Anti-jamming Timing Channels for Wireless Networks

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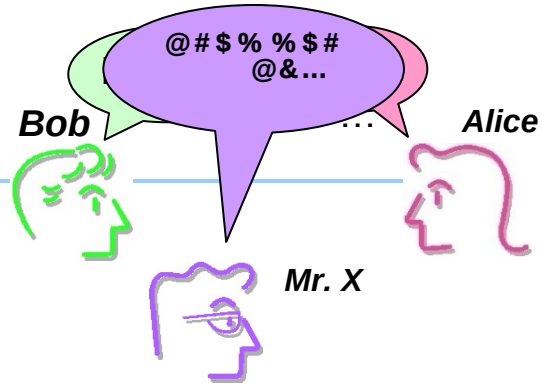
Roadmap

- Introduction and motivation
- Jamming / radio interference
  - Observations
- Timing channel
  - Two party prototype
  - Multiple senders
- Ongoing work & Conclusions

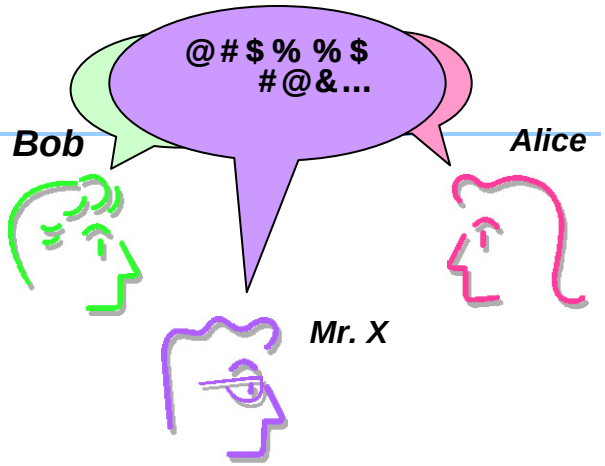
Jamming or Interference



- *Jamming:*
  - *Behavior that prevents other nodes from using the channel to communicate by interfering with the physical transmission and reception of wireless communications*
- *Unintentional jamming:*
  - Co-existing devices: 802.11b/g interferes with cordless phone, Bluetooth, Microwave oven...
  - Equipment accidentally emits a signal on an frequency band that does not belong to it.

- *Intentional jamming:*
  - A transmitter, tuned to the same frequency as the receiving equipment, can override any signal with enough power

Defense Strategies



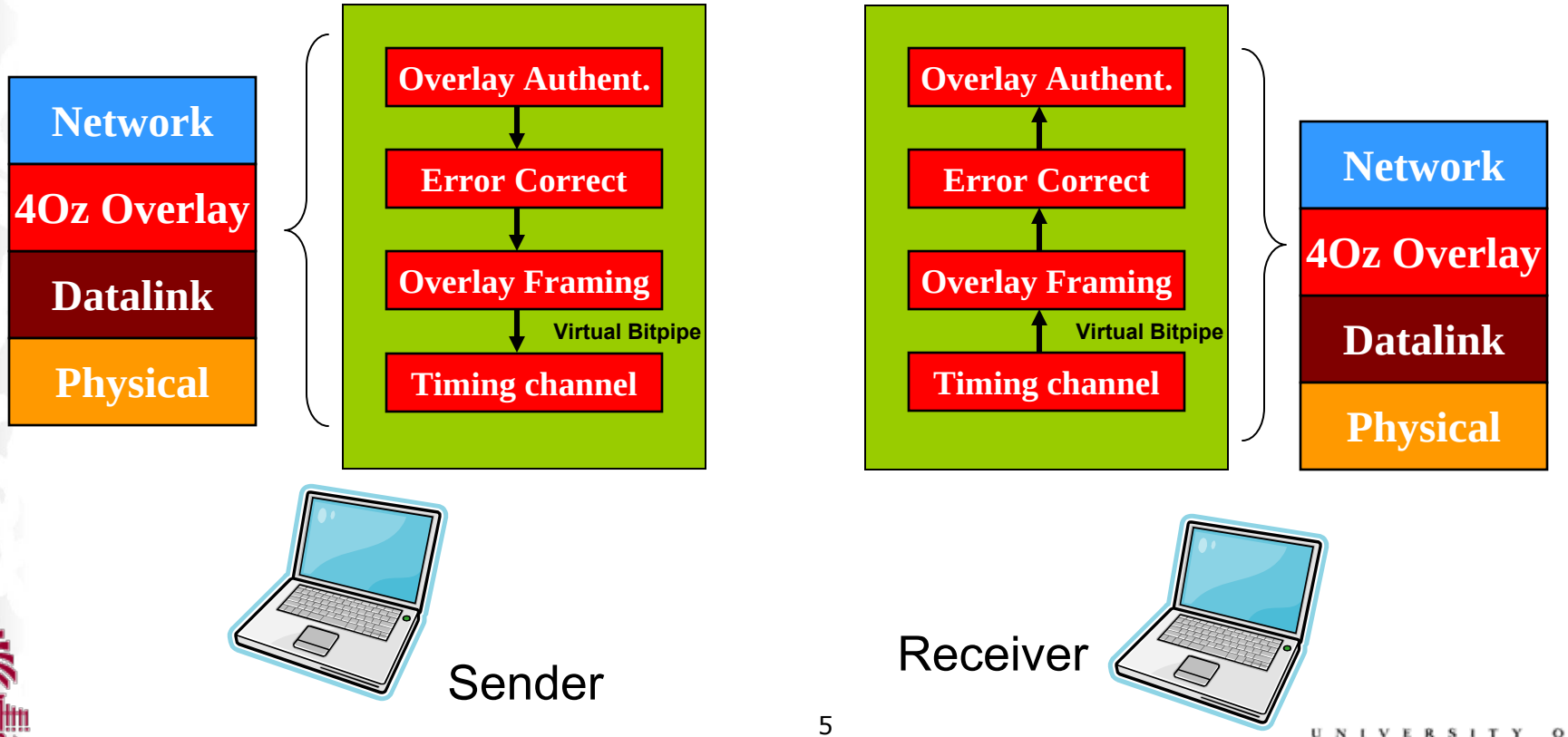
- *Goal:*
  - Convey information between Bob and Alice in the presence of Mr. X, the interferer.
  - Using existing wireless platforms (CSMA)

- Possible Strategies:
  - Channel Surfing -> interference-free channels available
  - Spatial retreat -> mobile wireless nodes
  - Power control -> increase transmission power

- What can you do if:
  - No interference-free channels are available.
  - Mobility is not an option.
  - You cannot over-power the jammer
  - You have a *short emergency* packet to send

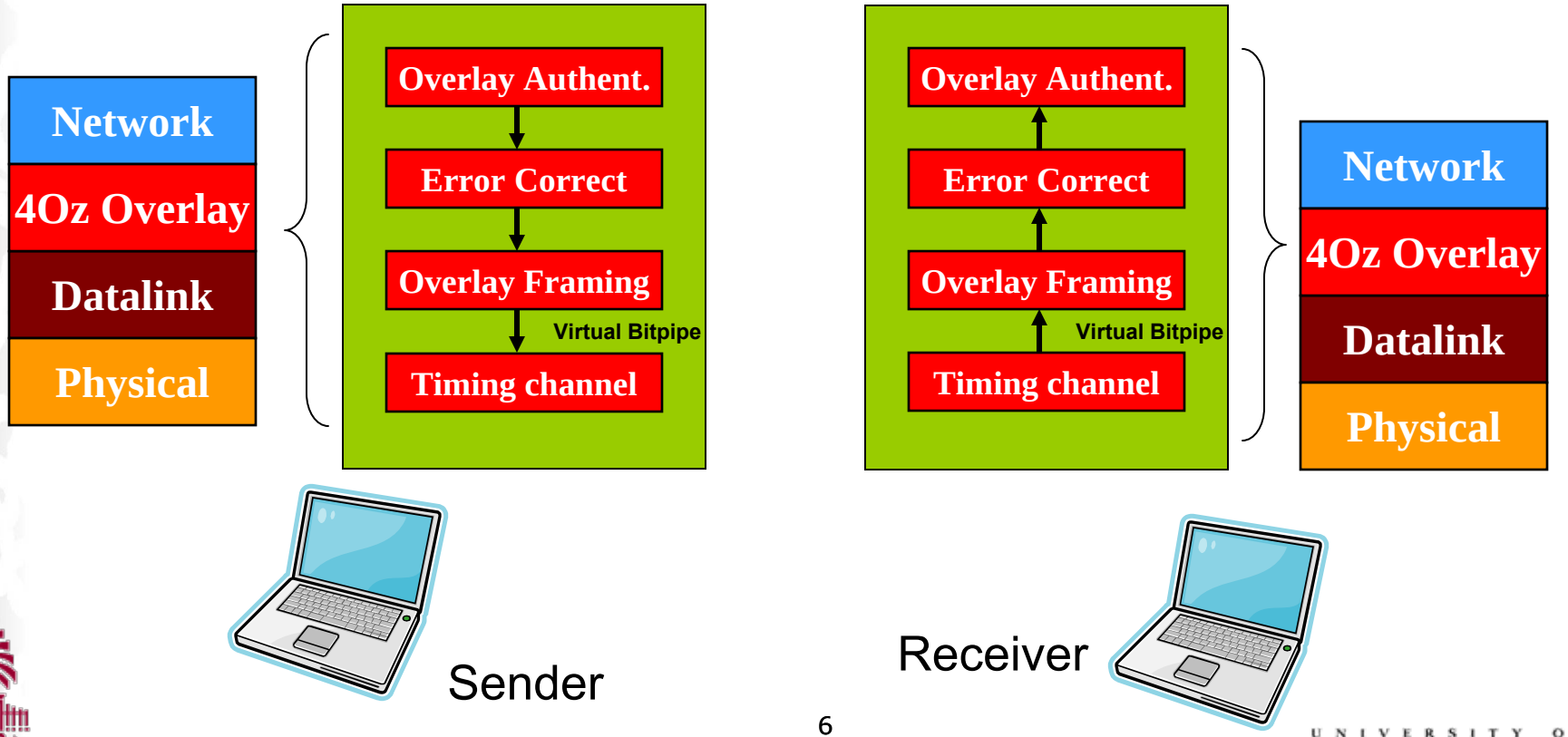
Timing Channel

- Idea:
  - Alice and Bob: Alice did not know exactly what Bob was saying, but she knew that Bob said something by looking at *his lip movements*.
  - Wireless network: exploit the fact that there was an attempted, incoming packet to convey information.



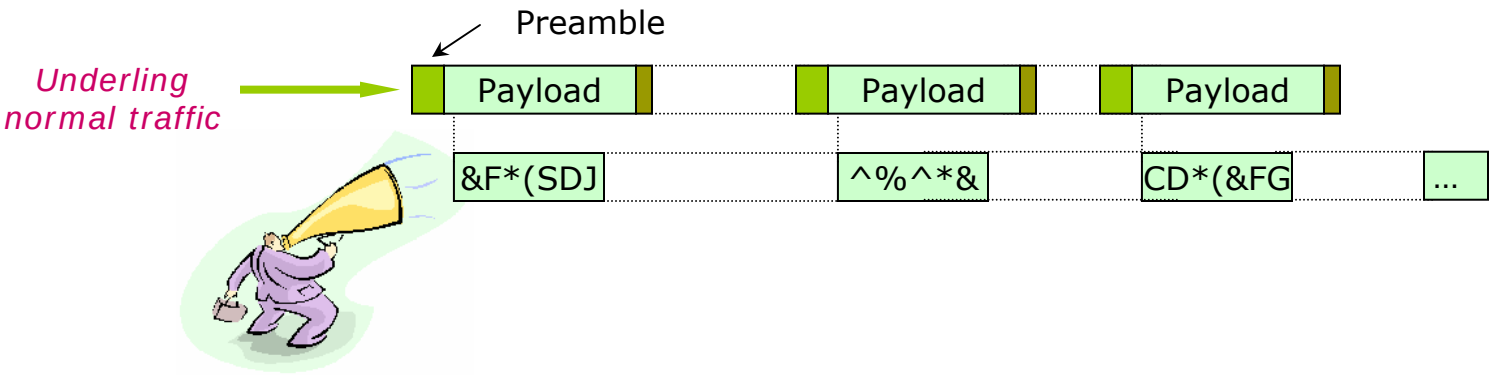
Timing Channel

- Sub-problems:
  - Can you detect a packet in spite of the radio interference?
  - Can you modulate the events of incoming packet?
  - Can you implement such a strategy in a real system?



Can you detect a packet in spite of the failed packet reception?

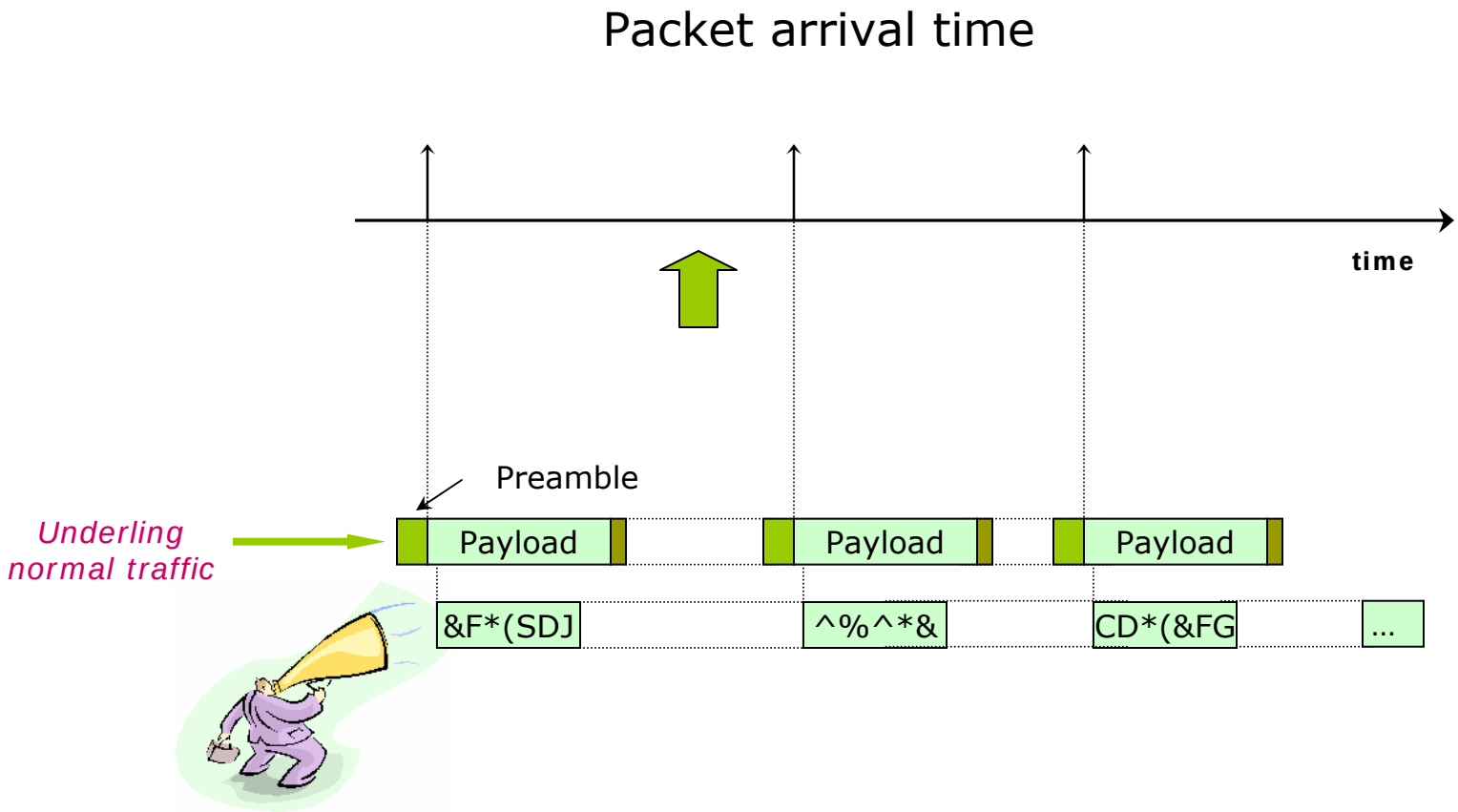
Malicious Jammer



- Reactive jammer:
  - Stays quiet when the channel is idle, but starts jamming as soon as it senses activity on the channel.
- Observation
  - CANNOT decode packets correctly
  - Preamble CAN be detected correctly by the receiver

d_{jr} (feet)	1	2	3	4	6	8
PDR(%)	0.10	0.70	0.15	98.65	100	99.85
DR(%)	99.80	99.80	99.60	99.95	99.65	99.95

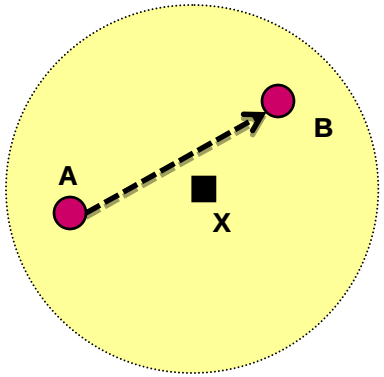
Packet Arrival Times



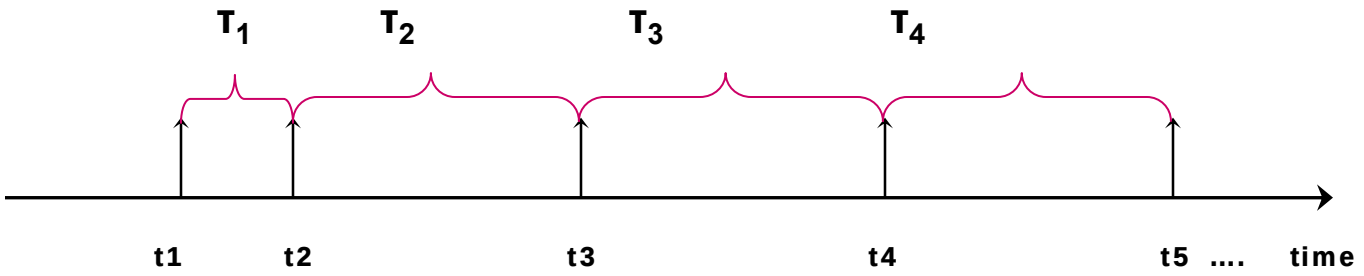
How to modulate inter-arrival time?

Two Party Prototype

- Two party scenario
  - A: Sender
  - B: Receiver
  - X: Interferer

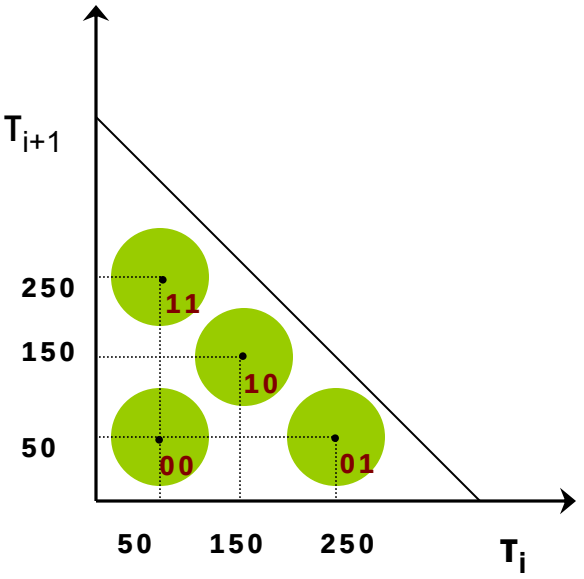


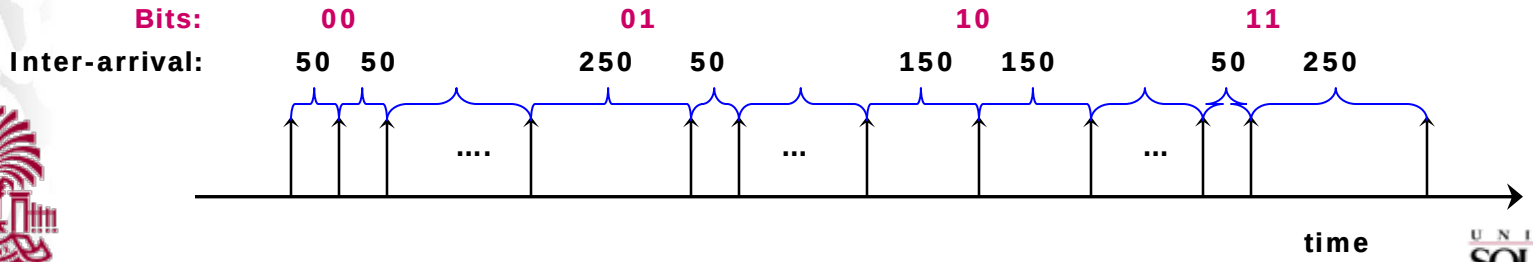
- What B observes:
  - t_i: the arrival time of the i^{th} packet
  - τ_i: the inter-arrival time, $\tau_i = t_{i+1} - t_i$



Example of Inter-arrival Time Coding

- Use (τ_i,τ_{i+1}) to code 2-bit symbols
  - Triangular simplex
  - Each circle represents 2 bits
    - (50,50) -> 00
    - (250,50) -> 01
    - (150,150) -> 10
    - (50,250) -> 11
  - Sender *encodes*:
    - 00->(50,50)
    - Send pkts at time 0, 50 & 100
  - Receiver *decodes* (nearest neighbor):
    - Receive packets at 0, 50 and 100
    - Get inter-arrival time pair (τ_i,τ_{i+1})=(50,50)
    - (τ_i,τ_{i+1}) -> Calculate the Euclidean distance





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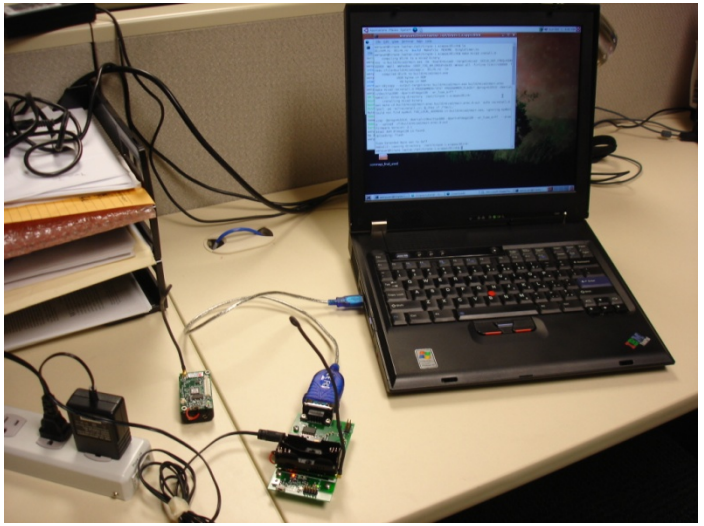
Experimental Validation

- Mica2 Motes
  - 8-bit CPU at 4MHz,
  - 128KB flash, 4KB RAM
  - 916.7MHz radio
  - OS: TinyOS

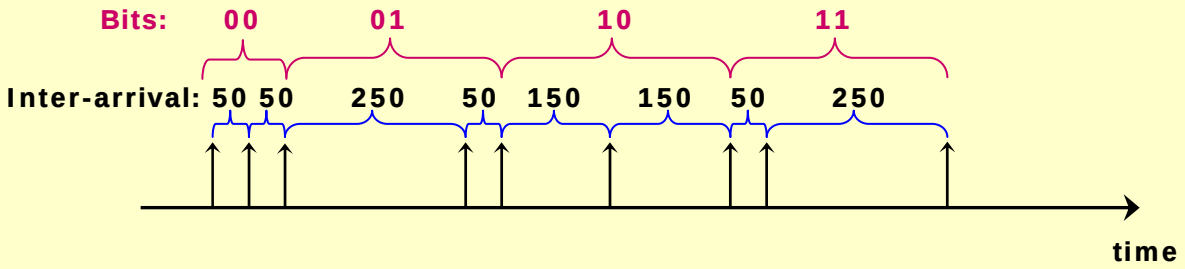


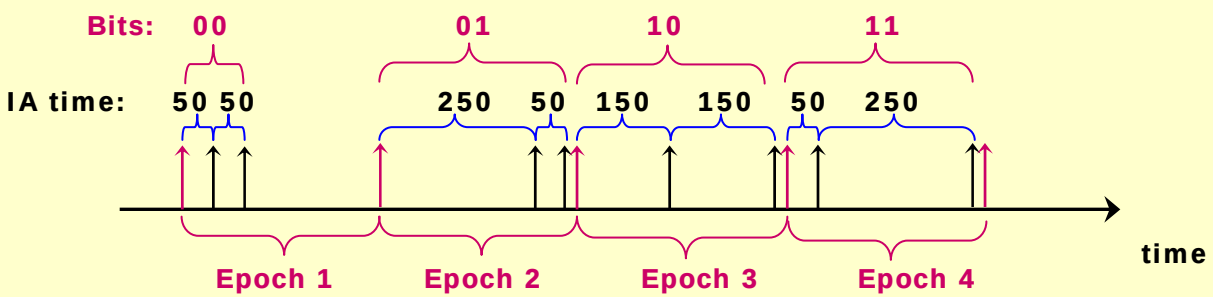
- Three nodes:
  - Sender:
    - Send 00, 01, 10, 11, 00…
  - Receiver
  - Interferer: Reactive jammer

- *Challenges:*
  - Jitter
    - *disable carrier sensing and back-off*
    - *code design*
  - Clock skew
  - *How to achieve efficient symbol streaming through the timing channel?*

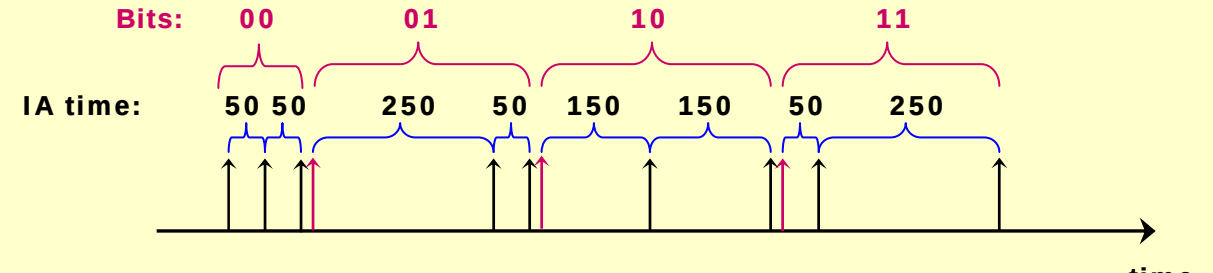
Symbol Streaming Strategies

Back-to-back streaming





Fixed interval streaming



Marker streaming

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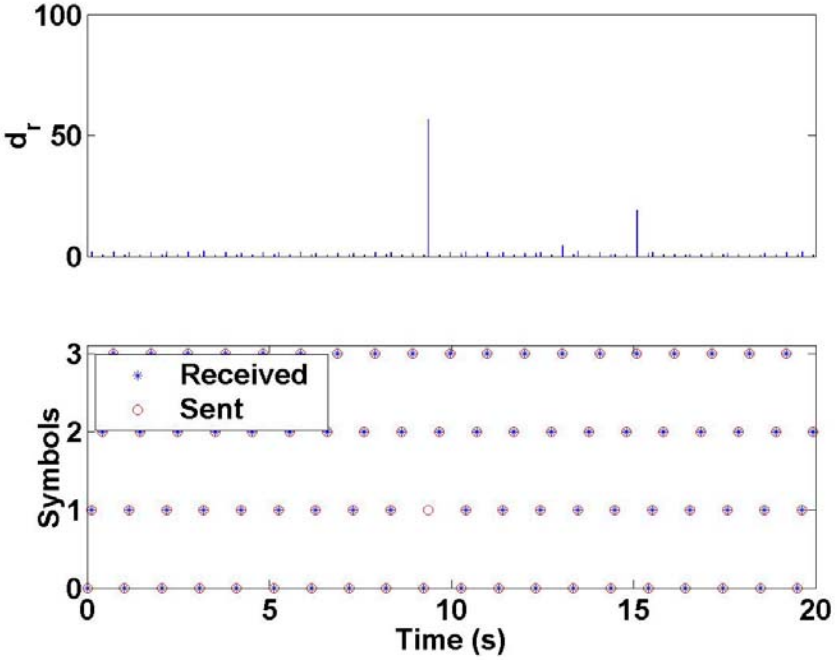
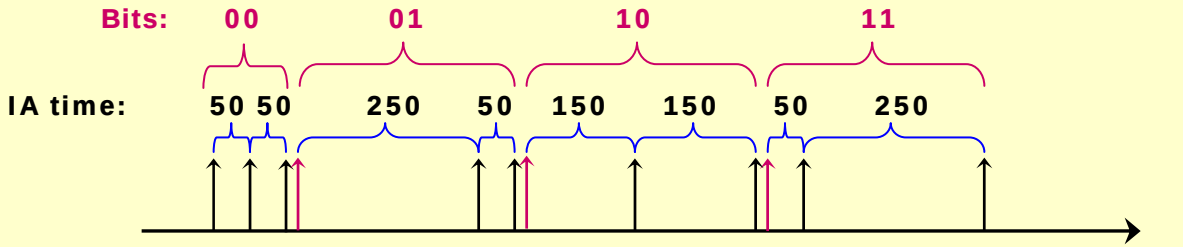
Symbol streaming strategies

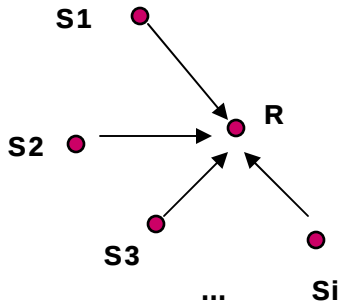


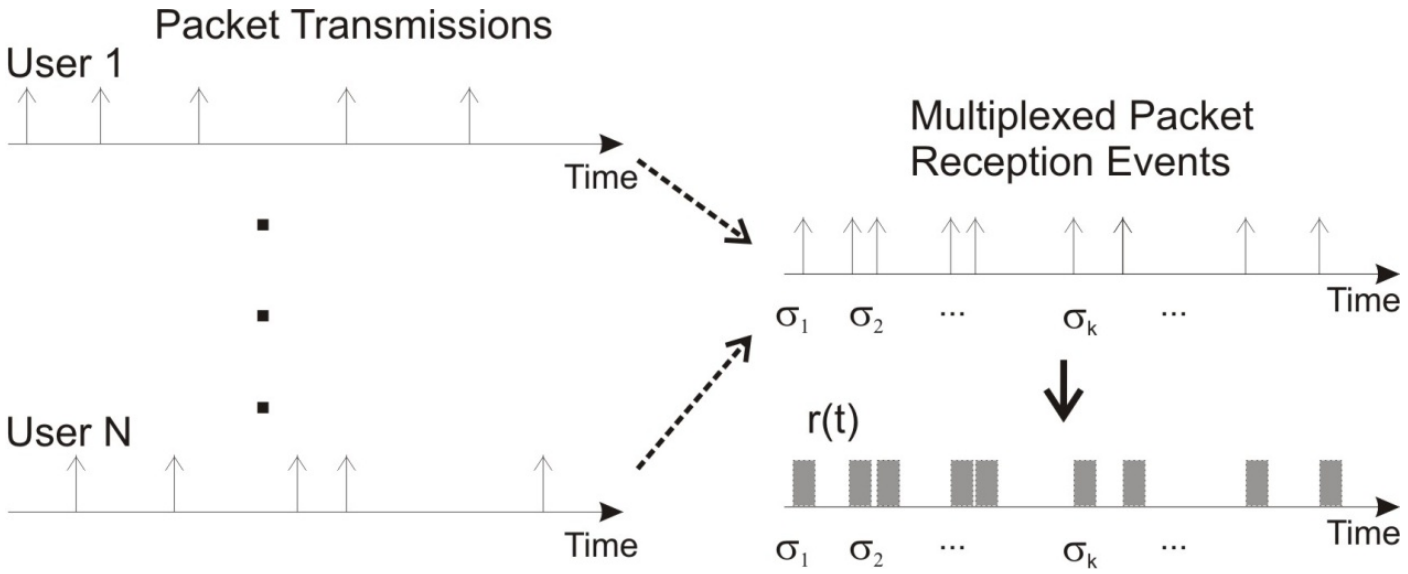


Marker streaming

Multiple Senders

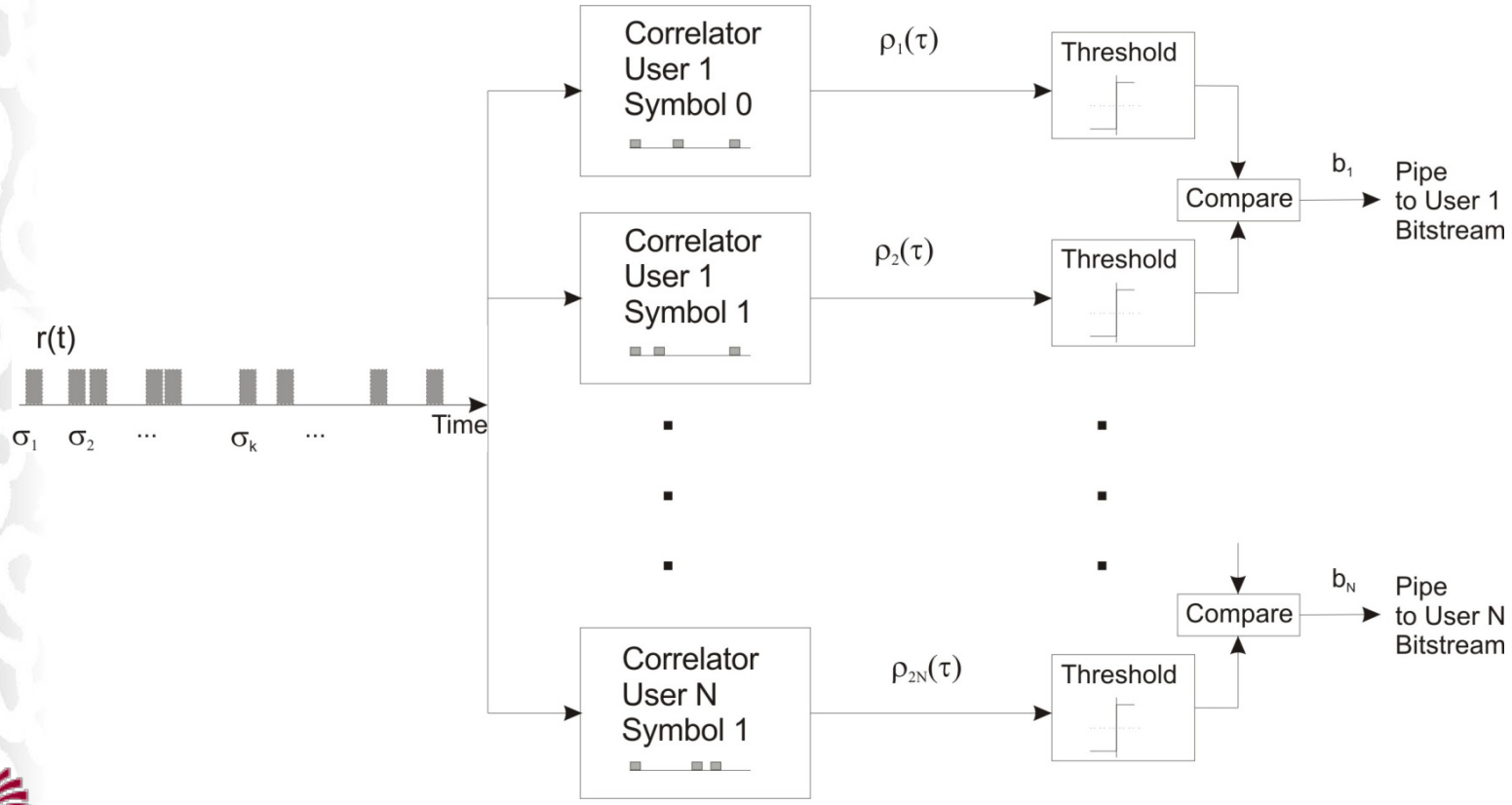
- Challenges:
  - Packets from various receivers interleave with each other
  - Extract individual sender's communications from the mixed packet arrivals at the reciever





Multiple Senders

- Idea: design transmission sequences based on optical orthogonal codes (OOC)
  - The cross-correlation between different code words is very small
  - The auto-correlation is high



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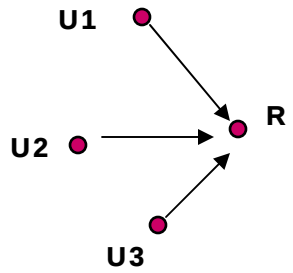
Experimental Validation

- Setup-5 MICA2 motes
  - Senders -u1, u2 & u3
  - One receiver R
  - One reactive jammer



- OOC code (37, 3, 1)

- Scenarios:
  - u2 and u3 sent, u1 remain silent
  - u1, u2 & u3 send

- Each user sends out 650 symbols, the receiver tries to decode and calculate the symbol error ratio.

Table1: Codewords

User	Symbol 0	Symbol 1
u1	{0, 1, 11}	{0, 2, 9}
u2	{0, 3, 17}	{0, 4, 12}
u3	{0, 5, 18}	{0, 6, 12}

Table2: The symbol error rate

Scenarios	u1	u2	u3
(u2, u3)	0%	0.64%	0.48%
(u1, u2, u3)	0.15%	0.31%	0.46%

Challenge & Ongoing Work

- Multiple-users:
  - We would like to have OOC's that are not based on a slotted time system
  - General continuous code design is underway
  - Looking for alternative modulation schemes
- Putting it together:
  - Further in the future: integrating into a holistic ad hoc network system where only small portions of network are jammed

Thank you!

Questions?

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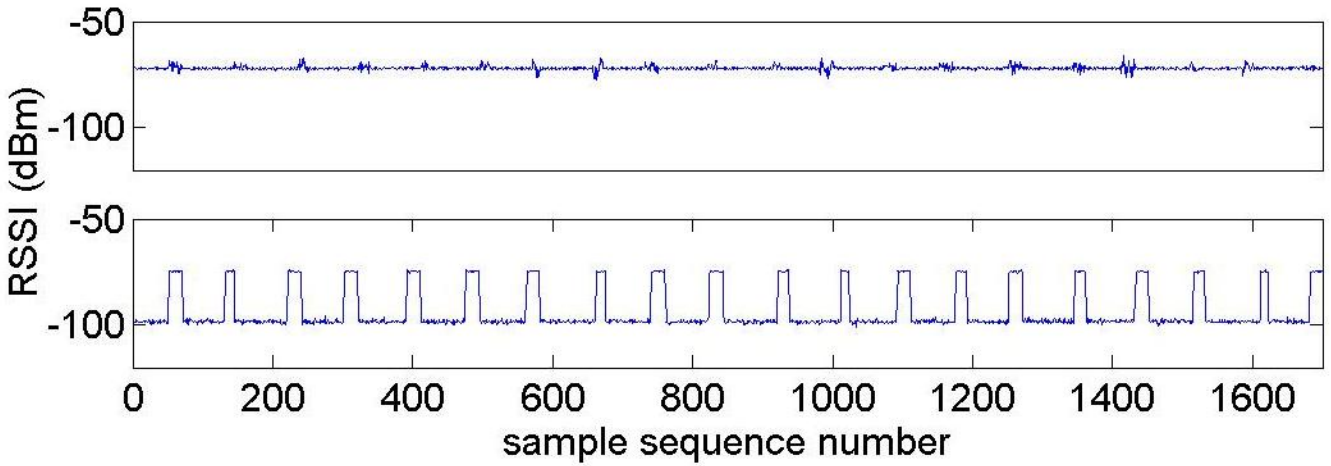
Unintentional Radio Interferer

- Constant Interferer:
  - Continuously emits a radio signal
- Observation:
  - Bob CANNOT decode packets correctly
  - Bob MAY observe the *spikes*, representing the presence of packet on the air….
  - The ability to observe the spike depends on the transmission power levels of the sender and interferer and the sensitivity of the receiver.



Jamming or Radio Interference

- Observation
  - CANNOT decode packets correctly
  - CAN observe the *presence* of a packet
- Information: packet-arrival time → inter-arrival time
- Idea:
  - Using inter-arrival time to build a *timing channel*
  - Modulate inter-arrival time