Introduction to Wireless Networks: protocols and performance analysis

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Cumulative credits: some figures have been taken from slides found on the web, by the following authors (in alfabethical order):

J.J. Garcia Luna Aceves (ucsc), James F. Kurose & Keith W. Ross, Jochen Schiller (fub), Nitin Vaidya (uiuc)

PHY modelling issues

- **Usually the PHY layer is considered a Black box in the simulation model (e.g. when studying higher layers)**
- **Many PHY parameters can have a deep effect on higher layers' behavior (and are inherently "continuous"...)**
  - a modeler needs to know what is required to be modeled for obtaining significant results (e.g. mapping to "discrete"...)
  - simplifying assumptions can lead to wrong results
    - Warning: more analysis?
- **Usually the choice is to model only few parameters of the PHY layer, describing the aggregate effect of main parameters (see later) and their values' distributions.**
  - Trace driven simulation? Regression data from logged trace results?
  - e.g. channel states → Bit error rate → prob. of packet error?
  - e.g. network topology → interference → bit error rate?
  - e.g. coding and trasmission technique → data rate?

PHY modelling issues

- **Homework: analitical analysis of a PHY system**
  - a given channel is DSSS with 8 chips/bit
  - maximum chipping rate = 2.000.000 chip/sec
  - can recover up to 2 chip errors/bit
  - probability of chip error = Pce
  - probability of a bit error?
  - frame length (constant) = 1500 Bytes
  - probability of frame error?

  will be used as the PHY (black box) reliability parameter...

  - timeout delay before packet retransmission attempt = 1 sec

  average delay before tagged frame's successful transmission?

PHY modelling issues

- **Homework: Solution**
  - Probability of a bit error?

$$p_{bit\_ok} = (1 - p_{ce})^8 + 8 \cdot p_{ce} \cdot (1 - p_{ce})^7 + \binom{8}{2} \cdot p_{ce}^{\ 2} \cdot (1 - p_{ce})^6$$

$$p_{bit\_error} = 1 - p_{bit\_ok}$$

  - Probability of frame error?

1 Frame = 1500 Byte = 1500*8 bit = 1500*8*8 chip

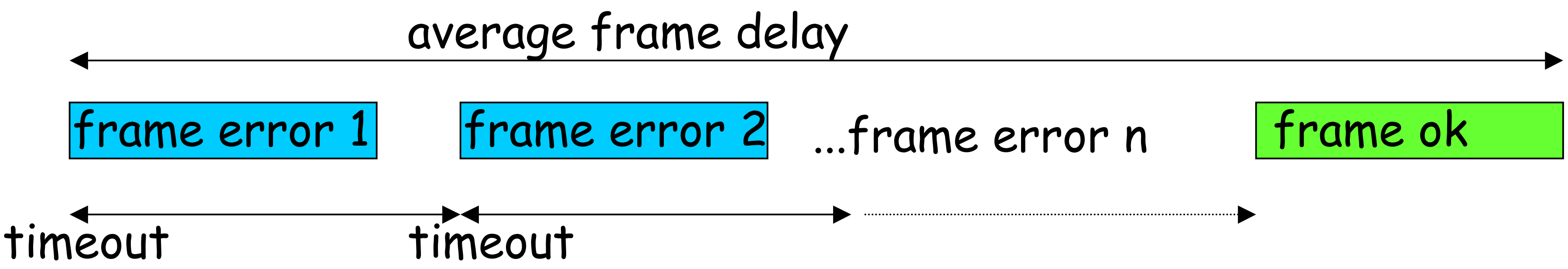
$$P_{FrameError} = P\{at\_least\_one\_bit\_error\} = 1 - p\{all\_bits\_ok\}$$

$$p_{FrameError} = 1 - p_{bit\_ok}^{\ (1500 \cdot 8)}$$

PHY modelling issues

- **Homework: Solution**
  - Average delay before successful transmission of a tagged frame?

Avg. Delay = (Avg._Number_Retrans.*Timeout)+Frame Delay



$$avg\_delay = \left[\sum_{i=1}^{\infty} i \cdot \left(p_{FrameError} \right)^{i-1} \cdot \left(1 - p_{FrameError} \right) \right] \cdot Timeout + \frac{[1500 \cdot 8 \cdot 8]}{2.000.000}$$

$$avg\_delay = \frac{1}{1 - p_{FrameError}} \cdot Timeout + 0.048 = \frac{1}{p_{bit\_ok}^{1500 \cdot 8}} \cdot Timeout + 0.048$$

Modelling network topology and mobility

- **Fixed (static) topology**
  - fixed (static) model
- **Ad Hoc topologies**
  - many hosts with topology parameters
    - 2D position (X,Y) or 3D position (X,Y,Z)
    - Links: related to mutual reachability (mono,bi-directional)
      - TX Power (Coverage area)
        - » circular (multiple coverage sub-areas)
        - » exagonal (approximation for regular infrastructure models, e.g. cellular AP)
        - » square (highly approximated)
      - Rx sensitivity (reception threshold)
        - » Interference model?
        - » asymmetric coverage area
      - Obstacles?

Modelling network topology and mobility

- **Ad Hoc mobility**
  - mobility dinamically affects network topology
  - many hosts with mobility parameters
    - (assume 2D position (X,Y) for simplicity)
    - host state: fixed or mobile
      - two-state model: probability distribution
      - fixed-position state : zero mobility
      - mobile state : non-zero mobility
        - » various mobility models define the mobility parameters
        - » Velocity is a vector (speed, direction, orientation)
        - » position shift is vector (Velocity*time)
  - Problem: mobility is a continuous process
    - how to model mobility effects in discrete event simulation?
      - discrete quantization? -> approximation of effects
      - fine quantization -> many events -> slow simulation

- **Random Waypoint model**
  - is completely random (pattern-less)
  - This model is less affected by the initial position of hosts
  - Host N
    - step i = 1..I starting at time Tn_i
      - » Host N selects random target position (x,y) in the plane
      - » host N moves with constant velocity Vn_i (randomly generated)
      - » Step duration is a function of distance and velocity
    - node mobility is not correlated -> link failures are independent.

Modelling network topology and mobility

- **Random Direction model**
  - is completely random (pattern-less)
  - host mobility characterized by a sequence of "epoch"
  - Host N
    - epoch i = 1..I starting at time Tn_i with duration DTn_i
      - » epoch duration DTn_i is a stochastic variable, esponentially distributed, average 1/λn (consecutive duration independent)
      - » host N moves with constant velocity Vn_i
      - » host N moves in constant direction Dn_i (in polar coordinates)
      - » Number of epochs in a time interval t is a discrete stochastic process Nn(t)
    - for each host n, and for each epoch i, DTn, Vn, Dn are NOT correlated -> node mobility is not correlated -> link failures are independent.

Modelling network topology and mobility

- **Random Direction model**
  - implementation 1:
    - given pos(n,i) the position of node n in epoch i, and Rn(i) the vector defining the movement in epoch i for node n (constant speed and direction for the time DTn_i)

      pos(n,i+1)=pos(n,i)+Rn(i)
  - Implementation 2:
    - DTn_i is constant (epoch duration is constant)
    - randomly generated pos(n,0), pos(n,1)...pos(n,I)
      - » Rn(i) is derived from pos(n.i)
  - Variation:
    - a node after each movement wait for a constant time

Modelling network topology and mobility

- **Random Direction model**
  - how to evaluate the presence of a link between node a and b in a time interval [t0,t1]?
    - evaluate mobility of node a in [t0,t1]
    - evaluate mobility of node b in [t0,t1]
    - evaluate relative mobility of nodes a,b in [t0,t1]
      - compare with the model assumption about Tx range, etc.
      - N.B. given the model assumption, and given the model parameters, Prob (link from a to b) can be defined analitically
      - N.B. since the model assumptions make the node mobility not correlated, a route between multiple nodes (multi-hop) can be defined analitically with the joint probabilities P(a to b)*P(b to c)...
    - This is interesting property: can validate simulation results?

Modelling network topology and mobility

- **Random Direction model**
  - is the discrete counterpart of the Brownian motion
    - e.g. see http://www.phys.virginia.edu/classes/109N/more_stuff/Applets/brownian/applet.html
    - e.g. see Project MFR (credits Quadalti, Massera, Capece)
  - it is not much realistic for network scenarios
  - can be used sometimes as "worst case" analysis because it describes the most "unpredictable" mobility pattern
  - it can be described and validated analitically

Modelling network topology and mobility

- **Reference Point Group Mobility (RPGM)**
  - it relates to group mobility in ad hoc networks
  - each "group" of hosts has a "logic centre"
  - the "logic centre" mobility defines the global mobility parameters of the group
  - mobile hosts are uniformly distributed inside the "domain area" of the "logic center" of the group
  - each host has a random mobility around a "reference point" (RP) which moves relative to the "logic center" mobility

Modelling network topology and mobility

- **Reference Point Group Mobility (RPGM)**
  - implementation is based on
    - Vgi: vector for group motion (logic center)
    - Vhi: vector for host motion around RP
  - check points define discrete time advance Dt
  - at check point time t the group moves to current position
  - Advantage
    - can be used to model realistic scenarios
    - can be used for modelling "logged traces" of real mobility pattern (snapshot recorded as vectors Vgi, Vhi for each checkpoint

Modelling network topology and mobility

- **Natural Random Model (NRM)**
  - a model for highly predictable paths
    - assumes low variation of mobility vector vs. time
  - for a given host h:
    - mobility vector M(xv,yv) = the sum of
      - Base Vector Bh(bx,by)
        - » main (group) mobility component
      - Variance Vector Vh(vx,vy)
        - » models the variation from the base vector of a single host
    - maybe MIN(xv,yv) < M(xv,yv) < MAX(xv,yv) to model realistic range of variation for node speed
    - by using polar coordinates, MIN and MAX variation of direction can be defined
    - finally, acceleration/deceleration can be controlled

Modelling network topology and mobility

- **Exponentially correlated random mobility (ECRM)**
  - host partitioned in G groups: Si hosts in group i

$$b(t+1) = b(t) \cdot e^{-\frac{1}{\tau}} + s \cdot \sigma \cdot \sqrt{1 - e^{-\frac{1}{\tau}}} \cdot r$$

  - b(t) is the position (polar coordinates) at time t
  - τ is a time constant (position-change rate)
  - σ is the variance for the position-changes
  - s is the host speed
  - r is a gaussian variable

Modelling network topology and mobility

- **Exponentially correlated random mobility (ECRM)**
  - motion of each group is independent
    - from other groups' motion
    - from motion of hosts in the group

Modelling network topology and mobility

- **Restricted random waypoint**
  - based on random waypoint
  - applied to large ad hoc networks
    - towns, highways...
  - Ordinary hosts
    - follow random waypoint modelling of towns
    - towns are geographic areas (grid)
  - commuter hosts
    - after a single motion in town, they move to another town, becoming Ordinary hosts
    - they run (constant speed and direction) over highways

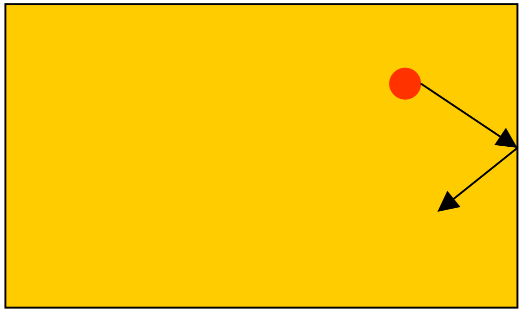
Modelling network topology and mobility

- **Column model**
  - model characterized by "leader" host and a set of related hosts following the leader
  - each host i has a reference point RPi(x,y)
  - each host i has a random motion component vector RVi with respect to its reference point RPi
  - each reference point RP has a global motion component vector AV
  - position of node i at time t+Dt:
    - pos(t+Dt) = RP(t+Dt)+RV(t)
    - where RP(t+Dt) = RP(t)*AV(t)

- **Pursue Model**
  - model similar to set of nodes following a target host
  - non-target hosts are limited in the amount of distance they run towards the target in a given time by A(target_pos(t)) (their pursue of the target is approximated)
  - non-target hosts motions are biased by the random component vector RV
  - position of host i at time t+Dt :
    pos(t+Dt)=pos(t)+A(target_pos(t))+RV(t)

Modelling network topology and mobility

- **The area boundary policy**
  - **reflection** (concentrate host distribution in the middle of the area)



  - **toroidal** (uniform distribution)