# The CMU Monarch Project's Wireless and Mobility Extensions to *ns*


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# ns (Network Simulator)

Advantages of using ***ns*** as a basis:

- Widely used in other areas of networking research
- Provides good support for TCP and other protocols
- Freely available in source

Problems for wireless and mobile simulation:

- Nodes in network have no explicit physical position
- Links between nodes are independent:
  - Behavior/performance not related to node positions
  - Behavior/performance not affected by physically (electromagnetically) overlapping transmissions on other links

# Our Mobility Support

Mobility support for each network node:

- Each node has ***location***, ***direction***, and ***speed***
- Events can be programmed to change direction or speed
- Current position of node can always be calculated as function of time

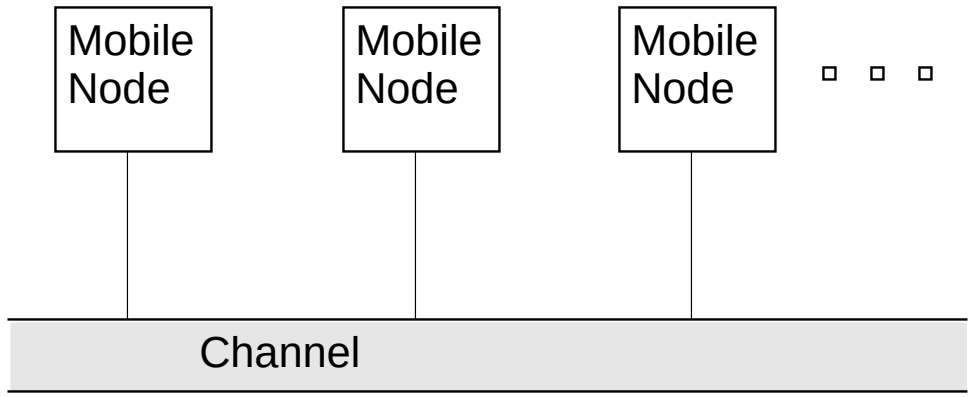
Our current movement model (***random waypoint*** model):

- Pick random starting location, then repeat:
  - Wait for ***Pause Time*** seconds
  - Pick random new destination (uniform distribution)
  - Pick velocity between 0 and maximum (uniform distribution)
  - Move steadily to destination
- Pause Time controls rate of mobility

# Our Physical Link Model

Each mobile node may have one or more wireless network interfaces:

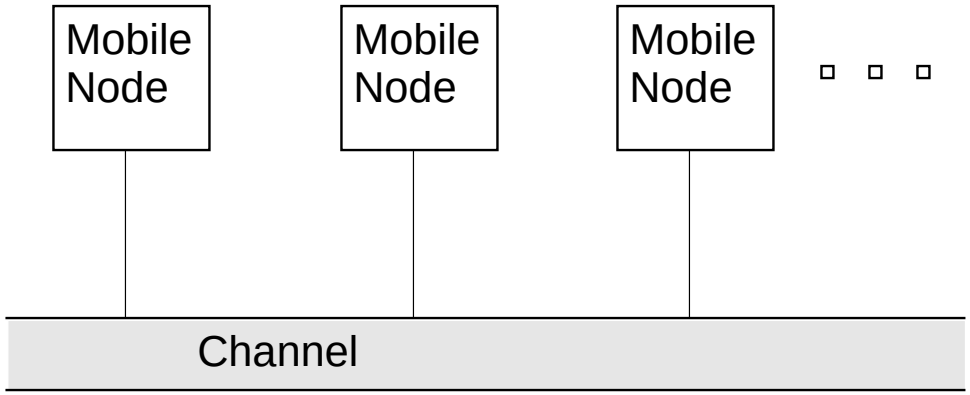
- Each antenna has a defined offset from node's location
- Each has properties like transmit power, antenna gain, etc.
- Interfaces of same type may be attached to a shared channel



# Physically Transmitting a Packet

To transmit a packet:

- Sender calculates propagation delay to all other nodes on channel based on distance and speed of light
- Schedules “packet reception” event for each node
- Signals arrival of first bit of a new packet



# Physically Receiving a Packet

When packet reception event occurs:

- Receiver calculates received signal strength
- Compared to two thresholds:
  - If below ***carrier sense threshold***, packet is discarded as noise
  - Else, if below ***receive threshold***, packet is marked as "in error" and passed to MAC level
  - Else, packet is passed to MAC level

# Physically Receiving a Packet (cont'd)

- If MAC receiver state not idle, check for ***capture effect***:
  - If existing receive at least 10 dB $>$ new packet, assume capture, discard new packet, continue existing packet
  - Else, assume collision, both packets in error
- MAC layer schedules "packet reception complete" event for itself based on packet size and channel bit rate
- When reception complete event occurs:
  - Verify packet is not in error, and discard if error
  - Perform destination MAC address filtering
  - Pass packet up protocol stack

# Radio Propagation Model

Combined Friss free-space and two-ray ground reflection model:

- Up to ***reference distance***, attenuation is $1/r^2$
- Beyond this, attenuation is $1/r^4$
- $r$ is distance between transmitter and receiver antennas
- This is standard approximation used by radio engineers
- Assumes specular reflection off a flat ground plane

Enhancements in progress:

- Blockage, reflection, diffraction off of terrain
- Also off of moving obstacles

# Additional Support

Media Access Control (MAC) protocol

- Full implementation of IEEE 802.11 Distributed Coordination Function (DCF)
- Similar to MACA and MACAW:
  - Unicast packets use RTS/CTS/Data/ACK exchange
  - Uses both physical carrier sense and virtual carrier sense

Address Resolution Protocol (ARP):

- Based on standard BSD ARP implementation
- Buffers one packet while waiting for ARP Reply

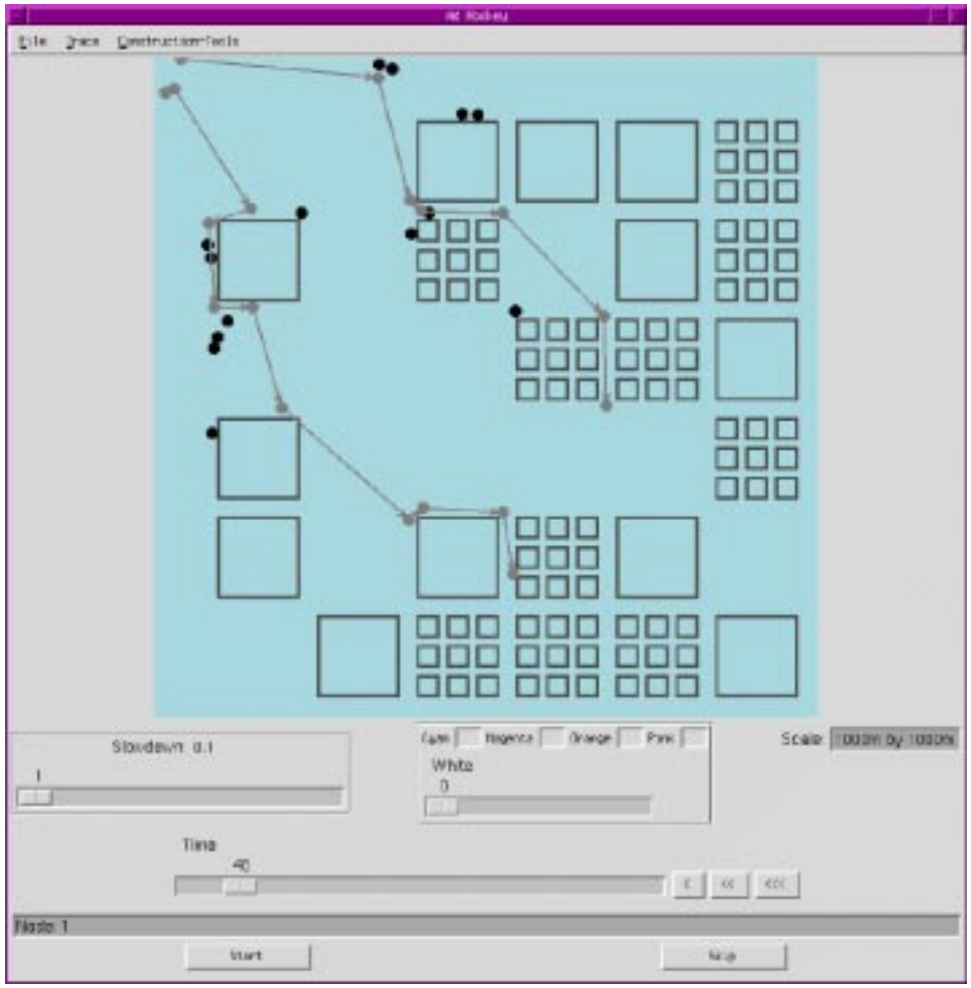
# Visualization and Scenario Tool

Also developed ***ad-hockey*** tool:

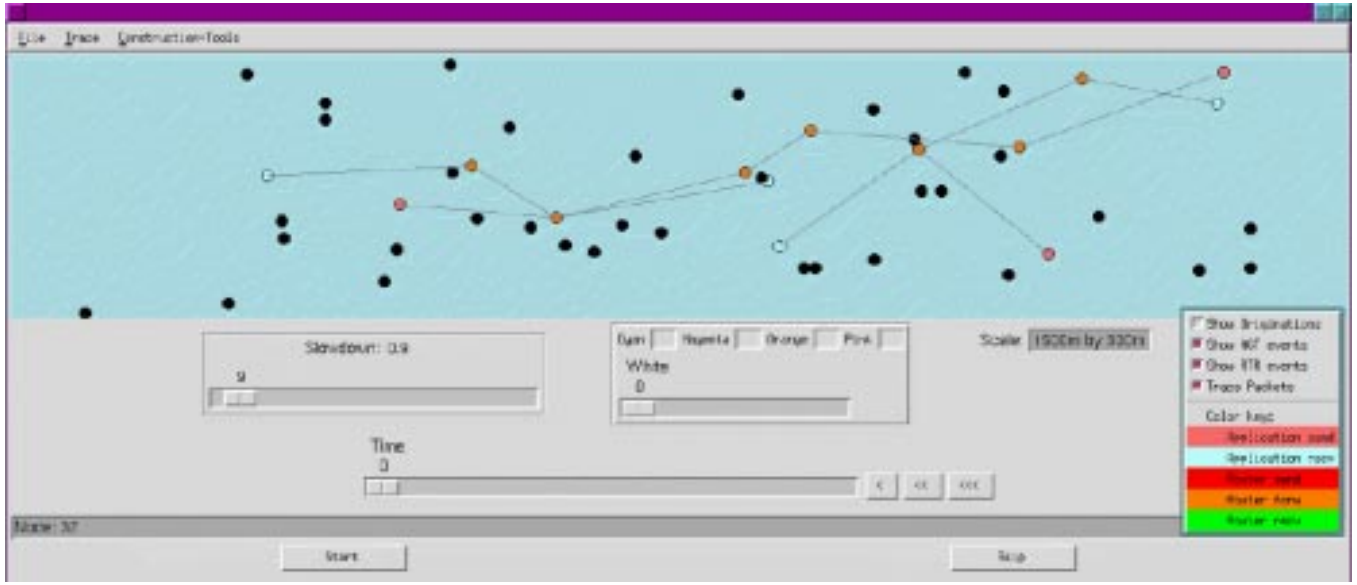
- GUI tool for building movement and communication scenarios of nodes in ad hoc network
- Visualizer for output of simulation runs

Uses X-Windows, Written in Perl/Tk

# Scenario Generation Example



# Trace Visualization Example



# Status and Availability

Standard ***ns*** is available from:

- **`http://www-mash.CS.Berkeley.EDU/ns/`**

Release ***1.0.0 Beta*** of our extensions released August 12 on our web pages at:

- **`http://www.monarch.cs.cmu.edu/`**

We have used in large simulation of ad hoc routing protocols:

- "A Performance Comparison of Multi-Hop Wireless Ad Hoc Network Routing Protocols," to appear at ***MobiCom'98***, Oct 25–30, 1998, Dallas, Texas
- DSDV, DSR, TORA, and AODV for 50 mobile nodes
- Finishing final version of paper right now. . .