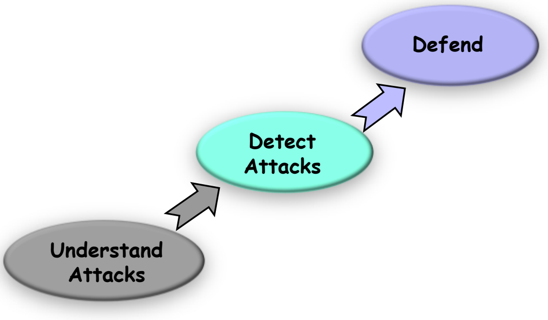
Wireless Security

Why is Security More of a Concern in Wireless?

- No inherent physical protection
  - physical connections between devices are replaced by logical associations
  - sending and receiving messages do not need physical access to the network infrastructure (cables, hubs, routers, etc.)
- Broadcast communications
  - wireless usually means radio, which has a broadcast nature
  - transmissions can be overheard by anyone in range
  - anyone can generate transmissions, which will be received by other devices in range
  - which will interfere with other nearby transmissions and may prevent their correct reception (jamming)
- Eavesdropping is easy
- Injecting bogus messages into the network is easy
- Replaying previously recorded messages is easy
- Illegitimate access to the network and its services is easy
- Denial of service is easily achieved by jamming

Overview



Attacking Wireless Networks

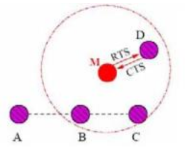
Attack 1: CSMA Selfish Behaviors

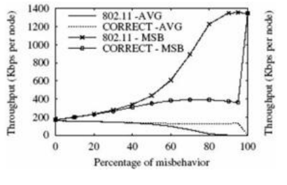
- Carrier sense: When a node wishes to transmit a packet, it first waits until the channel is idle
- Backoff Interval: used to reduce collision probability
- When transmitting a packet, choose a backoff interval in the range [0,cw]: cw is contention window
- Count down the backoff interval when medium is idle
  - Count-down is suspended if medium becomes busy
- When backoff interval reaches 0, transmit
- IEEE 802.11 DCF: contention window cw is chosen dynamically depending on collision occurrence

Binary Exponential Backoff

- When a node faced a transmission failure, it increases the contention window
  - *cw* is doubled (up to an upper bound)
- When a node successfully completes a data transfer, it restores *cw* to Cw_{min}
- *cw* follows a sawtooth curve

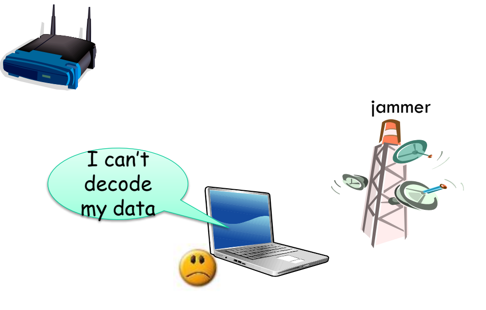
Attack 1: CSMA Selfish Behaviors



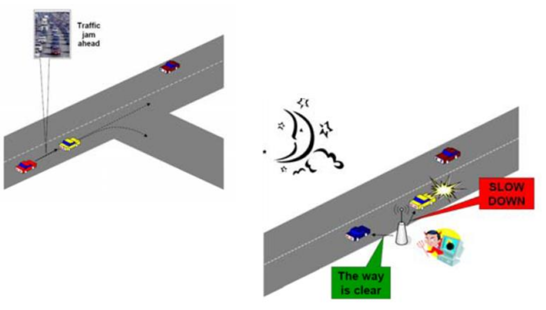


- Use smaller backoff window
  - Transmit with you should not
    - Attacker gets more bandwidth
  - Cause collisions to others

Attack 2: Jamming



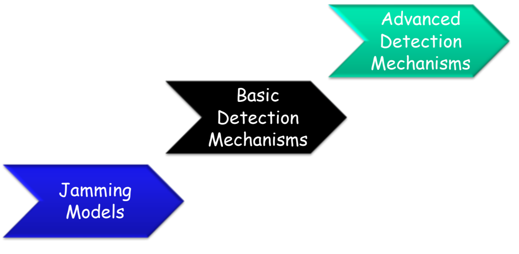
Attack 3: Injecting Bogus Information



Introduction

- Traditionally, Denial of Service (DoS) attacks involve filling receiving buffers and/or bringing down servers
- In the wireless domain, DoS is more fundamentally linked with the medium
  - MAC misbehavior or
  - Preventing nodes from even communicating (*i.e., jamming)*

Roadmap



What is a Jammer?

- A jammer is purposefully trying to interfere with the physical transmit/receive

Jammers -- Hardware

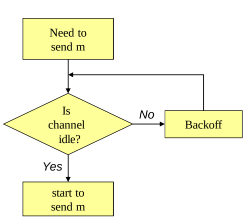
- Cell phone jammer unit
  - Block every cellular phone!!!
- Signal generator
- Conventional devices

Goal of Jammer

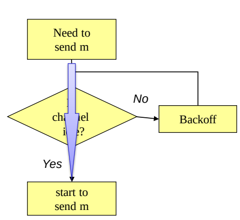
- Interference
  - Prevent a sender from sensing out packets
  - Prevent a receiver from receiving legitimate packets
- How to measure their effectiveness:
  - Packet Send Ratio (PSR):
    - Ratio of actual # of packets sent out versus # of packets intended
  - Packet Delivery Ratio (PDR):
    - Ratio of # of successfully delivered packets versus # of packets sent out
    - Measured at sender [ACKs] or receiver [CRC check]

Jammer Attack Models

Normal MAC protocol:



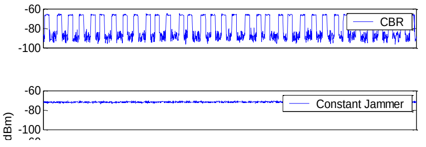
Jammer:



Jamming Models

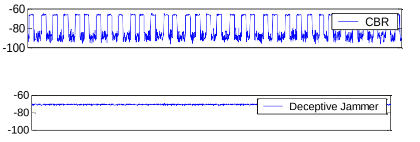
- Constant Jammer
  - Continuously emits radio signal (random bits, no MAC-etiquette)
- Deceptive Jammer
  - Continuously sends regular packets (preamble bits) without gaps in transmission
  - Targeting sending
- Random Jammer
  - Alternates between sleeping and jamming states.
  - Takes energy conservation into consideration
- Reactive Jammer:
  - Reacts to a sent message
  - Targeting reception;
  - Harder to detect

Constant Jammer



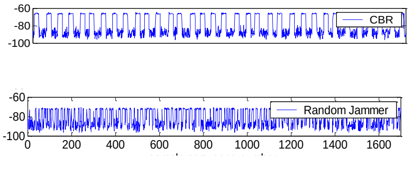
- Constant Jammer - continually emits a radio signal (noise). The device will not wait for the channel to be idle before transmitting. Can disrupt even signal strength comparison protocols .

Deceptive Jammer



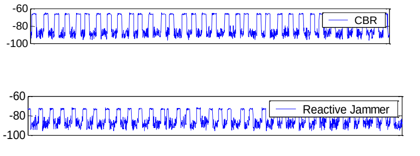
- Deceptive Jammer - constantly injects regular packets with no gap between packets. A normal device will remain in the receive state and cannot switch to the send state because of the constant stream of incoming packets.

Random Jammer



- Random Jammer - alternates between sleeping and jamming. Can act as constant or deceptive when jamming. Takes energy conservation into consideration.

Reactive Jammer



- Reactive Jammer - other three are active this is not. It stays quiet until there is activity on the channel. This targets the reception of a message. This style does not conserve energy however it may be harder to detect.

Basic Jamming Detection

What attributes will help us detect jamming?

- Signal strength (PHY-layer detection)
- Carrier sense (MAC layer detection)
- Packet Delivery Ratio
  - Detects all jamming models
  - Differentiates jamming from congestion
  - Cannot differentiate jamming from node failure, battery loss, departure, etc.

Detection 1: Analyzing Signal Strength

How can we use Signal Strength to detect Jamming?

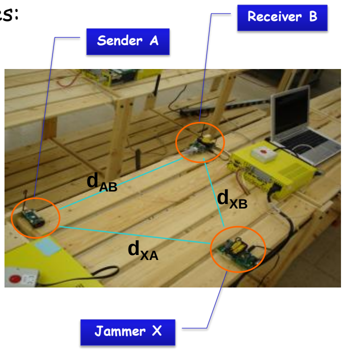
- Signal strength distribution may be affected by the presence of a jammer
- Each device should gather its own statistics to make its own decisions on the possibility of jamming
- Establish a base line or build a statistical model of normal energy levels prior to jamming of noise levels….But how??

Two Methods for Signal Strength

1. Basic Average and Energy Detection
   - We can extract two statistics from this reading, the average signal strength and the energy for detection over a period of time
2. Signal Strength Spectral Discrimination
   - A method that employs higher order crossings (HOC) to calculate the differences between samples
   - This method is practical to implement on resource constrained wireless devices, such as sensor nodes

Experiment Setup

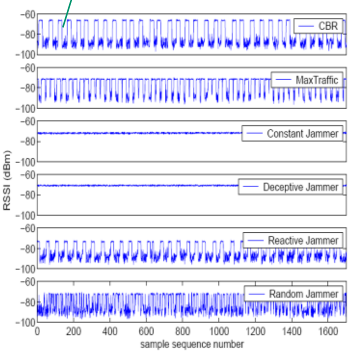
- Involving three parties:
  - Normal nodes:
    - Sender A
    - Receiver B
  - Jammer X
- Parameters
  - Four jammers model
  - Distance
    - Let $d_{XB} = d_{XA}$
    - Fix d_{AB} at 30 inches
  - Power
    - $P_A = P_B = P_X = -4$dBm



Signal Strength

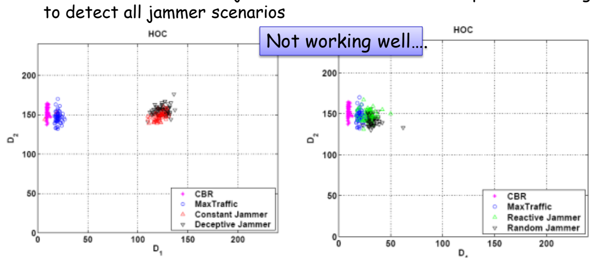
CBR: 20 packets per second

- The average values for the constant jammer and the MaxTraffic source are roughly equal
- The constant jammer and deceptive jammer have roughly the same average values
- The signal strength average from a CBR source does not differ much from the reactive jammer scenario
- These results suggest that we may not be able to use simple statistics such as average signal strength to identify jamming



Signal-Strength: Higher Order Crossing

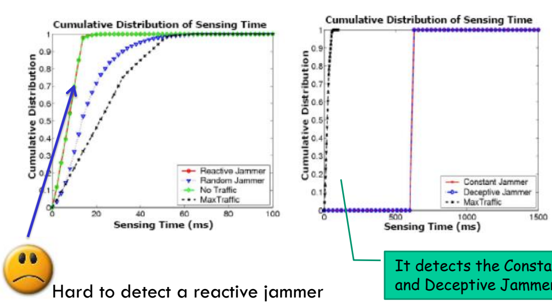
- We can not distinguish the reactive or random jammer from normal traffic
- A reactive or random jammer will alternate between busy and idle in the same way as normal traffic behaves
- HOC will work for some jammer scenarios but are not powerful enough to detect all jammer scenarios



Detection 2: Analyzing Carrier Sensing Time

- A jammer can prevent a legitimate source from sending out packets ← channel might appear constantly busy to the source
- Keep track of the amount of time it spends waiting for the channel to become idle (carrier sensing time)
  - Compare it with the sensing time during normal traffic operations to determine whether it is jammed
  - Only true if MAC protocol employs a fixed signal strength threshold to determine whether channel is busy
- Determine when large sensing times are results of jamming by setting a threshold
- Threshold set conservatively to reduce false positive

Detection 2: Analyzing Carrier Sensing Time

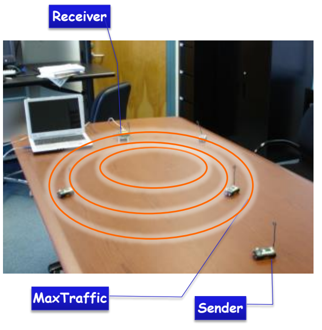


Hard to detect a reactive jammer

It detects the Constant and Deceptive Jammer

Detection 3: Analyzing Packet Delivery Ratio

- How much PDR degradation can be caused by non-jamming, normal network dynamics, such as congestion? (PDR 78%)
- A jammer causes the PDR drop significantly, almost to 100%
- A simple threshold based on PDR is a powerful statistic to determine Jamming vs. congestion
- PDR can not differentiate non-aggressive jamming attacks from poor channel quality…



Basic Statistics Summary

- Both Signal Strength and Carrier Sensing time can only detect the constant and deceptive jammer
- Neither of these two statistics is effective in detecting the random or the reactive jammer
- PDR is a powerful statistic to determine Jamming vs. congestion
  - It can not account for all network dynamics

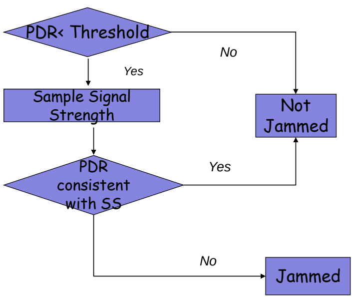
Solution: Consistency Checks

- PDR is relatively good
  - Normal scenario:
    - High signal strength → high PDR
    - Low signal strength → low PDR
  - Low PDR in real life
    - Poor channel quality
    - Jamming attacks → high signal strength
- Consistency check
  - Look at transmissions from neighbors
  - If at least one neighbor has high PDR
  - If all have low PDR → check signal strength → high → I am being jammed!

Location-Based Consistency Check

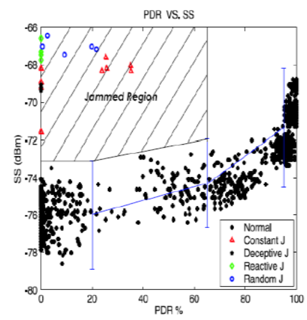
- Concept:
  - Close neighbor nodes → high PDR
  - Far neighbor nodes → lower PDR
- If all nearby neighbors exhibit low PDR → jammed!

PRD/Signal Strength Consistency



Results

- Observed Normal relationships
  - High signal strength yields a high PDR
  - Low signal strength yields a low PDR
- Jammed scenario: a high signal strength but a low PDR
- The Jammed region has above 99% signal strength confidence intervals and whose PDR is below 65%

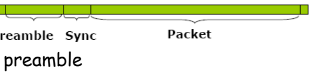


What Happens After Detection??

- This work has identified jamming models and described a means of detection
- Prevention? Reaction?
  - Channel surfing and spatial retreats
  - SSCH

Our Jammers

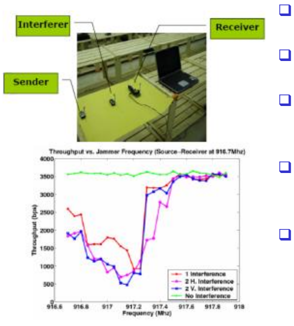
- MAC-layer Jammer
  - Mica2 Motes (UC Berkeley)
    - 8-bit CPU at 4MHz
    - 512KB flash, 4KB RAM
    - 916.7MHz radio
    - OS: TinyOS
  - Disable the CSMA
  - Keep sending out the preamble
- PHY-layer Jammer
  - Waveform Generator
  - Tune frequency to 916.7MHz



Escaping From Jamming Attacks

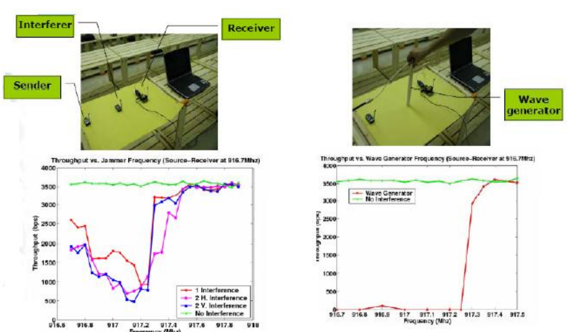
- Channel Surfing
  - Utilize frequency hopping if a node detects that it is being jammed it just switches to another channel
    - Inspired by frequency hopping techniques, but operates at the link layer
  - System Issues: Must have ability to choose multiple "orthogonal" channels
    - Practical Issue: PHY specs do not necessarily translate into correct "orthogonal" channels
    - Example: MICA2 Radio recommends: "choose separate channels with a minimum spacing of 150KHz" but…..

Throughput VS. Channel Assignment



- Sender sends the packet as fast as it can
- Receiver counts the packet and calculates the throughput
- The radio frequency of the sender and receiver was fixed at 916.7MHz
- Increased the interferer's communication frequency by 50kHz each time
- When the Jammer's communication frequency increases to 917.5MHz, there is almost no interference

Is Channel Surfing Feasible??



Escaping From Jamming Attacks

- "Orthogonal" channels
  - The fact is that we need at least 800KHz to escape the interference
  - Therefore, explicit determination of the amount of orthogonal channels is important
- Channel Surfing
  - Target: maximize the delay before the attacker finds the new channel
  - Solution: use a (keyed) pseudo-random channel assignment between nodes

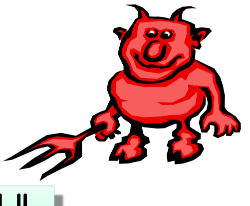
Escaping from Jamming Attacks

- Spatial Retreats:
  - If a node is jammed move spatially (physically) to another location
  - When a node changes location, it needs to move to a new location where it can avoid being jammed but minimize network degradation
  - Sometimes a spatial retreat will cause a network partition
- Two different strategies to defend against jamming
  - Channel-surfing: changing the transmission frequency to a range where there is no interference from the attacker
  - Spatial retreat: moving to a new location where there is no interference

Jammers will be Punished

- A man skilled in the operation of commercial wireless Internet networks was sentenced for intentionally bringing down wireless Internet services across the region of Vernal, Utah.
- Ryan Fisher, 24, was sentenced to 24 months in prison to be followed by 36 months of supervised release, and to pay $65,000 in restitution.
- In total, more than 170 customers lost Internet service, some of them for as long as three weeks

Bottom Line



Don't be Evil !!