
CSMA/CA: Collision Avoidance



MACA:
- Request To Send
- Clear To Send
- DATA

MACAW (Wireless)
- additional ACK

Exposed terminal problem



Parallel CSMA transfers are serialized by CSMA/CA

Collision avoidance can be too restrictive!

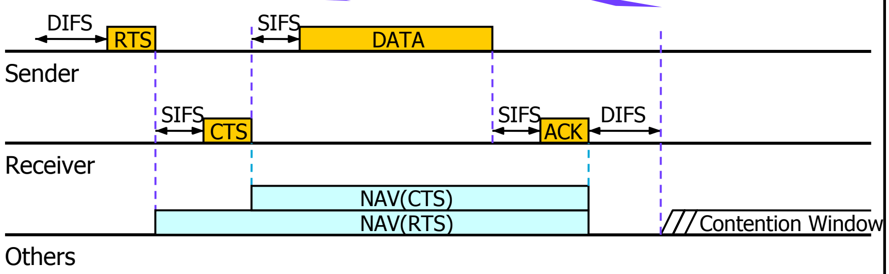
IEEE 802.11

Operation
- infrastructure mode (access point)
- ad-hoc mode

Power save mechanism; not for multi-hop

Protocol
- carrier sense
- collision avoidance (optional)

IEEE 802.11



Network Allocation Vector (NAV)
- collision avoidance
- overhearing avoidance: other nodes may sleep

Schedule-based MAC protocols

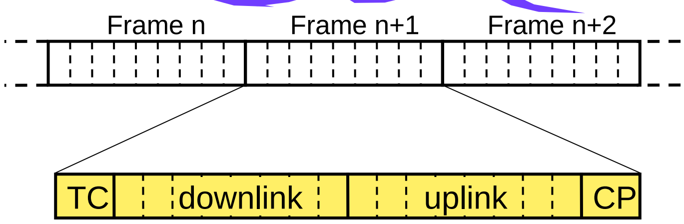
Communication is scheduled in advance

- no contention
- no overhearing
- support for delay-bound traffic (voice)

Time-Division Multiple Access

- time is divided into slotted frames
- access point broadcasts schedule
- coordination between cells required

TDMA



Typical WLAN setup

- no direct communication between nodes
- access point broadcast Traffic Control (TC) map
- (new) nodes signal needs in Contention Period (CP)

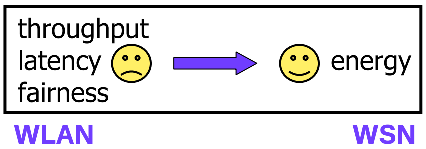
Requirements for Sensor Networks

Handle scarce resources

- CPU: 1 – 10 MHz
- memory: 2 – 4 KB RAM
- radio: ~100 Kbps
- energy: small batteries

Unattended operation

- plug & play, robustness
- long lifetime



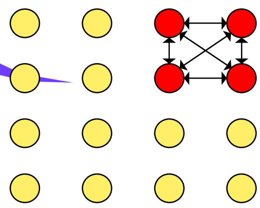
Communication patterns

WSN applications:

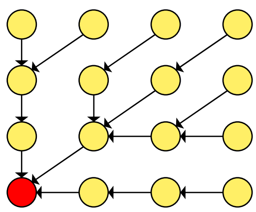
- local collaboration when detecting a physical phenomenon
- periodic reporting to sink

Characteristics:

- low data rates <1000 bps
- small messages ~25 bytes
- fluctuations (in time and space)



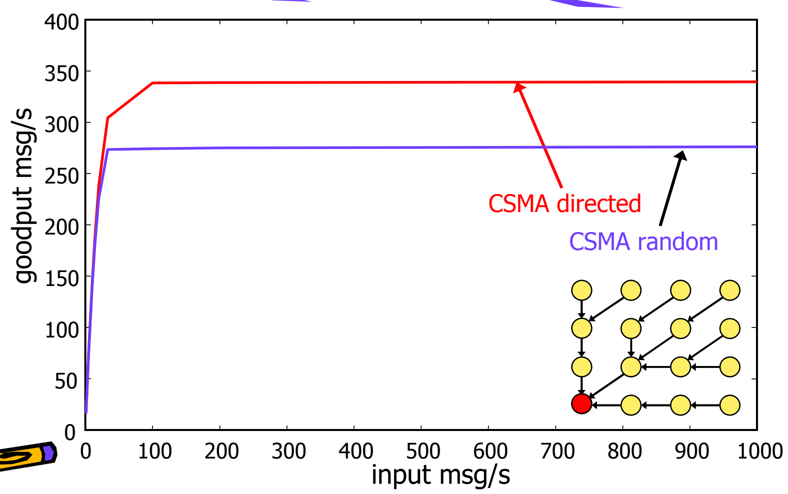
local gossip



convergecast

[Kulkarni:2004]

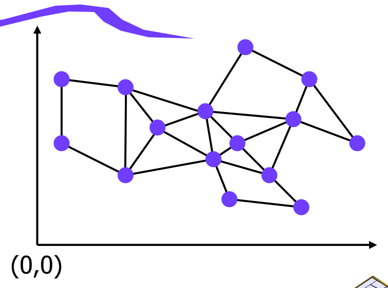
Directionality experiment



Localization

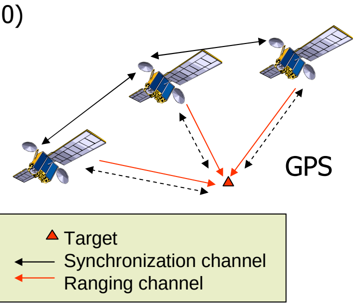
introduction

The localization problem

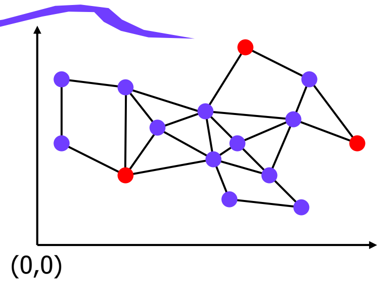


Scenario:
- install nodes
- determine positions

Choices:
- infrastructure vs. ad-hoc
- connectivity vs. ranging
- centralized vs. distributed



Ad-hoc localization



- Many nodes (> 100)
- NO infrastructure
- NO central processing
- Sparse **anchor** nodes
  - known position
- Other **nodes** determine their position using
  - anchor locations
  - distance measurements

Ranging Technologies

- Received Signal Strength Indicator (RSSI)
  - extremely noisy (reflections)
  - calibration
  - omi-directional (sort of)

range: ~10 m
accuracy: ~2-3 m

- Ultrasonic time-of-flight
  - (clock synchronization)
  - time-difference with RF
  - lope-shape beam angle

range: ~10-30 m
accuracy: ~2-5 cm

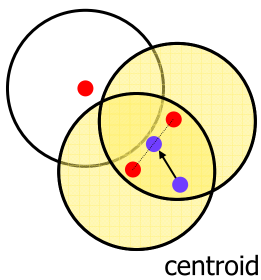
Range-free localization

Algorithms:

- Centroid [Bulusu2000]
- Convex optimization [Doherty2001]
- DV-hop [Niculescu2001]

Results:

- many anchors needed
- poor accuracy: > .5 Radio range



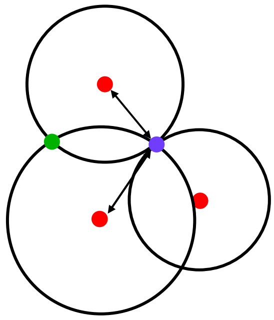
Range-based localization

Algorithms:

- Multihop lateration [Savvides2001]
- Robust positioning [Savarese2002]
- APS [Niculescu2001]

Lateration:

- intersect circles, solve [Ax=b]
- redundancy to handle errors
  - range measurements
  - sparse anchor scenario



Localization in sensor networks

Algorithms must limit

- processing
- communication

but fail to do so

- lateration implies NxN matrix invert
- periodic beaconing or flooding overheads

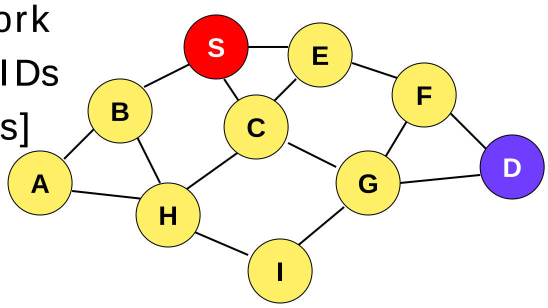
Routing

background

The routing problem

Find path between S and D

- ad-hoc network
- unique node IDs
- [mobile nodes]



Classification of routing protocols

Table-driven (proactive)

- Each node maintains a routing table (to all others)
- Topology changes are immediately propagated
- DSDV, OSLR, WRP, CGSR, …

maintenance vs discovery cost

Source-initiated (reactive / on-demand)

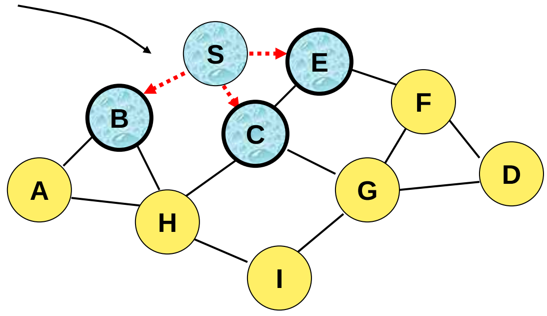
- Nodes maintain only information for active destinations
- Explicit route discovery (flooding)
- [Route maintenance procedure used to repair routes]
- **AODV**, DSR, TORA, SSR, …

AODV
Ad Hoc On-Demand Distance Vector Routing

- Now RFC 3561, based on DSDV
- Source sends Route Request Packet (RREQ) when a route has to be found
- Route Reply Packet (RREP) is sent back by destination
- Route Error messages update routes

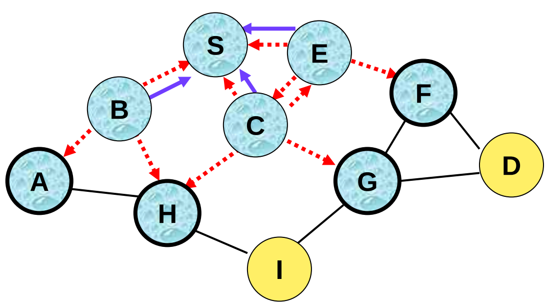
Route Requests in AODV

Broadcast transmission



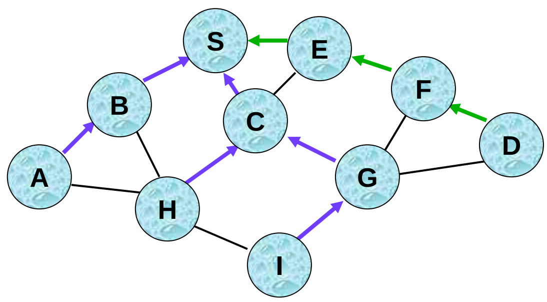
Represents transmission of RREQ

Route Requests in AODV



Represents links on Reverse Path

Route Reply in AODV



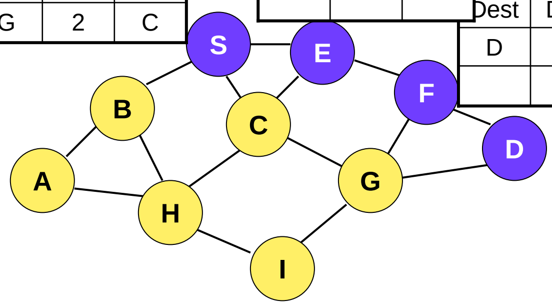
Represents links on path taken by RREP

Routing tables in AODV

Dest	Dist	Next
D	3	E
G	2	C

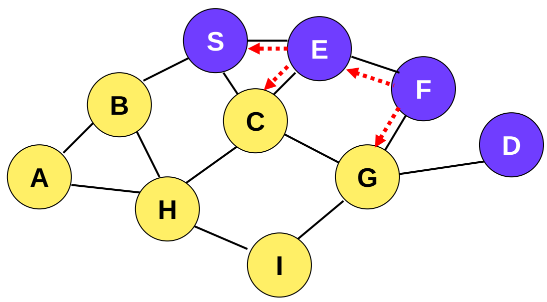
Dest	Dist	Next
D	2	F

Dest	Dist	Next
D	1	D



Route maintenance in AODV

S initiates new route discovery

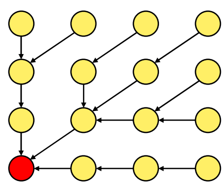


Represents transmission of RERR

Routing in sensor networks?

Often not needed!

- local gossip: broadcast
- convergecast: spanning tree
- sink-to-nodes: flooding



Routing table has one entry (to-sink)

Application-level solutions (in-band signaling)

Routing in sensor networks!

Problem: dynamic environment

- link/node failures
- multiple/mobile sinks
- node mobility

Solutions:

- factor in link quality: ETX (Expected #hops)
- factor in location info: geographical routing

Presentation basics

dos & don'ts

Speaker's instructions

- Preparations
  - contact your special topic instructor
  - browse recent literature
  - propose paper for presentation (**-1 week**)
  - prepare Powerpoint slides (**-2 days**)
- Performance
  - bring your own laptop OR a USB memory stick OR send Koen an e-mail (**before 09:00**)
  - present paper + lead discussion

Less is more

DO

- max 6 bullets per slide

DON'T

- write full sentences (because that gets your audience reading instead of paying attention to what you have to say, especially when you have to use a small font size to cramp it all on a single page!)
- use fancy fonts (sans serif is best)
- use animations (for experts only ☺)

A picture is worth a thousand words

DO

- use illustrations/graphs/tables (1 per slide)
- use color

DON'T

- show code listings
- show mathematical proofs

Practice makes perfect

DO

- rehearse your talk (and timing)

DON'T

- recite your text
- run over time

Body language

DO

- speak with your hands
- interact with your audience

DON'T

- stare at your shoes/laptop/me
- turn your back to the audience when pointing at your slides

Home work

- Read "classic" MAC papers
  - S-MAC (contention-based)
  - LMAC (TDMA)
- Submit summary via CPM
  - 300-500 words
  - PDF format
  - deadline: April 26th, 10:30 (before class)