EEC 687/787 Mobile Computing (Spring, 2009)

Ns-2 Laboratory #2

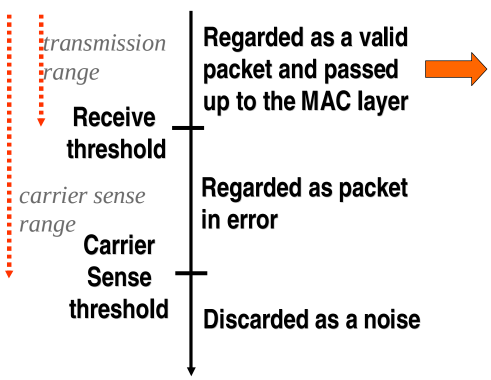
Prof. Chansu Yu

http://academic.csuohio.edu/yuc/
c.yu91@csuohio.edu

Receiving Radio Signals

"capture"

- The power level of a received packet is compared to two values



If the receiver is not idle (conflict),

-when the power level of the packet being received is at least 10dB greater than that of a new packet, discard the new packet

- otherwise, it is a "collision" and both packets are dropped

18.1 Free space model

The free space propagation model assumes the ideal propagation condition that there is only one clear line-of-sight path between the transmitter and receiver. H. T. Friis presented the following equation to calculate the received signal power in free space at distance d from the transmitter [12].

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L} \tag{18.1}$$

where P_t is the transmitted signal power. G_t and G_r are the antenna gains of the transmitter and the receiver respectively. $L (L \geq 1)$ is the system loss, and λ is the wavelength. It is common to select $G_t = G_r = 1$ and $L = 1$ in *ns* simulations.

18.2 Two-ray ground reflection model

A single line-of-sight path between two mobile nodes is seldom the only means of propation. The two-ray ground reflection model considers both the direct path and a ground reflection path. It is shown [29] that this model gives more accurate prediction at a long distance than the free space model. The received power at distance d is predicted by

$$P_r(d) = \frac{P_t G_t G_r {h_t}^2 {h_r}^2}{d^4 L} \tag{18.2}$$

where h_t and h_r are the heights of the transmit and receive antennas respectively. Note that the original equation in [29] assumes $L = 1$. To be consistent with the free space model, L is added here.

c.yu91@csuohio.edu

Configuration for PHY Layer

- Radio Propagation Model

Propagation/Shadowing	set	pathlossExp_	2.0
Propagation/Shadowing	set	std_db_	4.0
Propagation/Shadowing	set	dist0_	1.0
Propagation/Shadowing	set	seed_	0
Antenna/OmniAntenna	set	X_	0
Antenna/OmniAntenna	set	Y_	0
Antenna/OmniAntenna	set	Z_	1.5
Antenna/OmniAntenna	set	Gt_	1.0
Antenna/OmniAntenna	set	Gr_	1.0

- Where are they defined?

c.yu91@csuohio.edu

Configuration for PHY Layer

```
Phy/WirelessPhy  set  CPThresh_   10.0
Phy/WirelessPhy  set  CSThresh_   1.559e-11
Phy/WirelessPhy  set  RXThresh_   3.652e-10
Phy/WirelessPhy  set  bandwidth_  2e6
Phy/WirelessPhy  set  Pt_         0.28183815
Phy/WirelessPhy  set  freq_       914e+6
Phy/WirelessPhy  set  L_          1.0
```

- Where are they defined?
- Can you calculate
  - Carrier sense range?
  - Transmission range?

c.yu91@csuohio.edu

Specifying and Parameterizing the Propagation Model

- Three different radio propagation models.
  - Free space and two-way ground reflection models in fact comprise one model
  - Shadowing model is another
  - Shadowing model can be parameterized (beta and stdev values) => **must be defined before node configuration!!!**

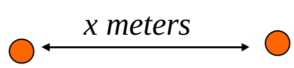
Check "tcl/lib/ns-default.tcl"

```
# first set values of shadowing model
Propagation/Shadowing set pathlossExp_ 2.0   ;# path loss exponent
Propagation/Shadowing set std_db_ 4.0        ;# shadowing deviation (dB)
Propagation/Shadowing set dist0_ 1.0         ;# reference distance (m)
Propagation/Shadowing set seed_ 0            ;# seed for RNG
```


c.yu91@csuohio.edu

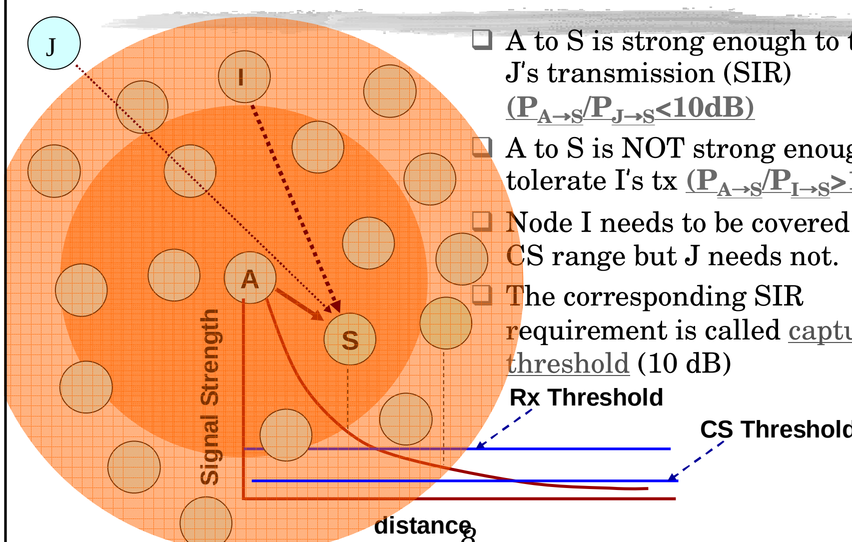
Lab Exercise #2 (in class)

- ❑ Download prop.tcl
  - ➢ This script takes one command-line argument: the distance between two nodes.
  - ➢ ns prop.tcl -dist {x}



- ❑ Run the simulation for TwoRayGround, and Shadowing (with different deviation values: 2, 4, and 8dB)
  - ➢ Vary x= 50m, 100m, 200m, 300m
  - ➢ Use linux commands (grep) to get pdr

Determining Carrier Sense Threshold



- ❑ A to S is strong enough to tolerate J's transmission (SIR) **($P_{A\to S}/P_{J\to S}$<10dB)**
- ❑ A to S is NOT strong enough to tolerate I's tx **($P_{A\to S}/P_{I\to S}$>10dB)**
- ❑ Node I needs to be covered in the CS range but J needs not.
- ❑ The corresponding SIR requirement is called capture threshold (10 dB)

Receiving Radio Signals

"signal capturing"

- The power level of a received packet is compared to two values

Regarded as a valid packet and passed up to the MAC layer

Receive threshold

Regarded as packet in error

Carrier Sense threshold

Discarded as a noise

If the receiver receives one signal while receiving another (conflict),

- P(old)/P(new)>10dB, can still receive the old one (new packet is dropped)

- Otherwise, it is a "collision" and both packets are dropped

c.yu91@csuohio.edu

Signal Capturing in ns-2

- mac/wireless-phy.cc

```
int WirelessPhy::sendUp(Packet *p) {
…
if (Pr < CSThresh_) pkt_recvd = 0;
if (Pr < RXThresh_) pkt_recvd = 1; hdr->error() = 1;
else pkt_recvd = 1; hdr->error() = 0;
```

- mac/mac-802_11.cc

```
void Mac802_11::recv(Packet *p, Handler *h) {
…
if (rx_state_ == MAC_IDLE) {
…
} else {
      if(pktRx_->txinfo_.RxPr / p->txinfo_.RxPr >= p->txinfo_.CPThresh) capture(p);
      else collision(p);
}
```

If medium idle, receive it

If medium is not idle, receive it if SINR>CPThresh. Collision, otherwise

c.yu91@csuohio.edu

Quiz: Packet capturing

- Investigate the effect of capture ratio.
  Phy/WirelessPhy set CPThresh_ 10.0

- What happens if
  - CPThresh_ = 1000.0: packet is successful when SIR>1000
  - CPThresh_ = 1.0001: packet is successful when SIR>1.0001

11

c.yu91@csuohio.edu

Multirate Control

- Multirate support
  - 802.11 supports 1 and 2 Mbps
  - 802.11b supports 1, 2, 5.5 and 11 Mbps
  - 802.11a supports 6, 9, 12, 18, 24, 36, 48 and 54 Mbps

- Advantages of high-rate communication
  - Faster delivery (less delay)
  - More throughput
  - Less energy

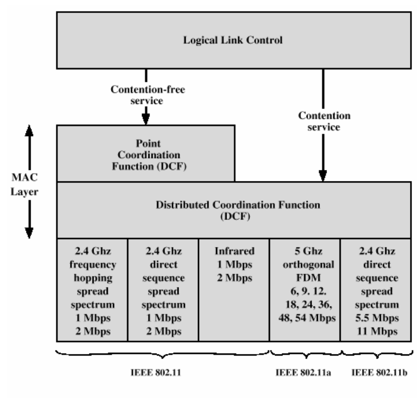


Figure 14.5 IEEE 802.11 Protocol Architecture

12

c.yu91@csuohio.edu

Multirate Control

- Signal-to-Interference Noise Ratio (SINR) required for successful reception at the receiver depends on the transmission rate being used.
- The ideal capacity of a channel with bandwidth B is given by Shannon's Equation: W=Blog(1+SINR), yielding SINR(reqd) >= (2^(W/B)-1).

- Recall that carrier-sense range (CSRange) is the distance from the transmitter upto which nodes assess the channel as busy, and thus CSThresh and CSRange possess an inverse relationship with each other.

c.yu91@csuohio.edu

Multirate Control

- A small CSThresh implies
  - that nodes far away shall detect the channel as busy, and defer
  - a larger CSRange, which means that more space is "reserved" ("guard zone" to protect current communication)

- On the contrary, a large CSThresh implies
  - that only nodes very close to a transmitter shall assess the channel as busy
  - a smaller CSRange, which means more concurrent transmissions but chances of collision are higher.

c.yu91@csuohio.edu

Multirate Control

- A higher rate packet
  - Travels less distance
  - More subjective to interference
- In terms of radio technology
  - Less communication distance means to require a signal strength (receive sensitivity)
  - More vulnerability to interference means to require a higher SNR for successful communication (capture threshold)

c.yu91@csuohio.edu

Multirate Control

Data rate (Mbps)	Receive threshold (dBm)	Communication distance (m)	Capture threshold (dB)	Capture distance (m)	*Carrier sense distance (m)*
6	-82	238	6.02	337	*575*
9	-81	224	7.78	351	*576*
12	-79	200	9.03	336	*536*
18	-77	178	10.79	331	*509*
24	-74	150	17.04	400	*550*
36	-70	119	18.80	351	*470*
48	-66	95	24.05	389	*484*
54	-65	89	24.56	366	*455*

** Transmit power: 6 dBm*

** For a successful communication, when a node transmits a packet, other nodes should not send theirs. This can lead to capture distance.*

** CSThresh = -91 dBm*

c.yu91@csuohio.edu

Lab Exercise #2 (in class)

- This exercise is aimed at exploring how rate control and adaptation of carrier sense threshold can affect spatial reuse (and hence aggregate throughput) in a multi-hop network.
- Download rate.tcl
  - A simulation topology of 100 nodes arranged in a 10x10 grid with a grid-spacing of 150m.
  - 25 CBR conversations between randomly chosen source-destination pairs are set up.
- The script takes as arguments the TX-Rate (in bps), the RxThresh (in Watts), CPThresh (ratio; no units), and the CSThresh (-91 dBm). (see the table)
  - Usage: ns rate.tcl -rate {rate (bps)} -rxthresh {rcv_threshold} -cpthresh {capture-threshold} -csthresh {carrier-sense threshold (W)}
  - For instance: ns rate.tcl –rate 6e6 -rxthresh 1.0e-8.2(mW) -cpthresh 1.0e0.602 -csthresh 1.0e-9.1(mW)
    => ns rate.tcl –rate 6e6 -rxthresh 1.0e-11.2 -cpthresh 1.0e0.602 -csthresh 1.0e-12.1

17

c.yu91@csuohio.edu

Multirate Control

- What does the data rate change affect?
  - Data rate (it will affect the packet time, etc.)
  - Receive threshold
  - Capture threshold

  * Do not forget to change the “Pt_” to 6dBm !!!
- How to make changes in ns-2?
  - Source file changes
  - Variable binding
  - Command method

18

c.yu91@csuohio.edu

Variable Binding

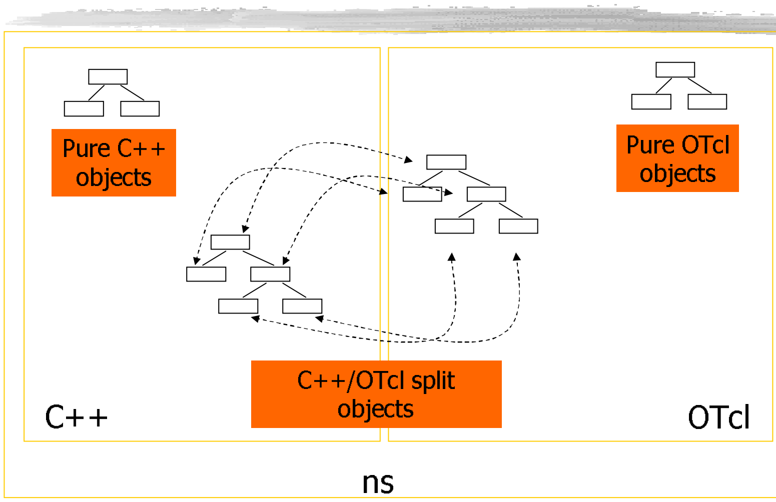
- Set/change a variable of C++ component from TCL run script
  - Advantage: No need to modify the source file (no need to compile & link)
- Special function “bind”
  - Interface: bind, bind_bw, bind_time, bind_bool

```
WirelessPhy::WirelessPhy() : Phy(), sleep_timer_(this), status_(IDLE) {
    bind("CPThresh_", &CPThresh_);
    bind("CSThresh_", &CSThresh_);
    bind("RXThresh_", &RXThresh_);
    bind("Pt_", &Pt_);
```

  - Default value is defined in $ns/tcl/lib/ns-default.tcl
    - Mac/802_11 set dataRate_ 1.0e6
    - Mac/802_11 set PLCPDataRate_ 1.0e6
    - Phy/WirelessPhy set CPThresh_ 10.0
    - Phy/WirelessPhy set RXThresh_ 3.652e-10
    - Phy/WirelessPhy set bandwidth_ 2e6
    - Phy/WirelessPhy set Pt_ 0.28183815

c.yu91@csuohio.edu

OTcl and C++



c.yu91@csuohio.edu

Parameters

```
# Tx = 6 dBm (3.981 mW or 3.981e-3)
Phy/WirelessPhy set Pt_ 3.981e-3
# CS = -91 dBm (7.943e-10 mW or 7.943e-13) => 399m
Phy/WirelessPhy set CSThresh_ 7.943e-13

if {$par0 == "06"} {
	# 6 mbps, -82 dBm (Rx), 6.02 dB (Cp) => 6.310e-12,
	3.999 => 238m
	Mac/802_11 set dataRate_	6.0e6
	Phy/WirelessPhy set bandwidth_ 6e6
	Mac/802_11 set PLCPDataRate_ 6.0e6
	Phy/WirelessPhy set CPThresh_ 3.999
	Phy/WirelessPhy set RXThresh_ 6.310e-12
}

if {$par0 == "18"} {
	# 18 mbps, -77 dBm (Rx), 10.79 dB (Cp) => 1.995e-11,
	11.995 => 178m
	Mac/802_11 set dataRate_	18.0e6
	Phy/WirelessPhy set bandwidth_ 18e6
	Mac/802_11 set PLCPDataRate_ 18.0e6
	Phy/WirelessPhy set CPThresh_ 11.995
	Phy/WirelessPhy set RXThresh_ 1.995e-11
}

if {$par0 == "36"} {
  # 36 mbps, -70 dBm (Rx), 18.80 dB (Cp) => 1.000e-10, 75.858 => 119m
  Mac/802_11 set dataRate_	36.0e6
  Phy/WirelessPhy set bandwidth_ 36e6
  Mac/802_11 set PLCPDataRate_ 36.0e6
  Phy/WirelessPhy set CPThresh_ 75.858
  Phy/WirelessPhy set RXThresh_ 1.000e-10
}

if {$par0 == "54"} {
  # 54 mbps, -65 dBm (Rx), 24.56 dB (Cp) => 3.162e-10, 285.759 => 89m
  Mac/802_11 set dataRate_	54.0e6
  Phy/WirelessPhy set bandwidth_ 54e6
  Mac/802_11 set PLCPDataRate_ 54.0e6
  Phy/WirelessPhy set CPThresh_ 285.759
  Phy/WirelessPhy set RXThresh_ 3.162e-10
}
```


c.yu91@csuohio.edu

Multirate Control

- Make your life a bit easier…
- Use a run batch file

```
TCL_FILE=carj.tcl
TRACE_FILE=out.tr
RES_AWK_FILE=delay.awk
RESULT_FILE=carj.out

for RATE in 06 18 36 54
  do
    for SPEED in 0 1 5 10 20
    do
      OPTION="$RATE $LAYOUT $SPEED"
      echo $OPTION ......
      echo $OPTION ...... >> $RESULT_FILE
      ns $TCL_FILE $OPTION
      awk -f $RES_AWK_FILE $TRACE_FILE >> $RESULT_FILE
    done
  done
```


c.yu91@csuohio.edu

Multirate Control

- How to pass values to TCL script?

```
set val(x)        4000

set val(y)        200

set val(nn)        96
set val(stop)      170

if {$argc != 3} {
      puts "Usage ns carj.tcl
      DataRate(06/18/36/54)
      Layout(chain/para)
      Speed(0/1/5/10/20)"
      exit
}

set par0 [lindex $argv 0]
set par1 [lindex $argv 1]
set par2 [lindex $argv 2]

if {$par0 == "06"} {
      Mac/802_11 set dataRate_       6.0e6
      Phy/WirelessPhy set bandwidth_ 6e6
      Mac/802_11 set PLCPDataRate_
      6.0e6
      Phy/WirelessPhy set CPThresh_ ????
      Phy/WirelessPhy set RXThresh_ ????
```

```
if {$par0 == "54"} {
      Mac/802_11 set dataRate_      54.0e6
      Phy/WirelessPhy set bandwidth_
      54e6
      Mac/802_11 set PLCPDataRate_
      54.0e6
      Phy/WirelessPhy set CPThresh_ ????
      Phy/WirelessPhy set RXThresh_ ????
}
…..
…..
if {$par2 == "1"} {
      $ns_ at 0.0 "$node_(0) setdest 3400.0
      1.0 1.0"
}
…..
if {$par2 == "20"} {
      $ns_ at 0.000000000000 "$node_(0)
      setdest 3400.0 1.0 20.0"
}
```


c.yu91@csuohio.edu

Lab Exercise #2 (Lab report)

- Run the simulations for all combinations of TX-rate and RXThresh. Obtain the aggregate CBR throughput for each run.
- Draw a chart drawing throughput versus TX-rate for each value of RXThresh

- Discussion: What trends may be observed? For this simulation topology, what combination seems to yield the best performance?

c.yu91@csuohio.edu