Wireless Network Security
Spring 2016

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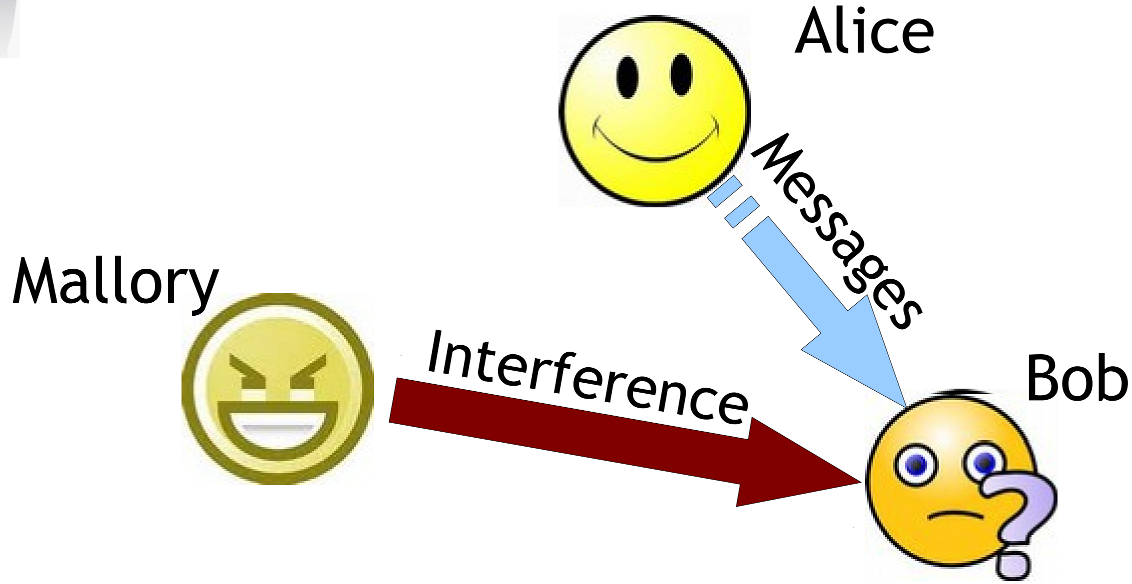
Class #5 – Jamming (cont'd);
"Physical Layer Security"

Class #5

- Anti-jamming
- "Physical layer security"
  - Secrecy using physical layer properties
  - Authentication using physical layer properties

Jamming



How can we protect against jamming?

Jamming Detection & Defense

[Xu et al., IEEE Network 2006]

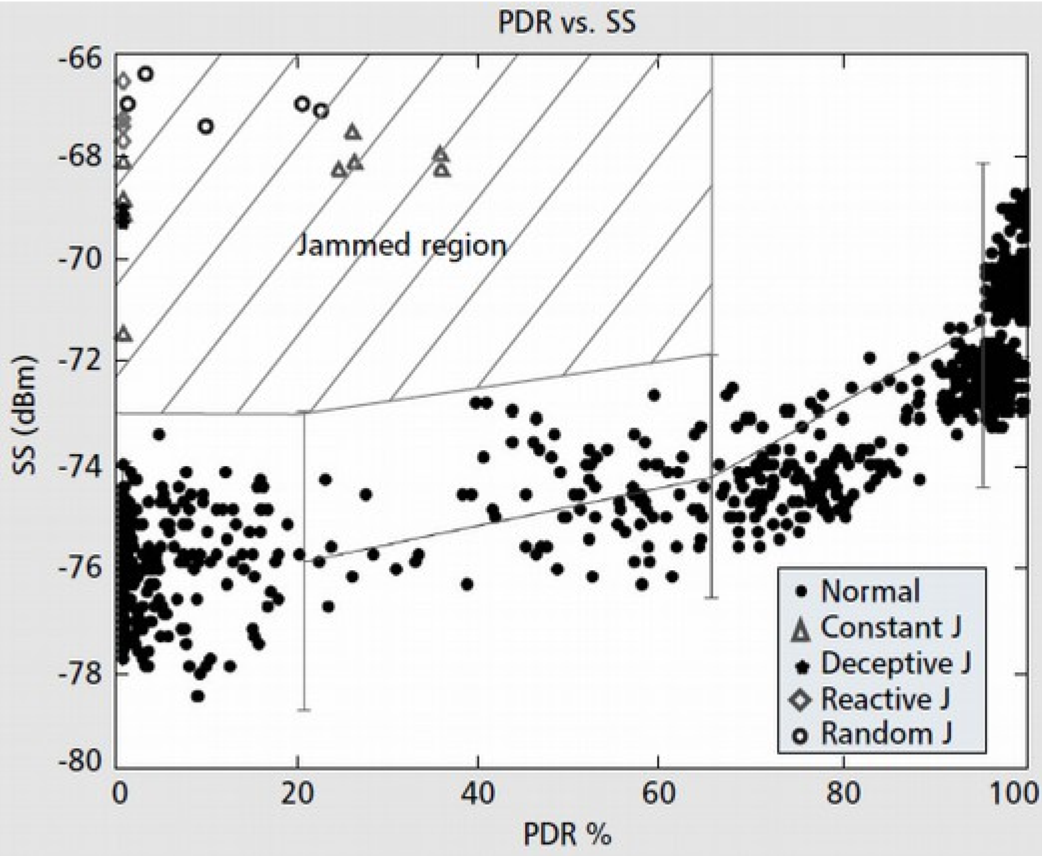
- **Goal**: detect and localize jamming attacks, then evade them or otherwise respond to them
- **Challenge**: distinguish between adversarial and natural behaviors (poor connectivity, battery depletion, congestion, node failure, etc.)
  - Certain level of detection error is going to occur
  - Appropriate for deployment in sensor networks
- **Approach**: coarse detection based on packet observation

Basic Detection Statistics

- Received signal strength (RSSI)
  - Jamming signal will affect RSSI measurements
  - Very difficult to distinguish between jamming/natural
- Carrier sensing time
  - Helps to detect jamming as MAC misbehavior
  - Doesn't help for random or reactive cases
- Packet delivery ratio (PDR)
  - Jamming significantly reduces PDR (to ~0)
  - Robust to congestion, but other dynamics (node failure, outside comm range) also cause PDR → 0

Advanced Detection

- Combining multiple statistics in detection can help
  – High PDR + High RSSI → OK
  – Low PDR + Low RSSI → Poor connectivity
  – Low PDR + High RSSI → ? → Jamming attack?

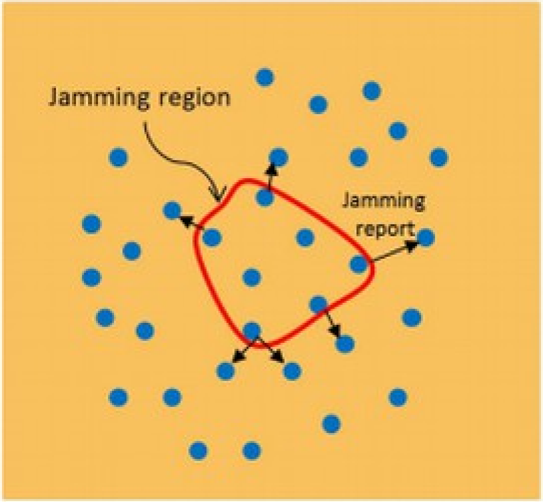


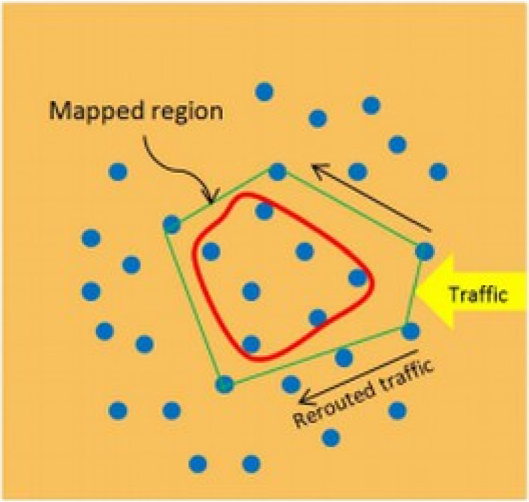
Caveat: this assumes RSSI can be accurately measured

See [DeBruhl & Tague, SECON 2013]

Jammed Area Mapping

- Based on advanced detection technique, nodes can figure out when they are jammed
- At the boundary of the jammed area, nodes can get messages out to free nodes
- Free nodes can collaborate to perform boundary detection using location information





Evading Jamming

- Nodes in the jammed region can evade the attack, either spectrally or spatially
  - Spectral evasion → "channel surfing" to find open spectrum and talk with free nodes
  - Spatial evasion → mobile retreat out of jammed area
    - Need to compensate for mobile jammers ability to partition the network (see figure in paper)

What about dynamic attack and defense strategies?

Optimal Jamming & Detection

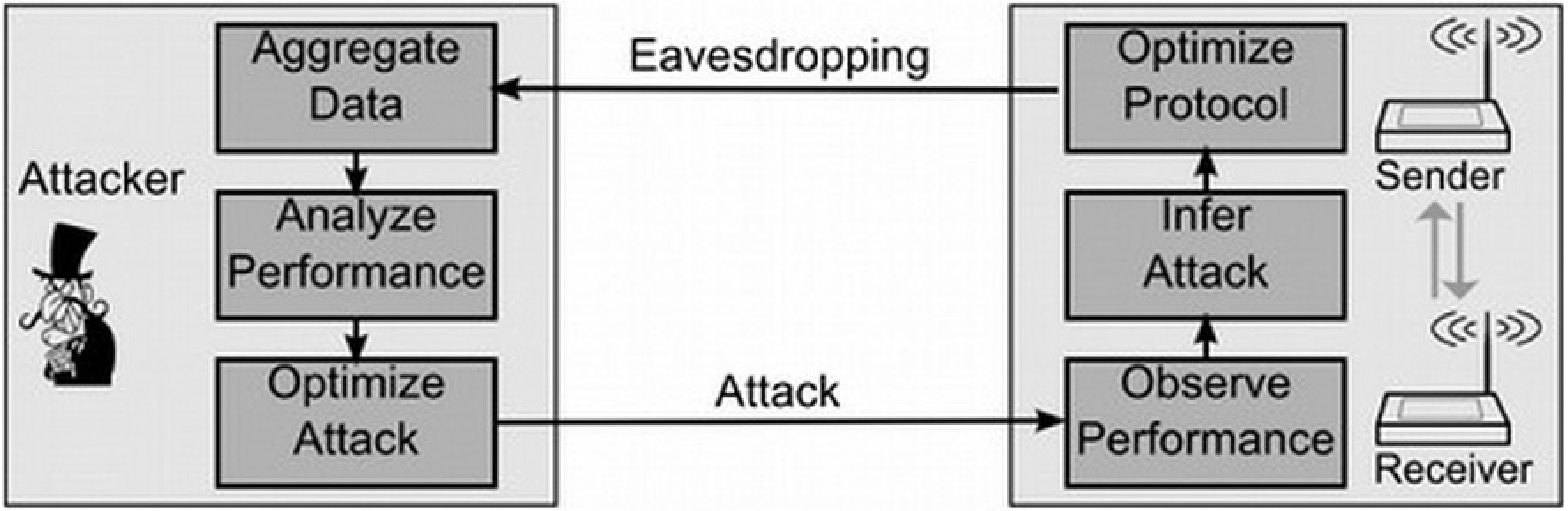
[Li et al., Infocom 2007]

- **Problem setup:** each of the network and the jammer have control over random jamming and transmission probabilities
  - Network parameter γ is probability each node will transmit in a time slot
  - Attack parameter q is probability the jammer will transmit in a time slot

- Opponents can learn about goals through observation and optimize for min-max/max-min

Jamming Games
[DeBruhl & Tague, PMC 2014]

- What if both the attacker and defender are freely adapting in response to each other?

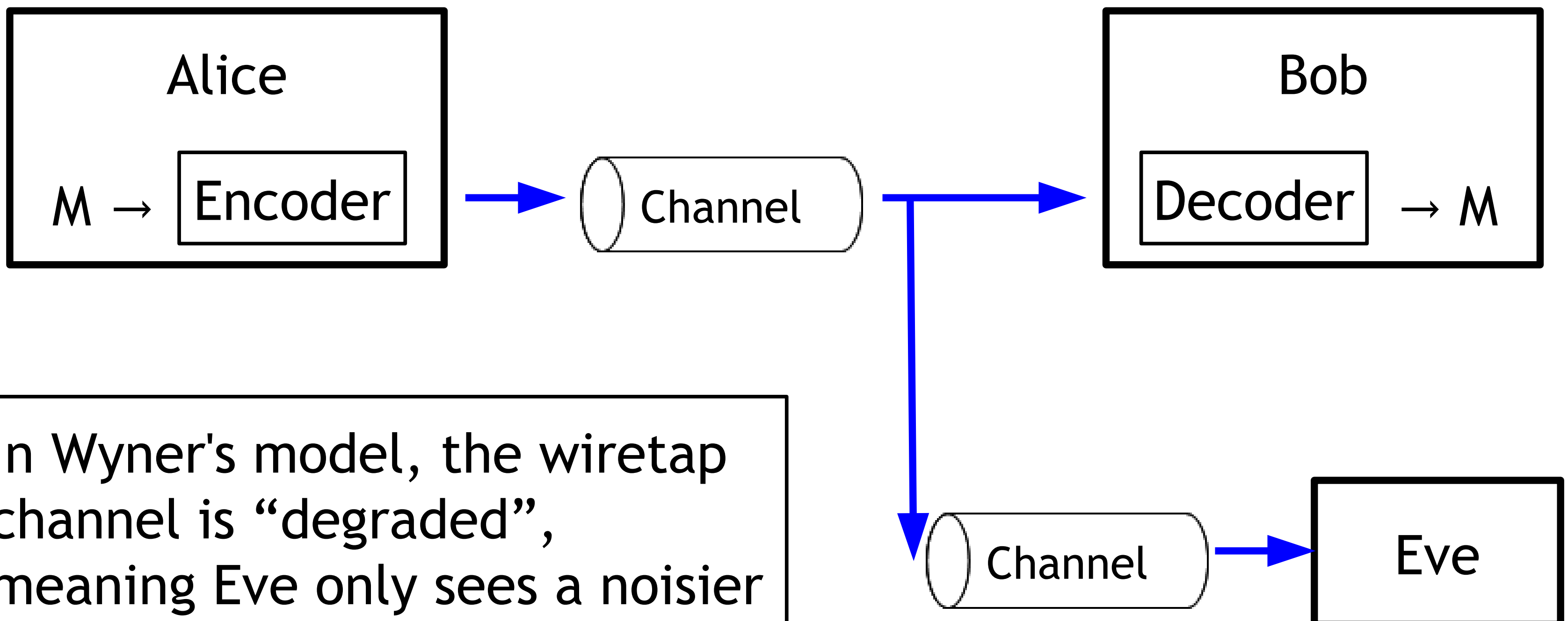


Eavesdropping / Snooping

How can the properties of the wireless medium actually **help** to achieve secure communication?

"Wiretapping"

- In 1975, A. D. Wyner defined the wiretap channel to formalize eavesdropping



In Wyner's model, the wiretap channel is "degraded", meaning Eve only sees a noisier signal than Bob sees

Secrecy Capacity

- Since the Alice → Eve channel is noisier than the Alice → Bob channel:
  - Eve can't decode everything that Bob can decode
  - i.e., there exists an encoding such that Alice can encode messages that Bob can decode but Alice can't
  - There's a really nice Information Theory formalization of the concept of secrecy capacity, namely the amount of secret information Alice can send to Bob without Eve being able to decode
  - I'll leave the details for you to explore

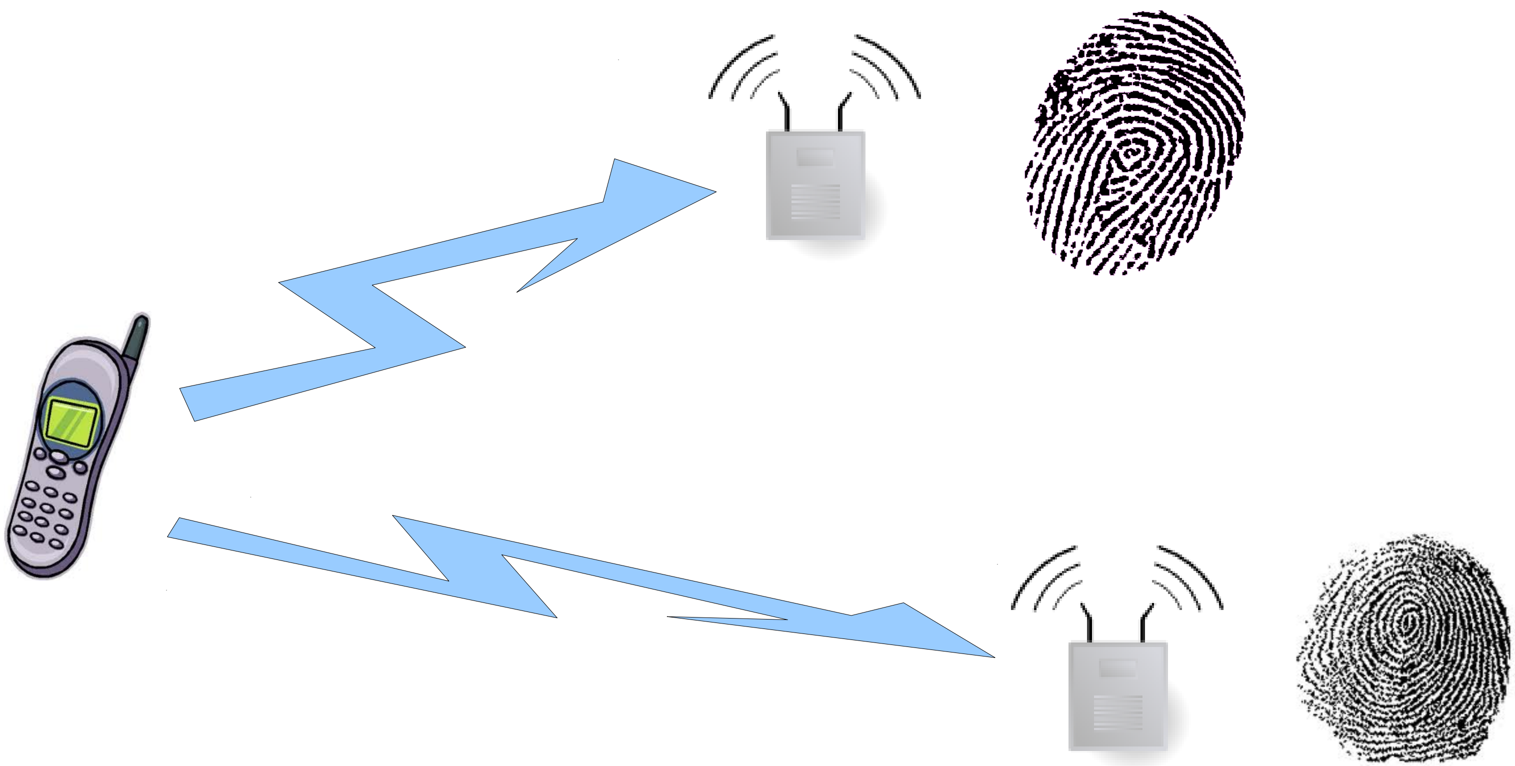
Degraded Eavesdropper?

- In a practical scenario, is it reasonable to assume the eavesdropper's signal is more degraded than the receiver's?
  - Probably not.

- What else can we do to tip the scales in the favor of the Alice-Bob channel?

Diversity of Receivers

The signal emitted by a transmitter looks "different" to receivers in distinct locations



Measurement + Feedback

- Channel State Information (CSI):
  - CSI is the term used to describe measurements of the channel condition
  - If Alice knows the CSI to Bob and to Eve, she can find an appropriate encoding using the measurements
  - If Alice and Bob interact repeatedly, the measurement and feedback actually **increase the secrecy capacity**
    - This can allow for secrecy capacity >0 *even if Eve's channel is less noisy than Bob's channel*

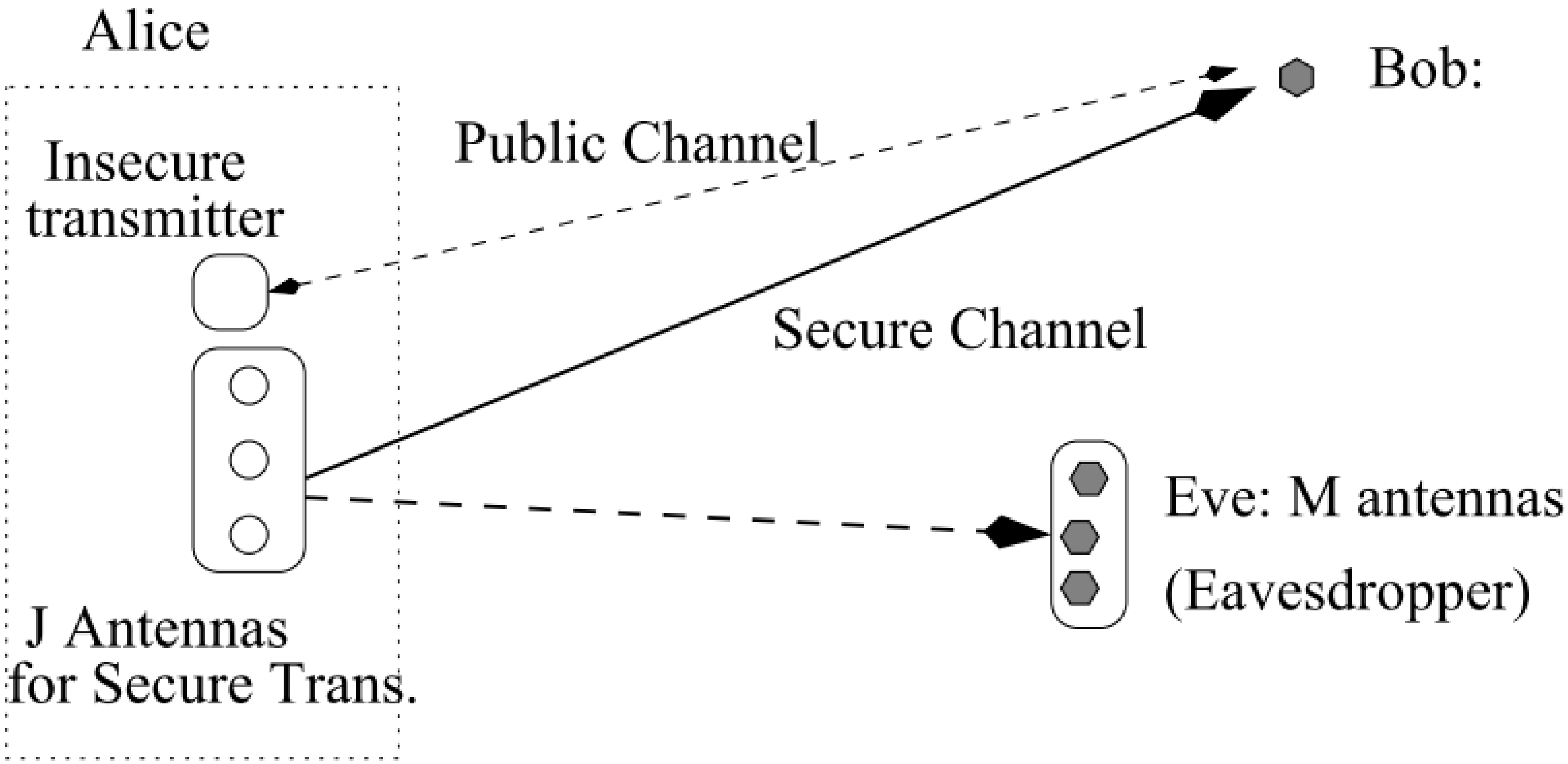
Jamming for Good

- If Alice has diversity in the form of multiple radios or some collaborators:
  - Alice & friends can use a jamming attack to prevent Eve from eavesdropping
  - As long as they don't jam Bob at the same time
  - **Ex:** if the deployment geometry is known, Alice can adjust power, antenna config, etc. so Bob's SINR is high but Eve's is low

Secure Array Transmission

[Li, Hwu, & Ratazzi, ICASSP 2006]

- Antenna control can be used for transmission with *low probability of interception*



Application

- Building on secrecy capacity:
  - If two devices can communicate with a high probability guarantee that eavesdroppers cannot hear them, whatever they say is secret
  - **Secret messages → keys!**
  - Secret key generation is now possible using inherent properties of the wireless medium

Further Reading

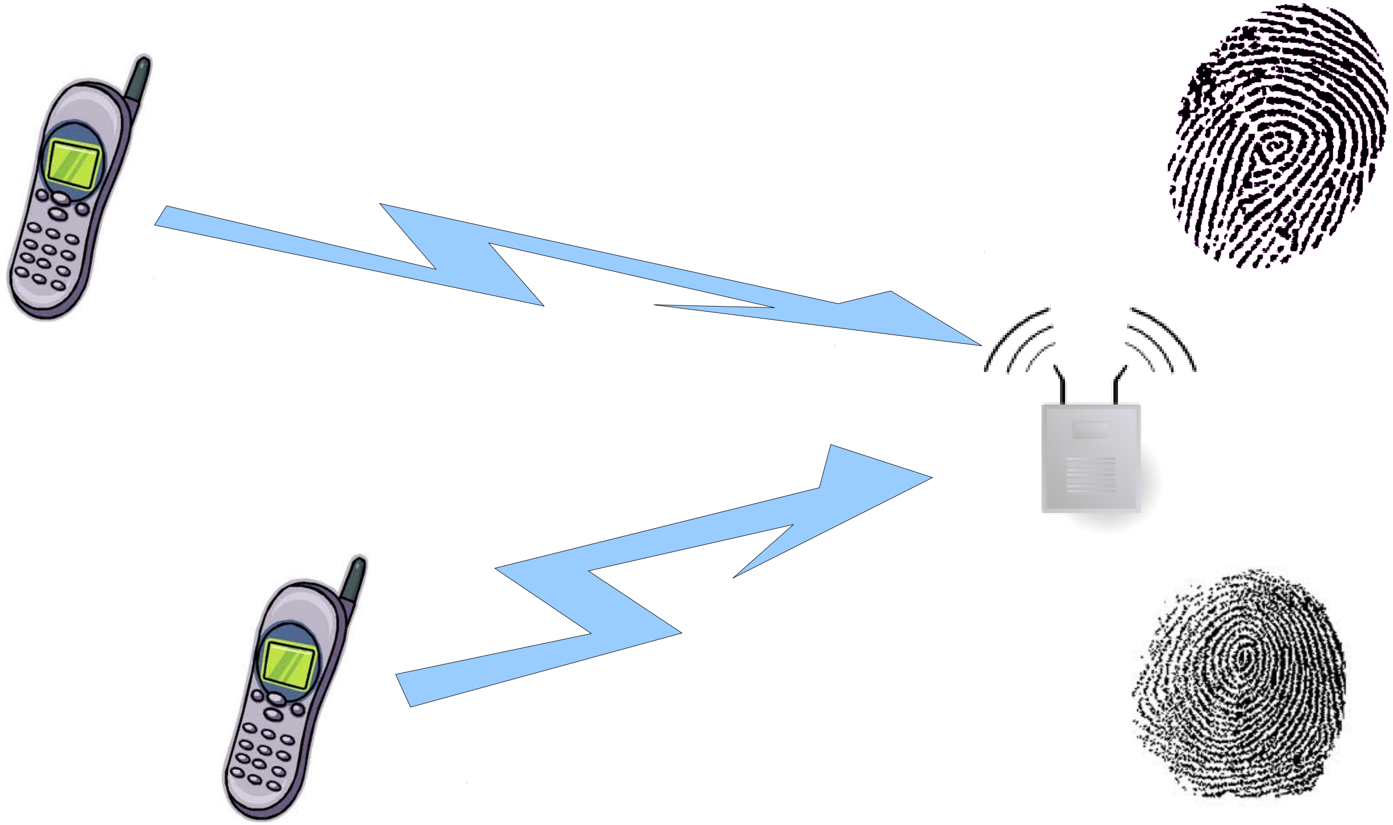
- For a really good summary of secrecy capacity, the formalization, secret key generation, and lots of excellent details:
  - "Physical Layer Security" by Bloch and Barros
    - Available as e-book through CMU library
    - I have a hard copy if anyone wants to borrow it

More Benefit for the Party?

Physical layer properties can help with authentication!

Diversity of Senders

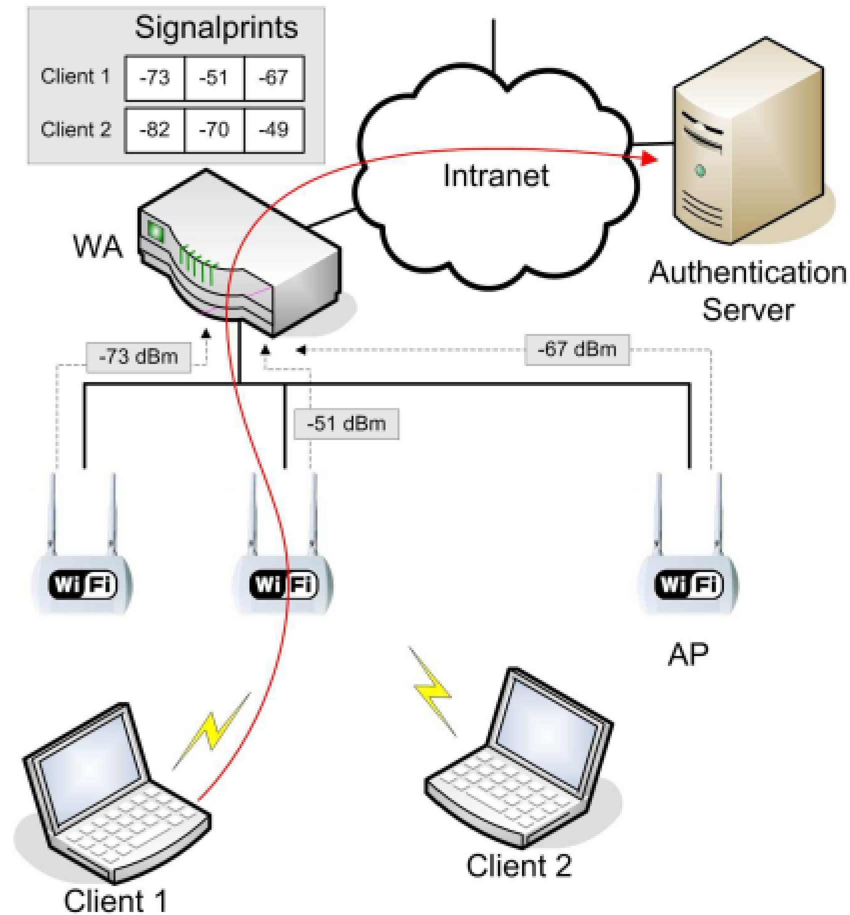
Signals captured by a receiver from senders in distinct locations look "different"



Signalprints

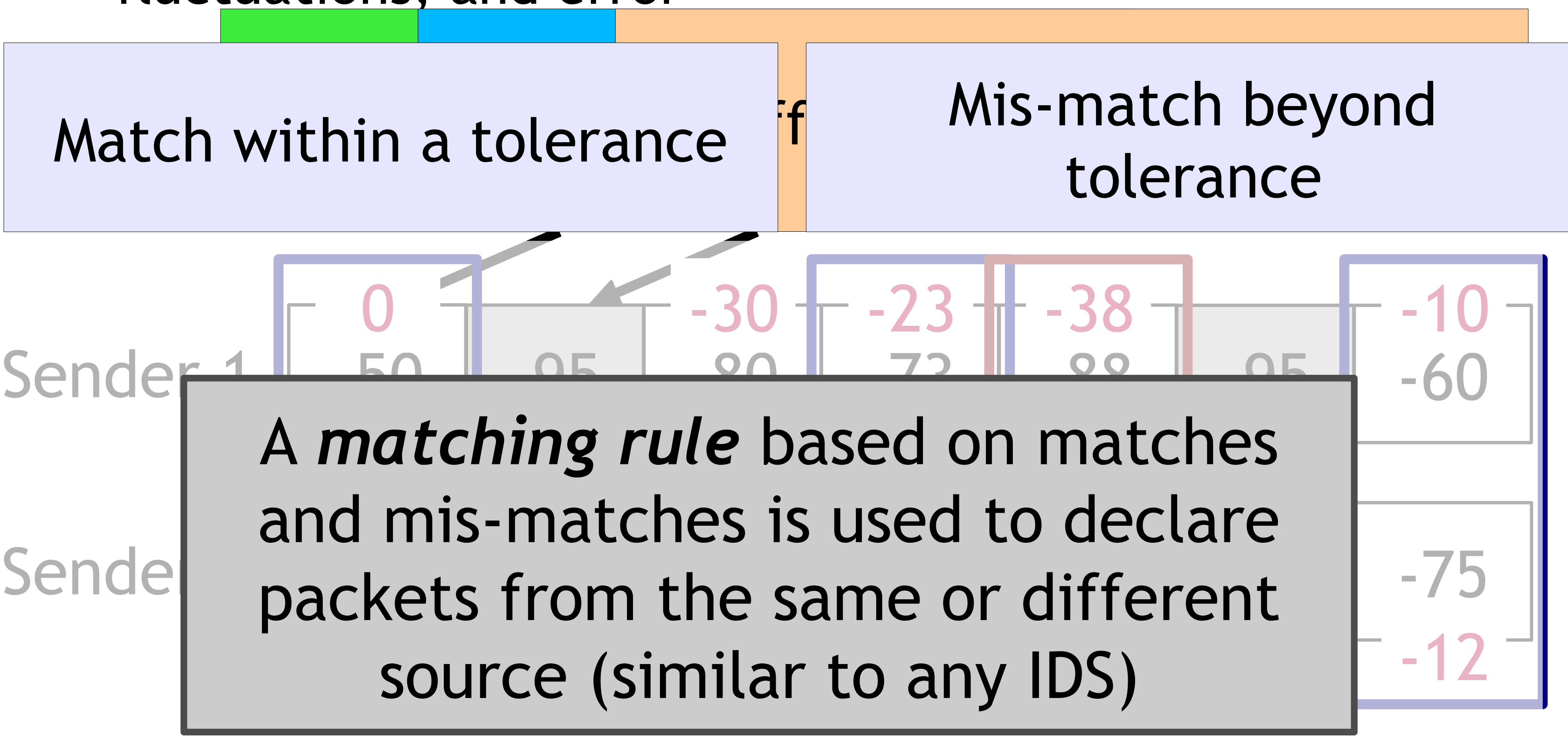
[Faria & Cheriton, WISE 2006]

- In a WLAN with multiple APs, each AP sees different characteristics of packets from each sender
  - Each AP can measure various packet features, some of which are relatively static over packets: e.g., received signal strength
  - A back-end server can collect measurements and keep history of packets from different senders



Verification & Matching

- Requirements for verification:
  - Robust to transmission power control, random fluctuations, and error



Match within a tolerance

Mis-match beyond tolerance

A *matching rule* based on matches and mis-matches is used to declare packets from the same or different source (similar to any IDS)

Signalprint Properties

- Difficult to spoof
  - Spoofing node would require control of medium
  - Transmission power control creates lower RSS at every AP; differential analysis reveals power control
- Correlated with physical location
  - Attacker needs to be physically near target device
- Sequential packets have similar signalprints
  - RSSI values are highly correlated for stationary sender and receiver
    - Note: not highly correlated with distance, but very highly correlated with subsequent transmissions

Limitations

- Signalprints with any reasonable matching rule cannot differentiate between nearby devices
  - Masquerading/spoofing attacks are possible if physical proximity is easily achieved
- Low-rate attacks cannot be detected
  - But, low-rate attacks have limited effects
- Multi-antenna attackers can cheat
- Highly mobile devices can't be printed

Summary

Interference and eavesdropping are two of the most fundamental yet least understood vulnerabilities in wireless. There's still a lot of work to be done.

Assignment #2

- Assignment #2 will be posted later today
  - Due date is February 11, 11:59pm PST
  - We're asking you to do a lot of things with OMNET++ and INET that we didn't cover in the tutorial. Use the other examples and resources before asking us how to do something.

January 28:
Link Layer Threats; WiFi Security