Ripple II: Faster Communication through Physical Vibration

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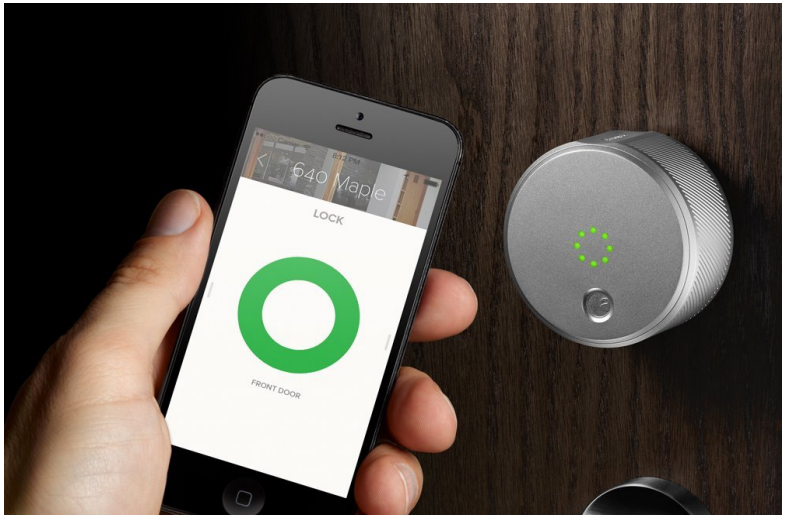
University of Illinois at Urbana-Champaign

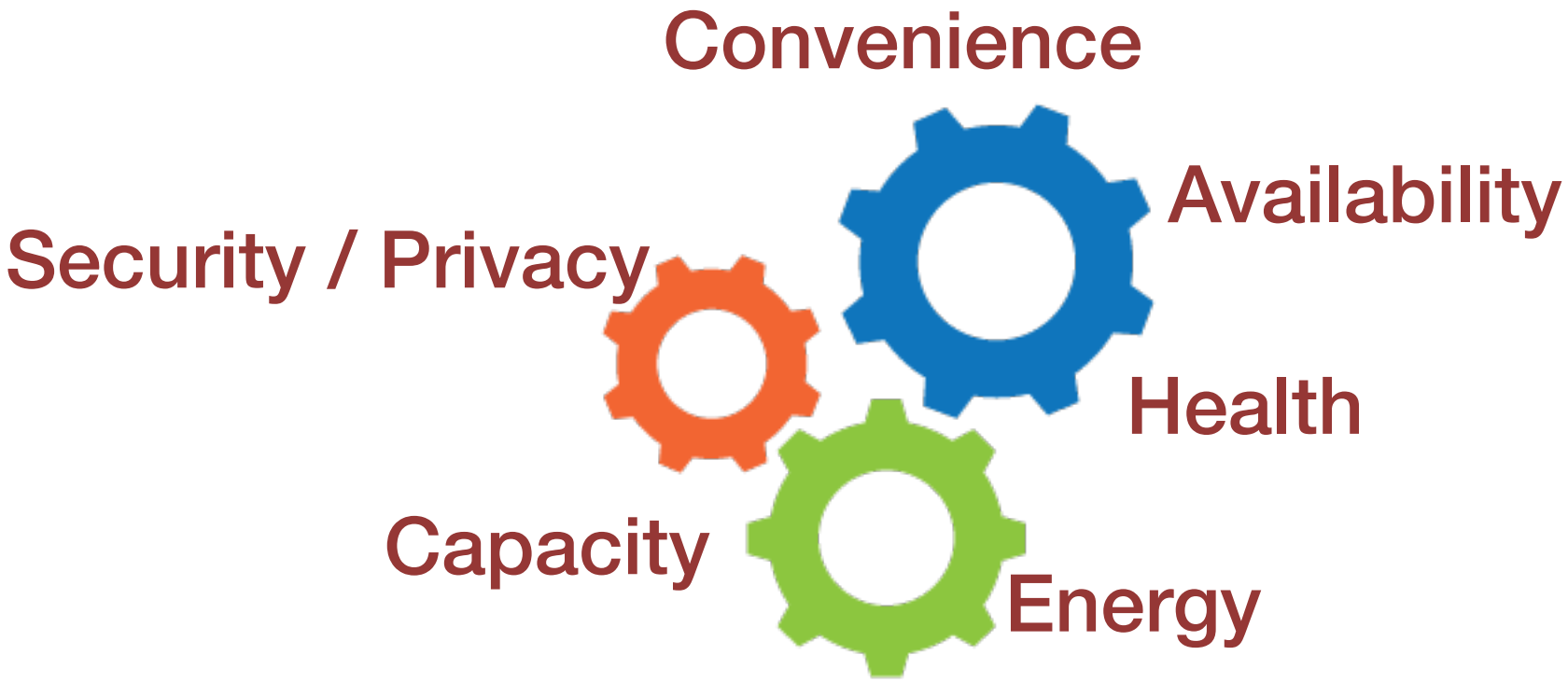
NSDI, March 18, 2016
Santa Clara, CA

Short range communication:
a new need of this decade



Short range communication:
a new need of this decade

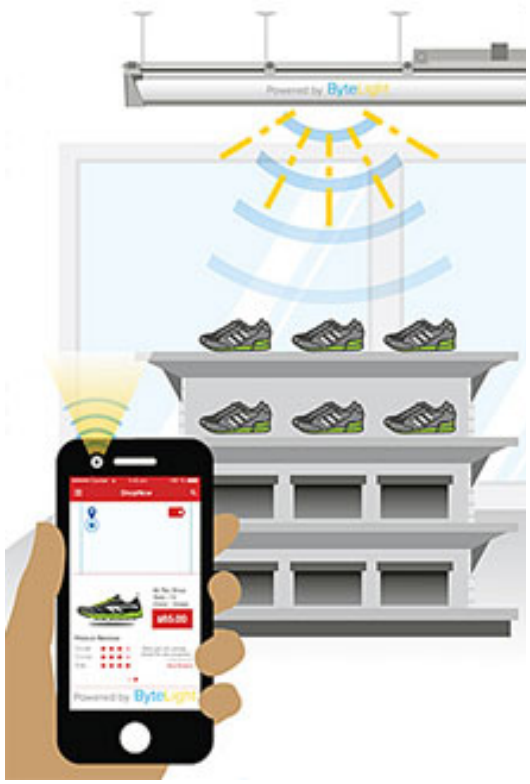
Emerging technologies for short range



Driving forces of short range communication research

Emerging technologies for short range

Visible Light Communication

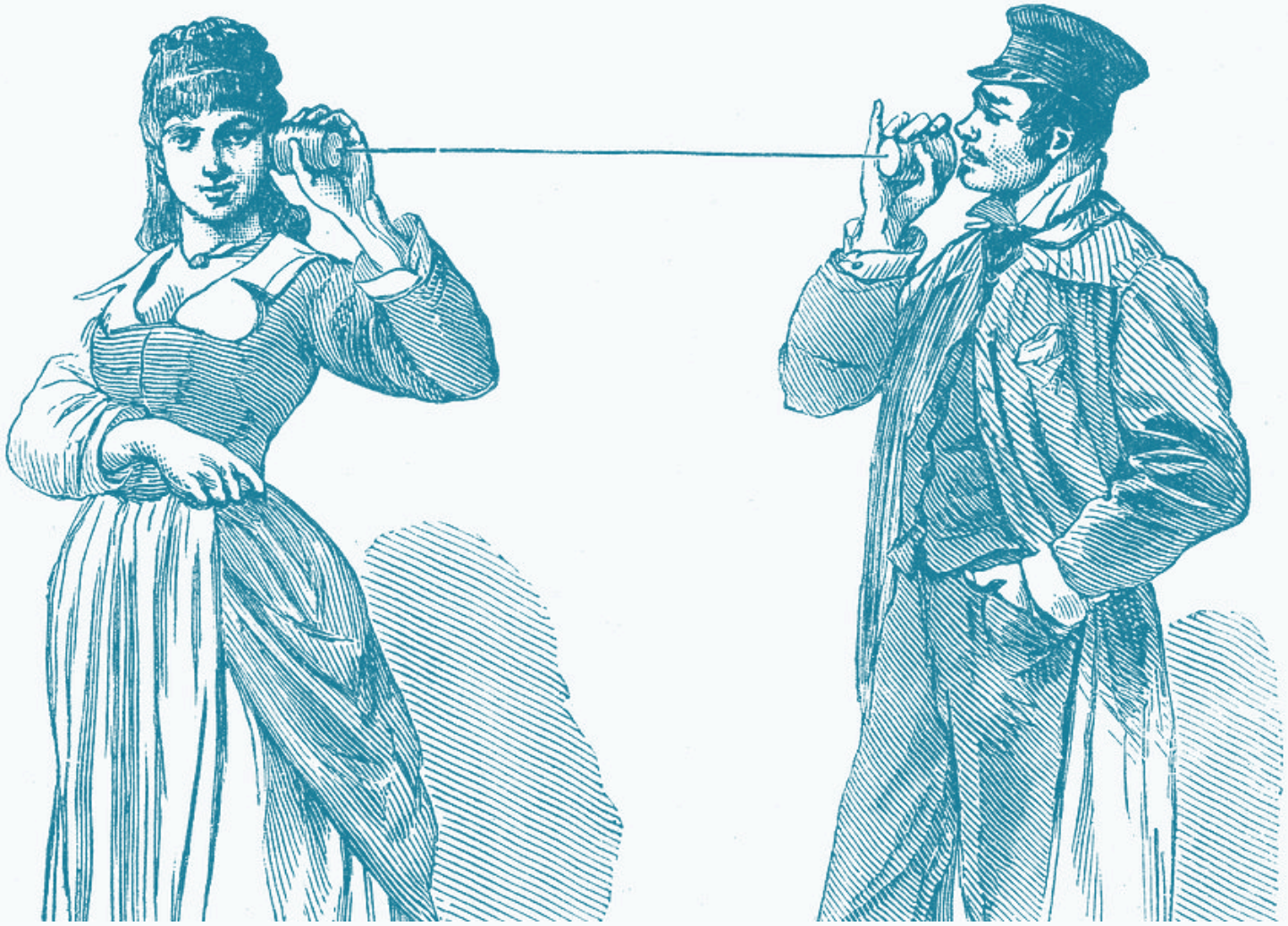


byte light

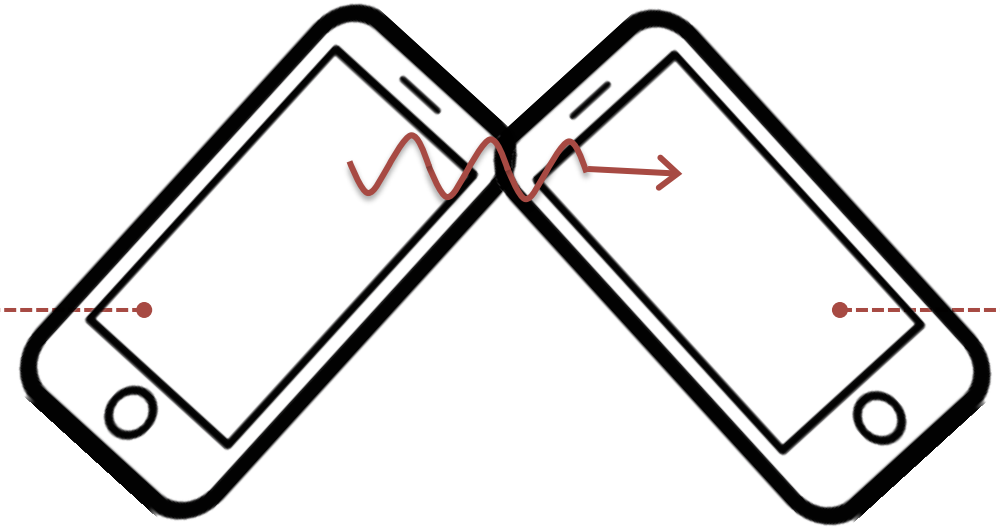
Acoustic NFC

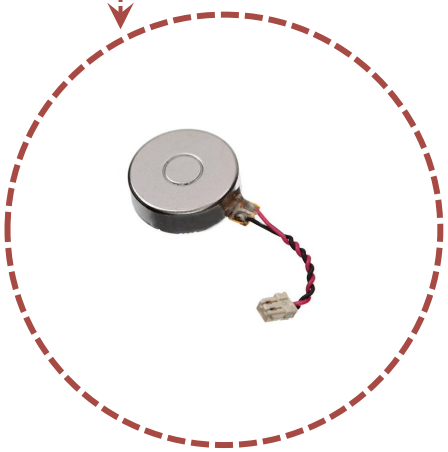
Zoosh
Powered by Naratte

Physical vibration:
a new mode of communication

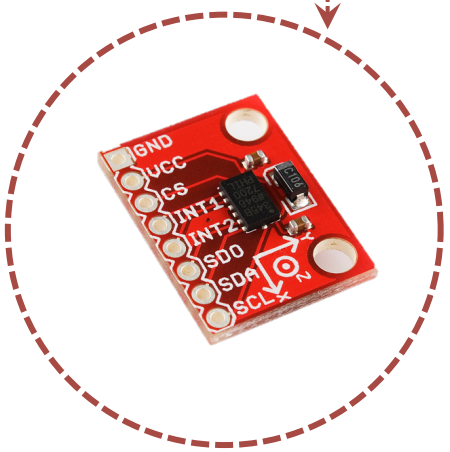


Physical vibration:
a new mode of communication



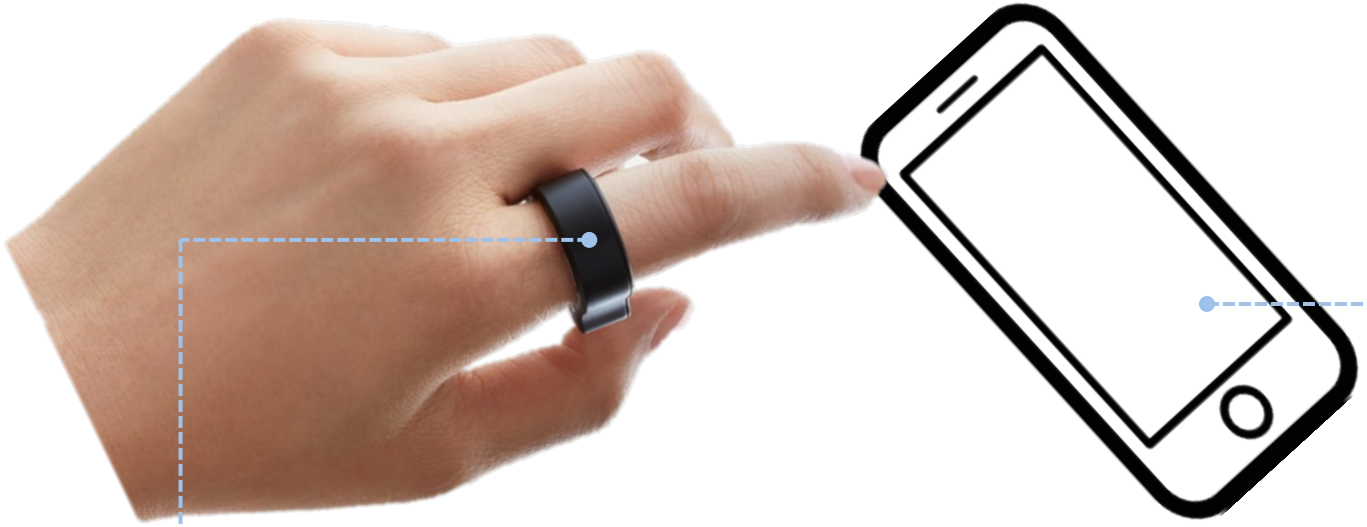


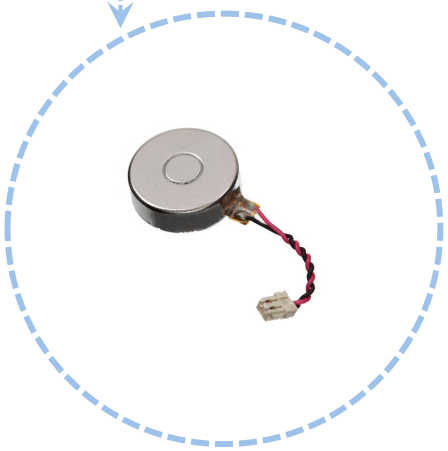
Vibration Motor



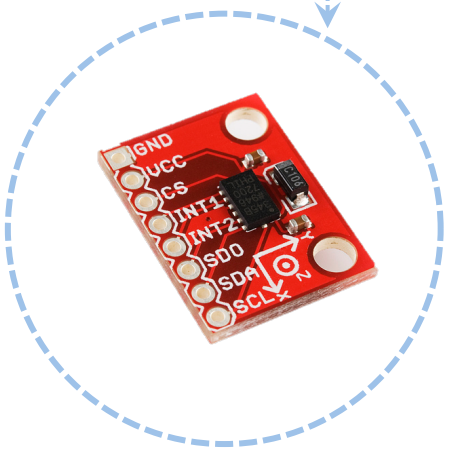
Accelerometer

Physical vibration:
a new mode of communication



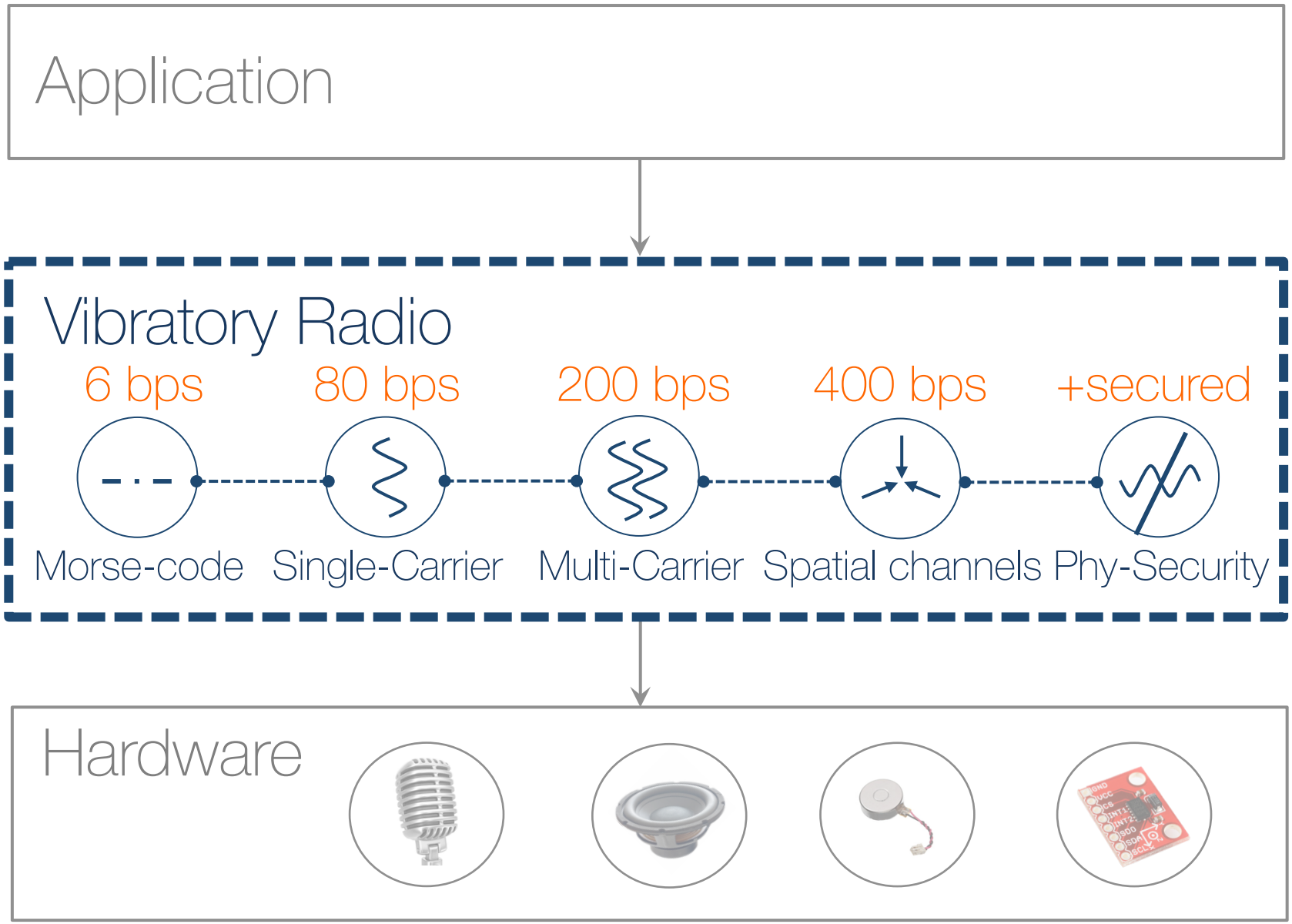


Vibration Motor

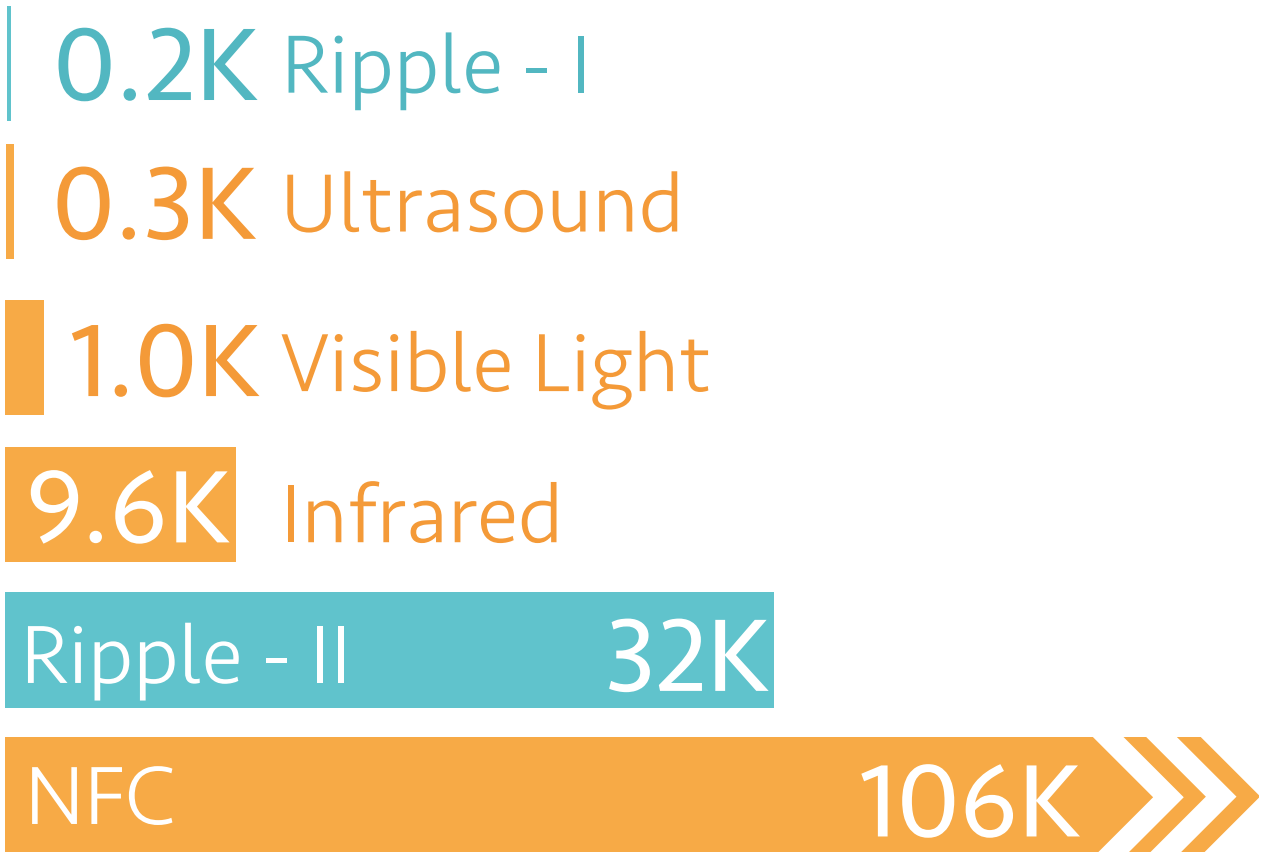


Accelerometer

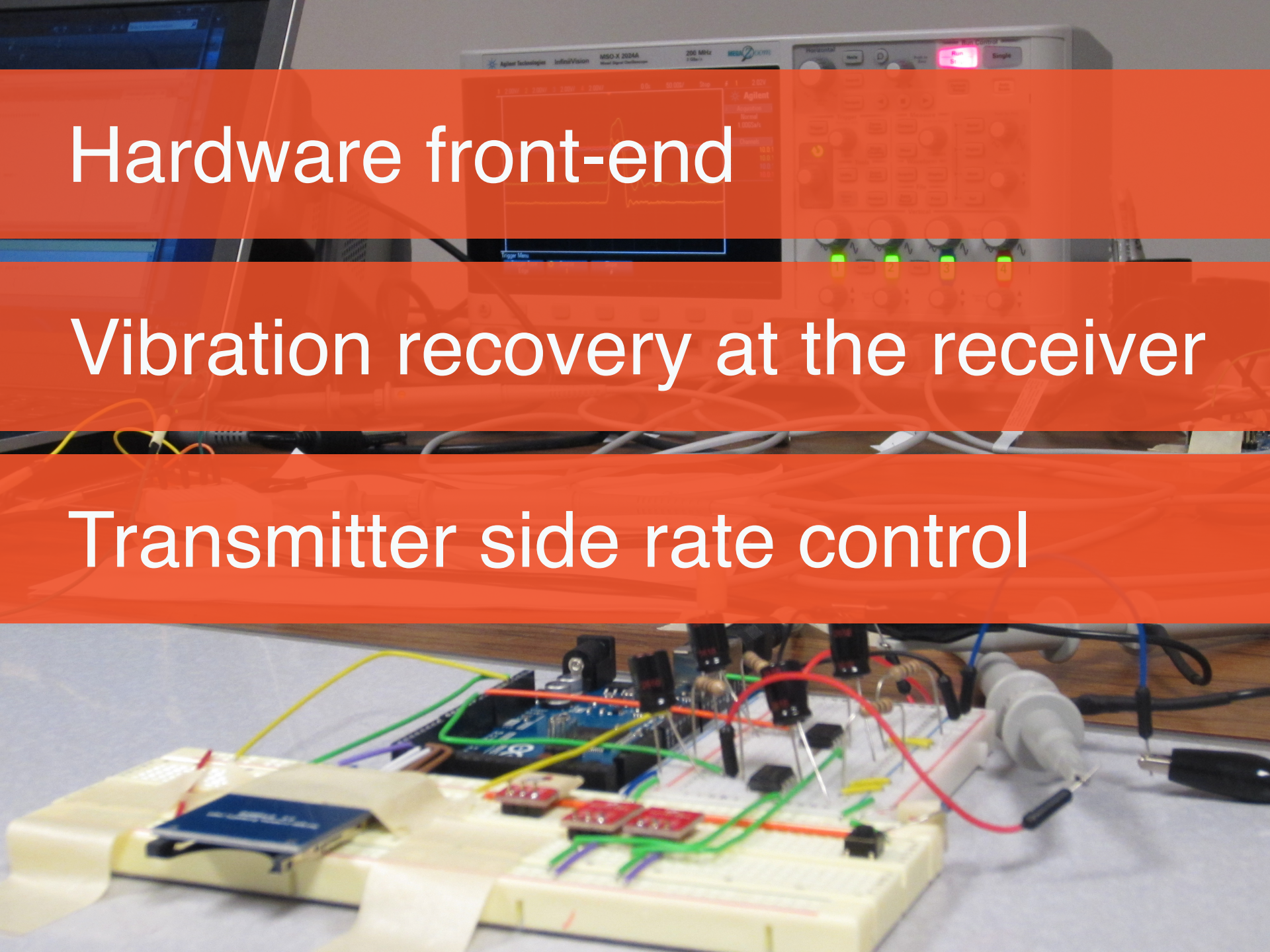
Ripple: vibratory communication



Search for a better Ripple



(bits-per-second, entry level versions)



Hardware front-end

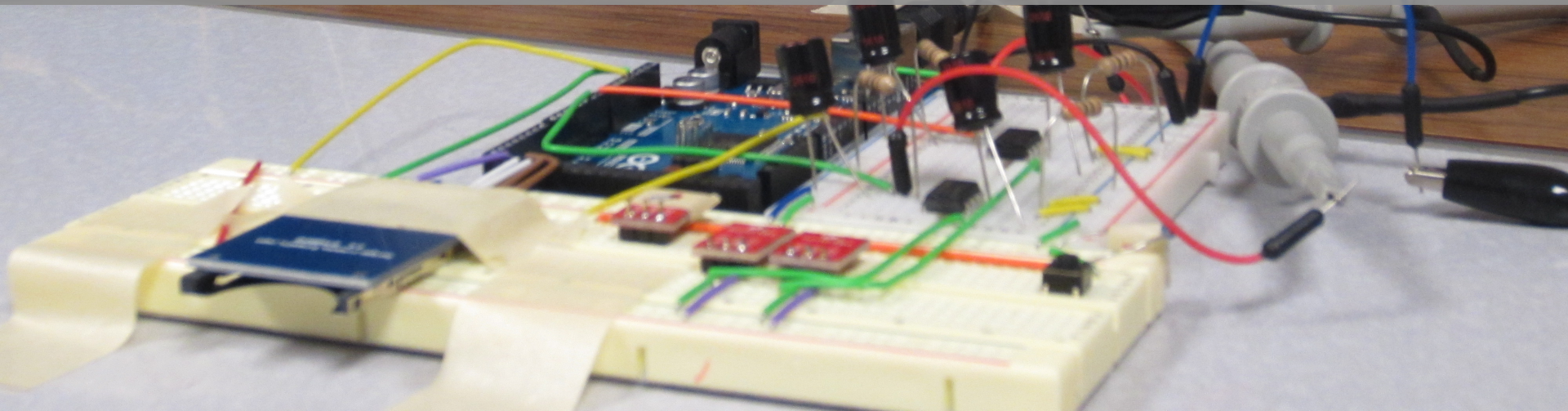
Vibration recovery at the receiver

Transmitter side rate control

Hardware front-end

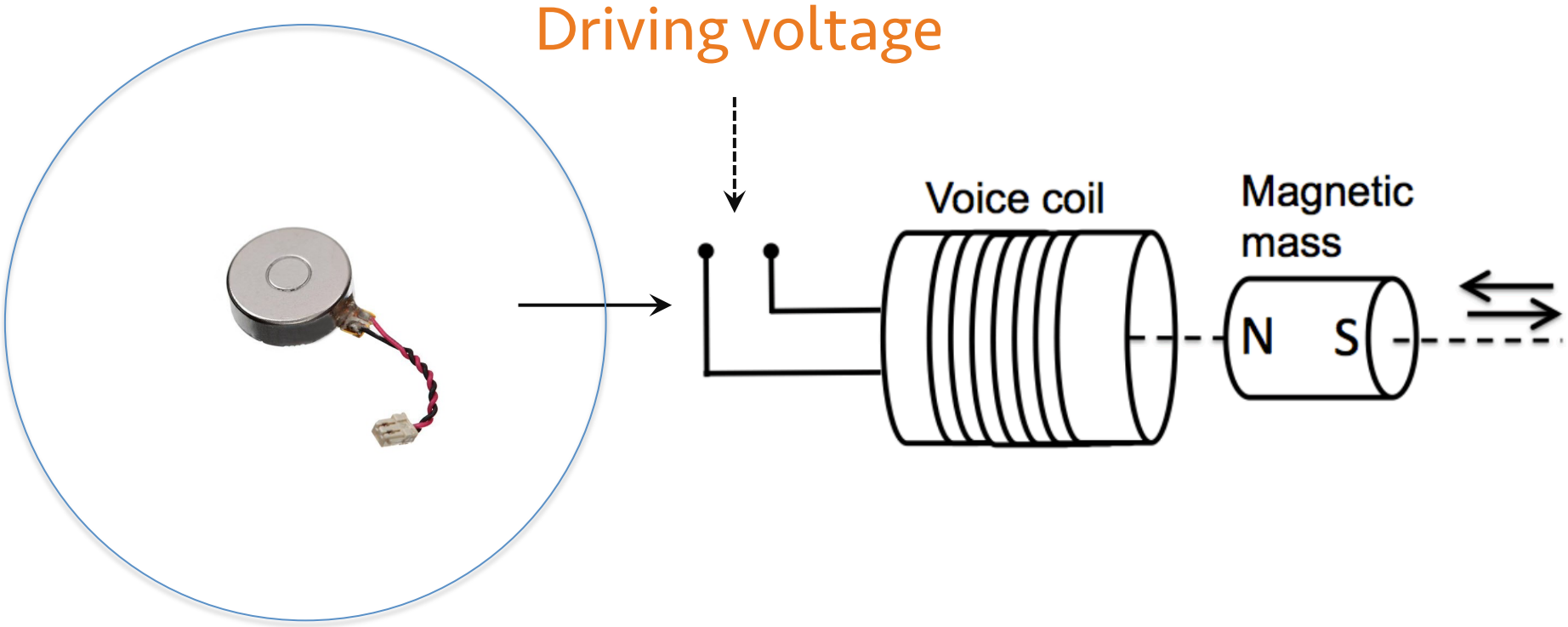
Vibration recovery at the receiver

Transmitter side rate control



A better sensor for physical vibration

The transmitter:

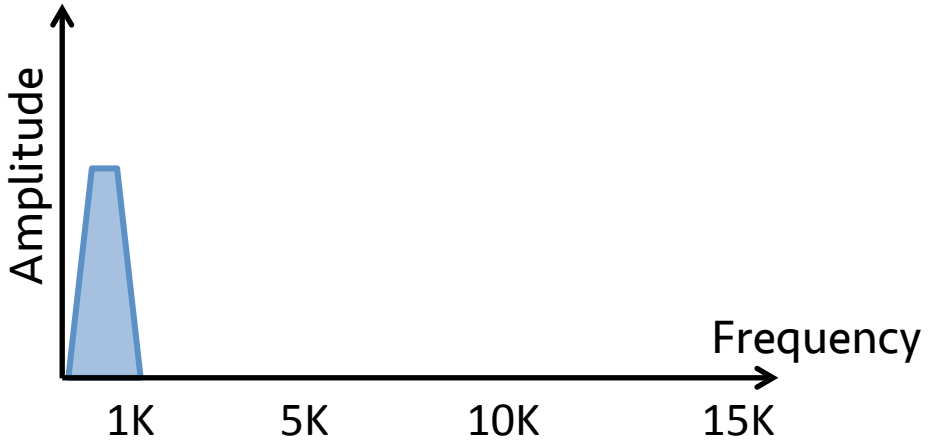


A better sensor for physical vibration

The receiver:

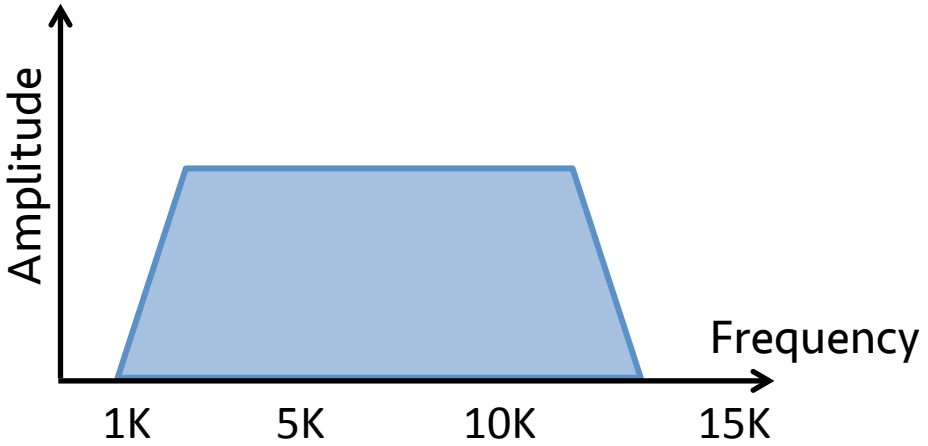
Accelerometer

Vibration



Microphone

Vibration
+ Sound

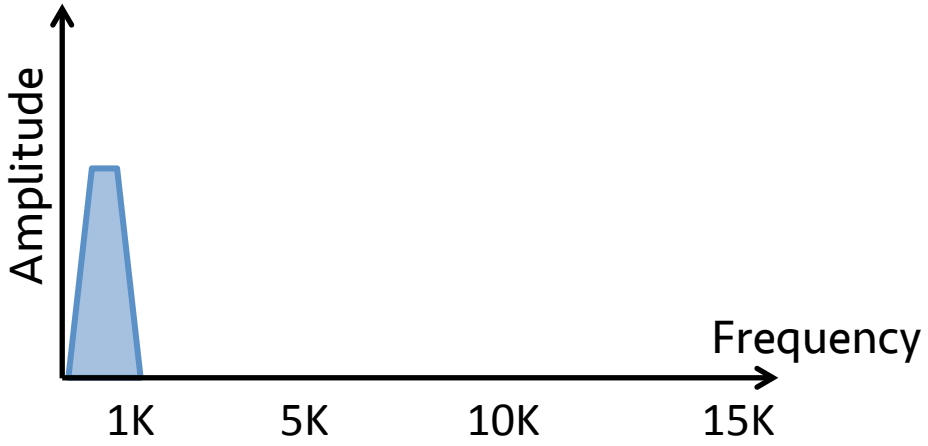


A better sensor for physical vibration

The receiver:

Accelerometer

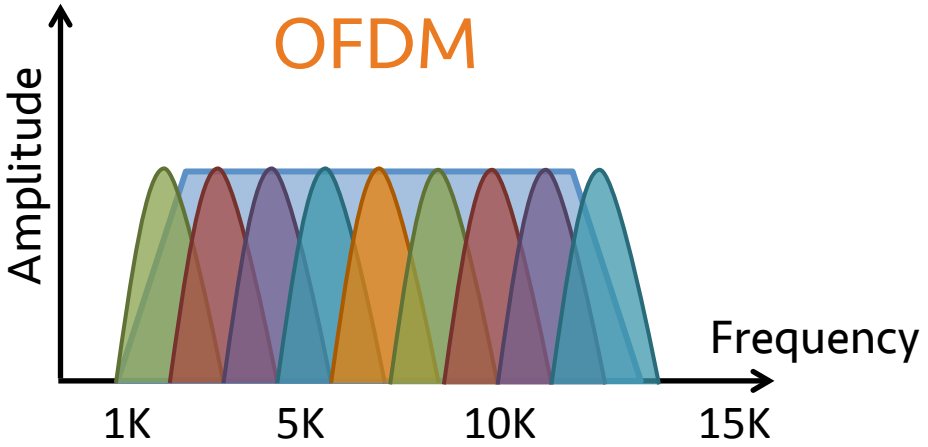
Vibration



Microphone

Vibration
+ Sound

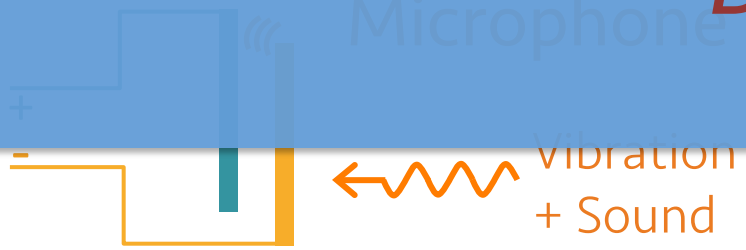
OFDM

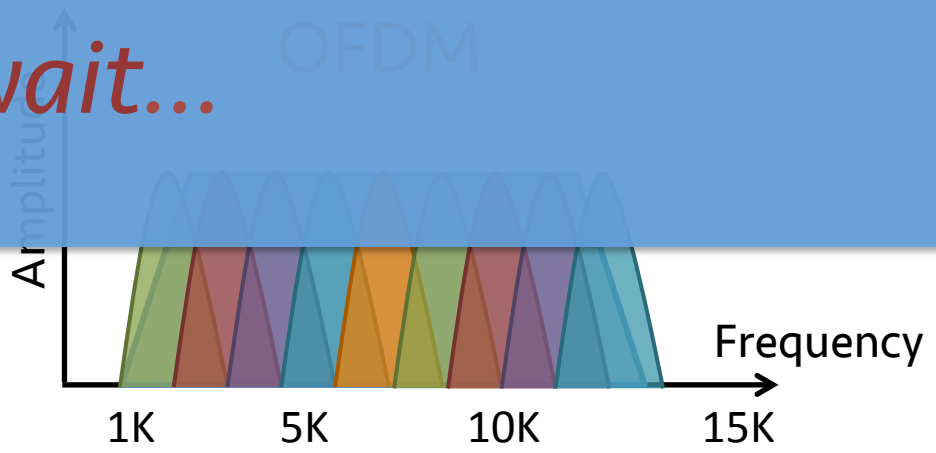


A better sensor for physical vibration

The receiver:

But wait…





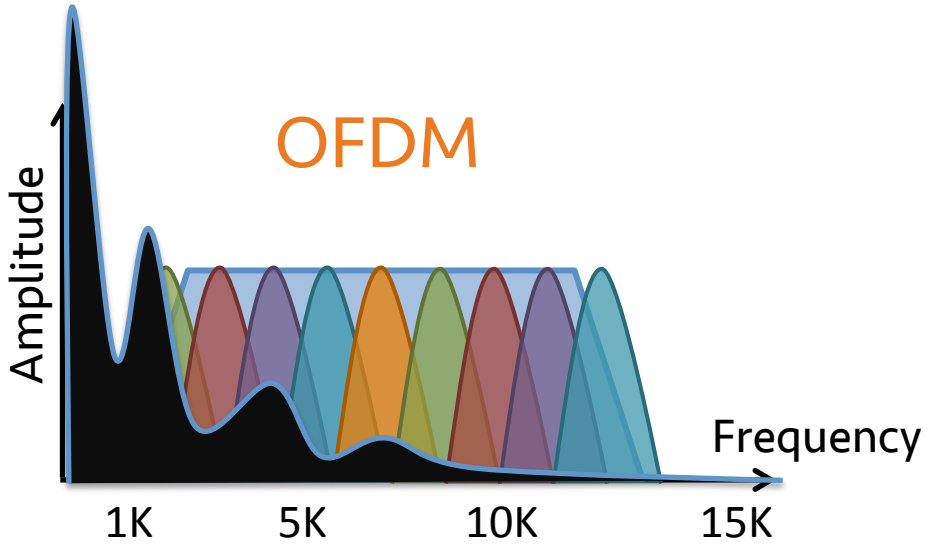
A better sensor for physical vibration

The receiver:

Ambient sound

Microphone

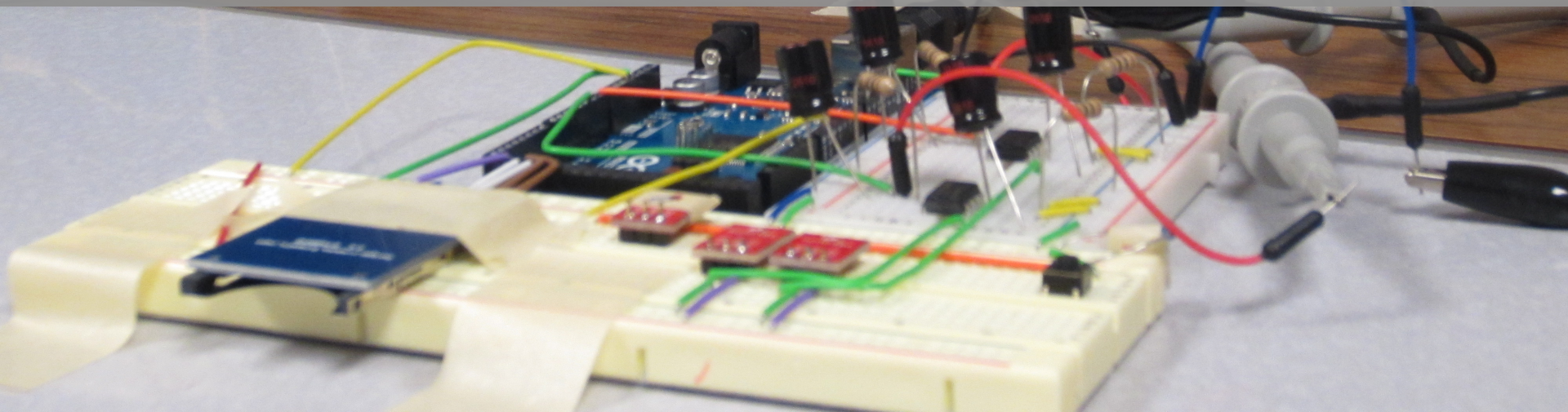
Vibration
+ Sound



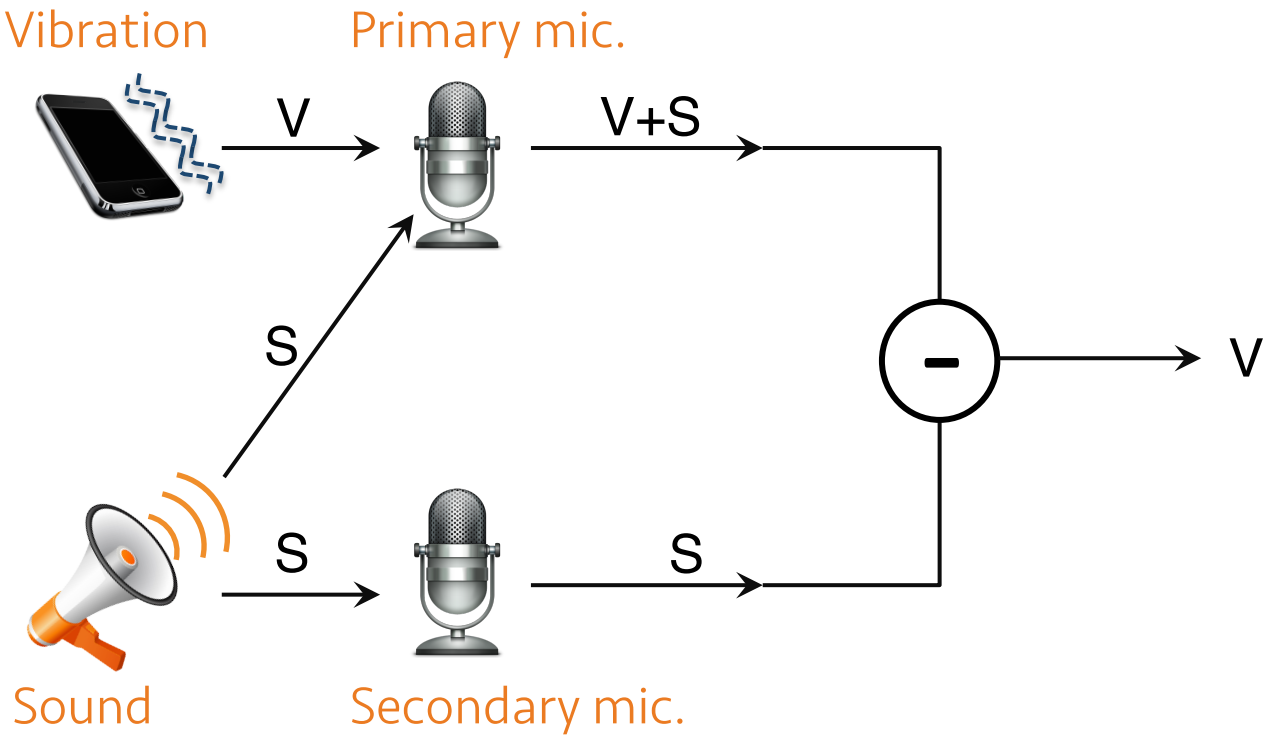
Hardware front-end

Vibration recovery at the receiver

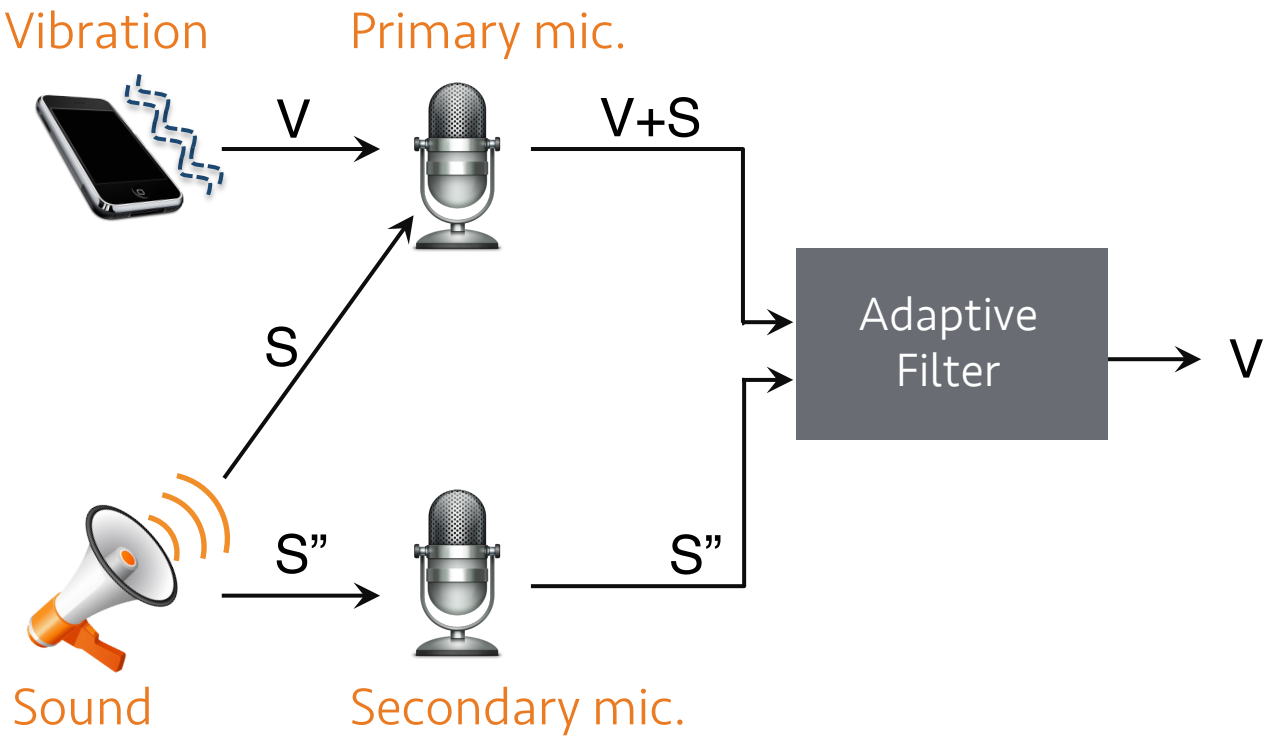
Transmitter side rate control



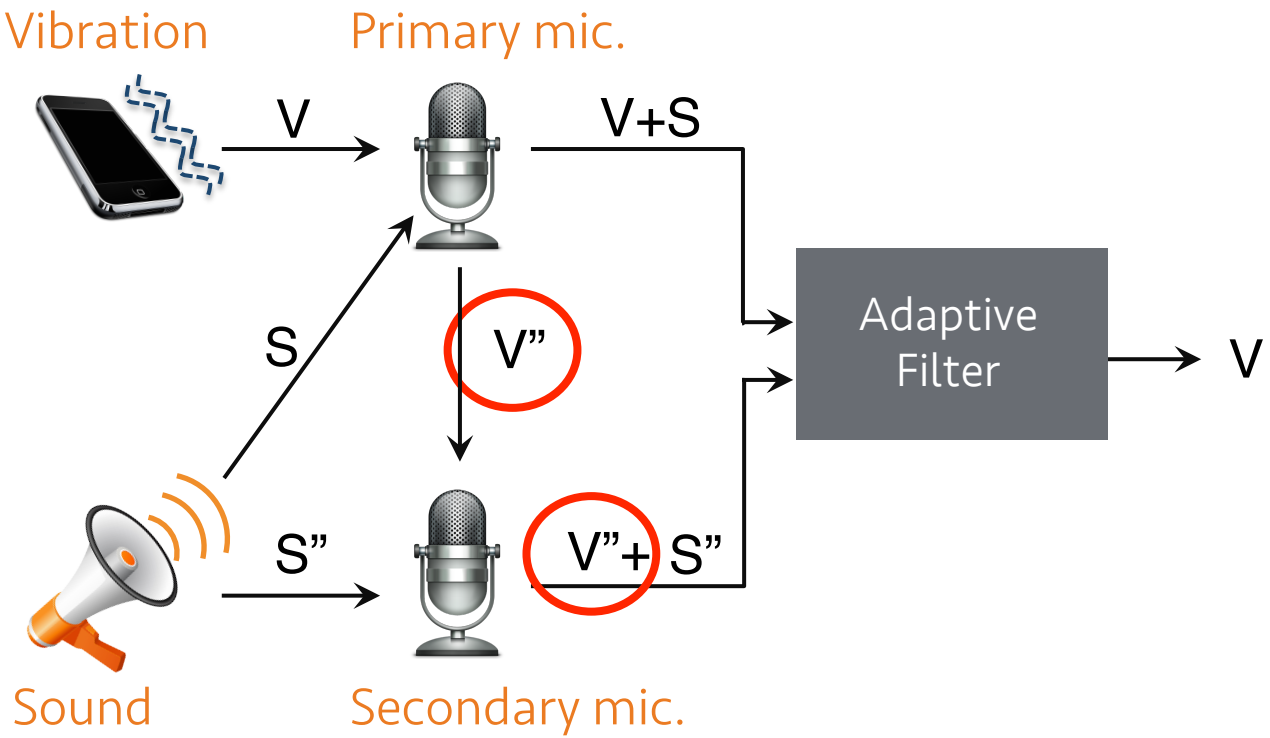
Vibration recovery at receiver



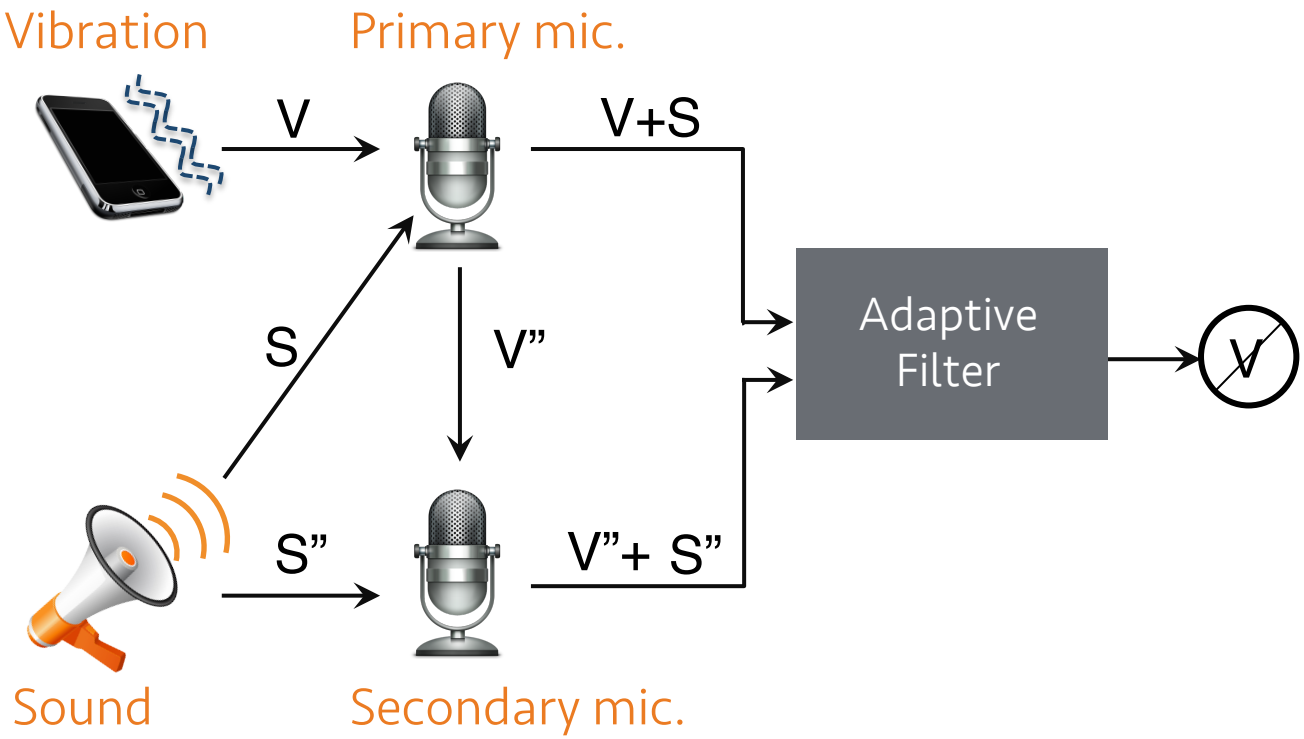
Vibration recovery at receiver



Vibration recovery at receiver

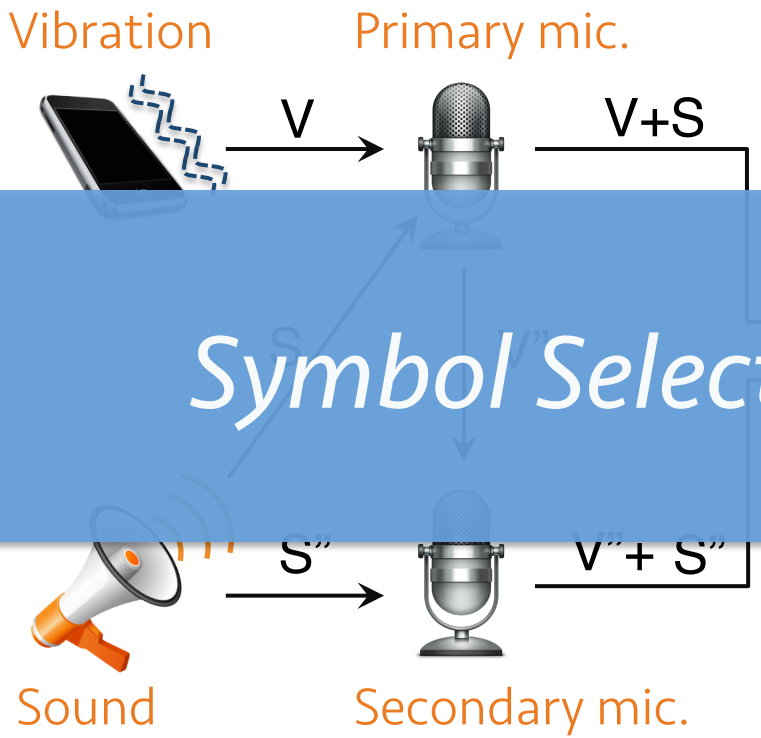


Vibration recovery at receiver



Signal sources are correlated

Vibration recovery at receiver

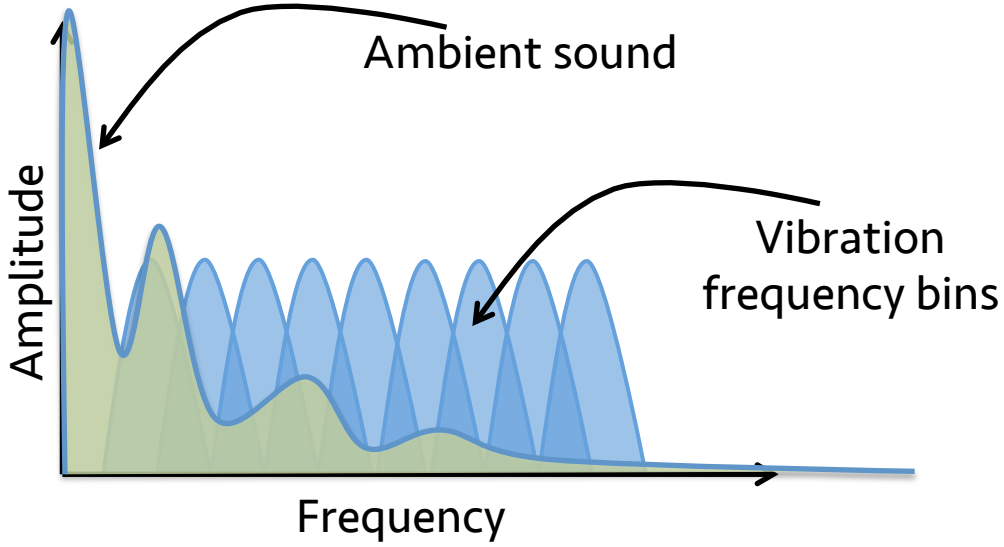


Symbol Selective Adaptive Filtering

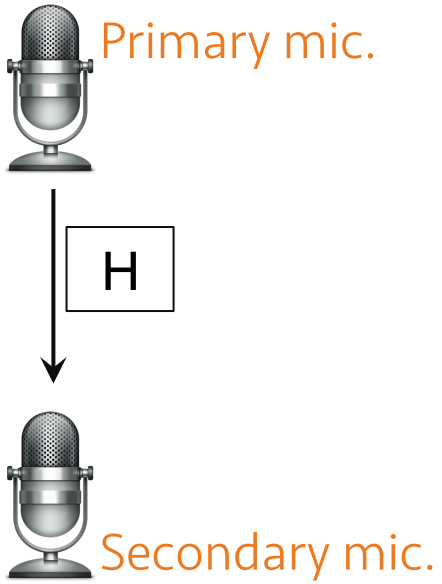
Signal sources are correlated

Vibration recovery at receiver

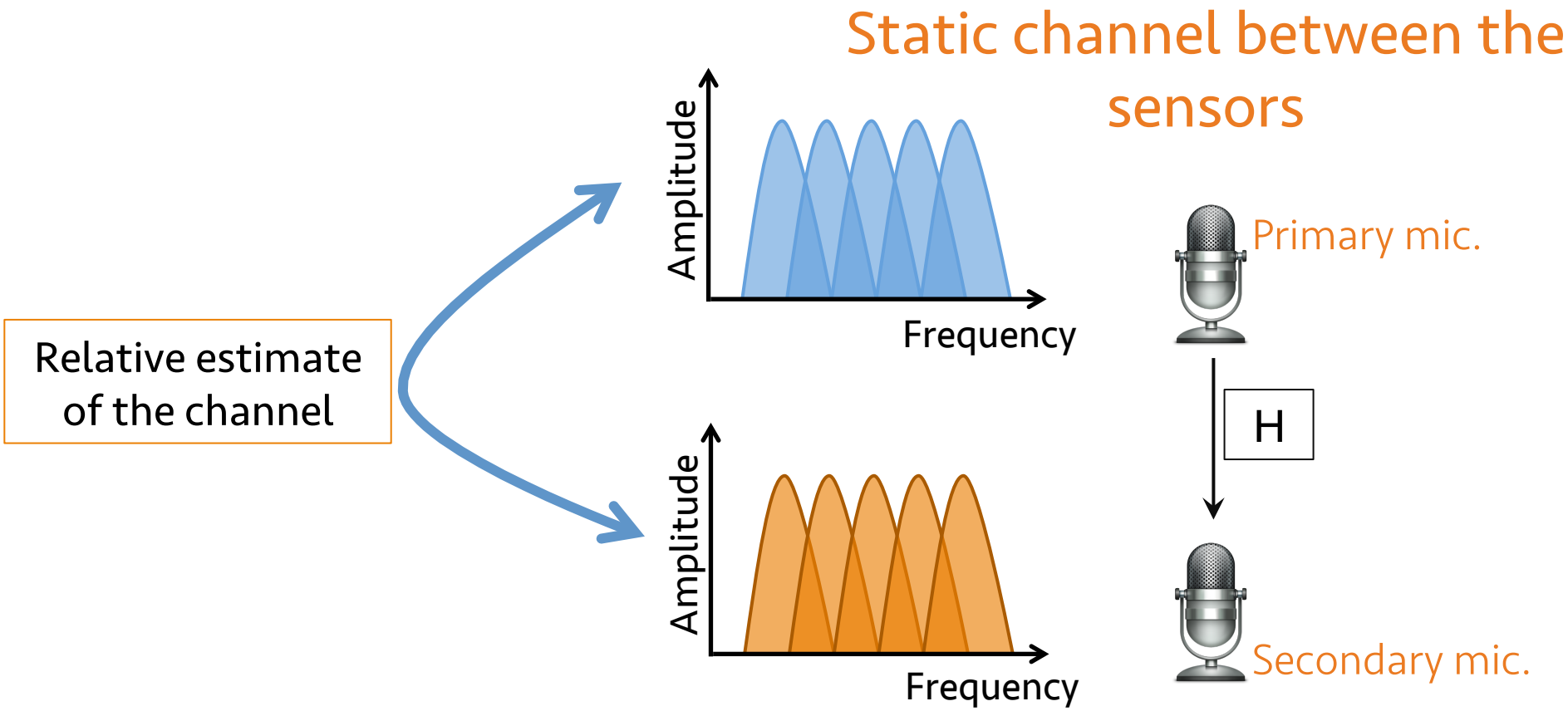
Noise is sparse in frequency



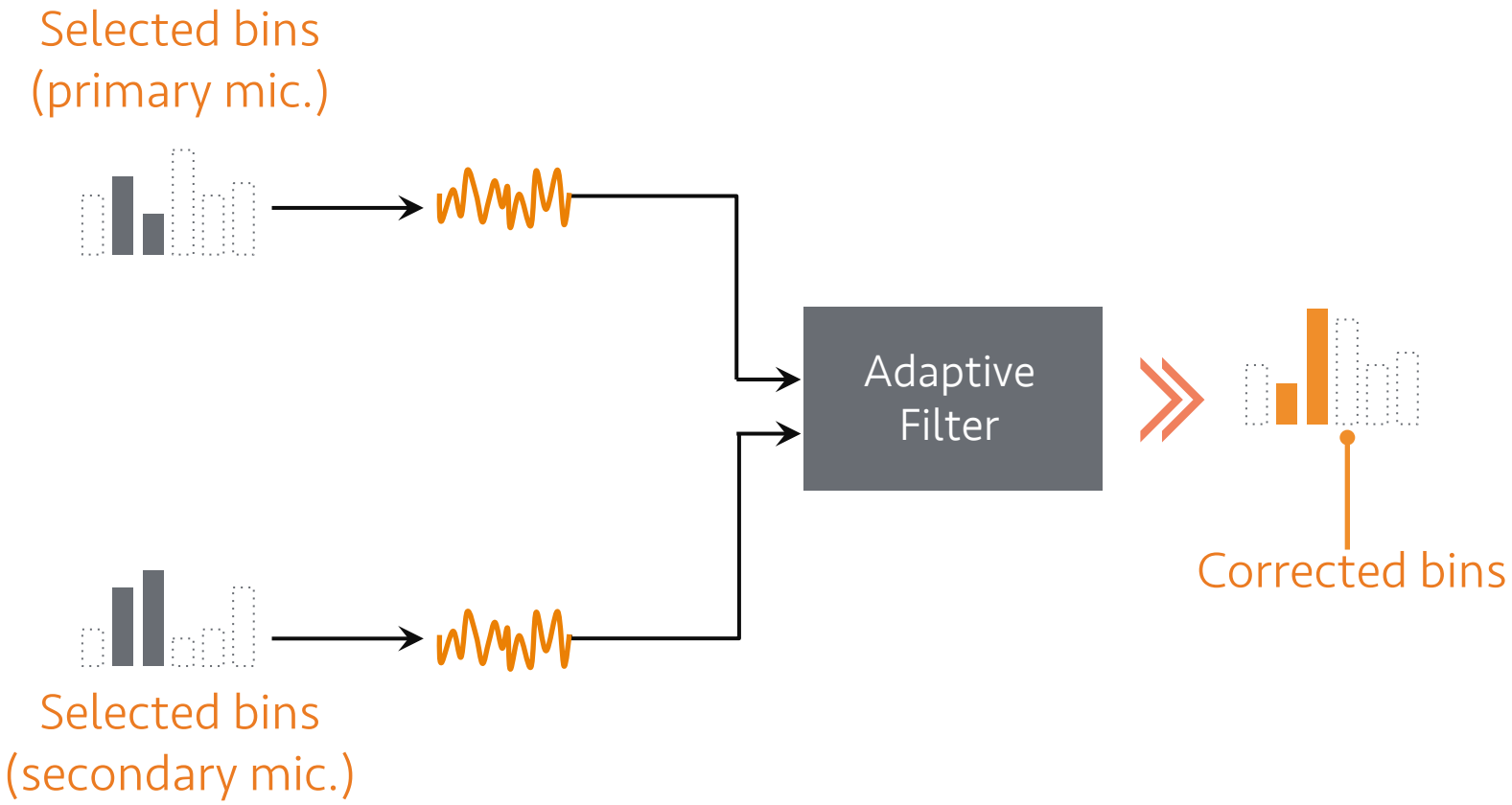
Static channel between the sensors

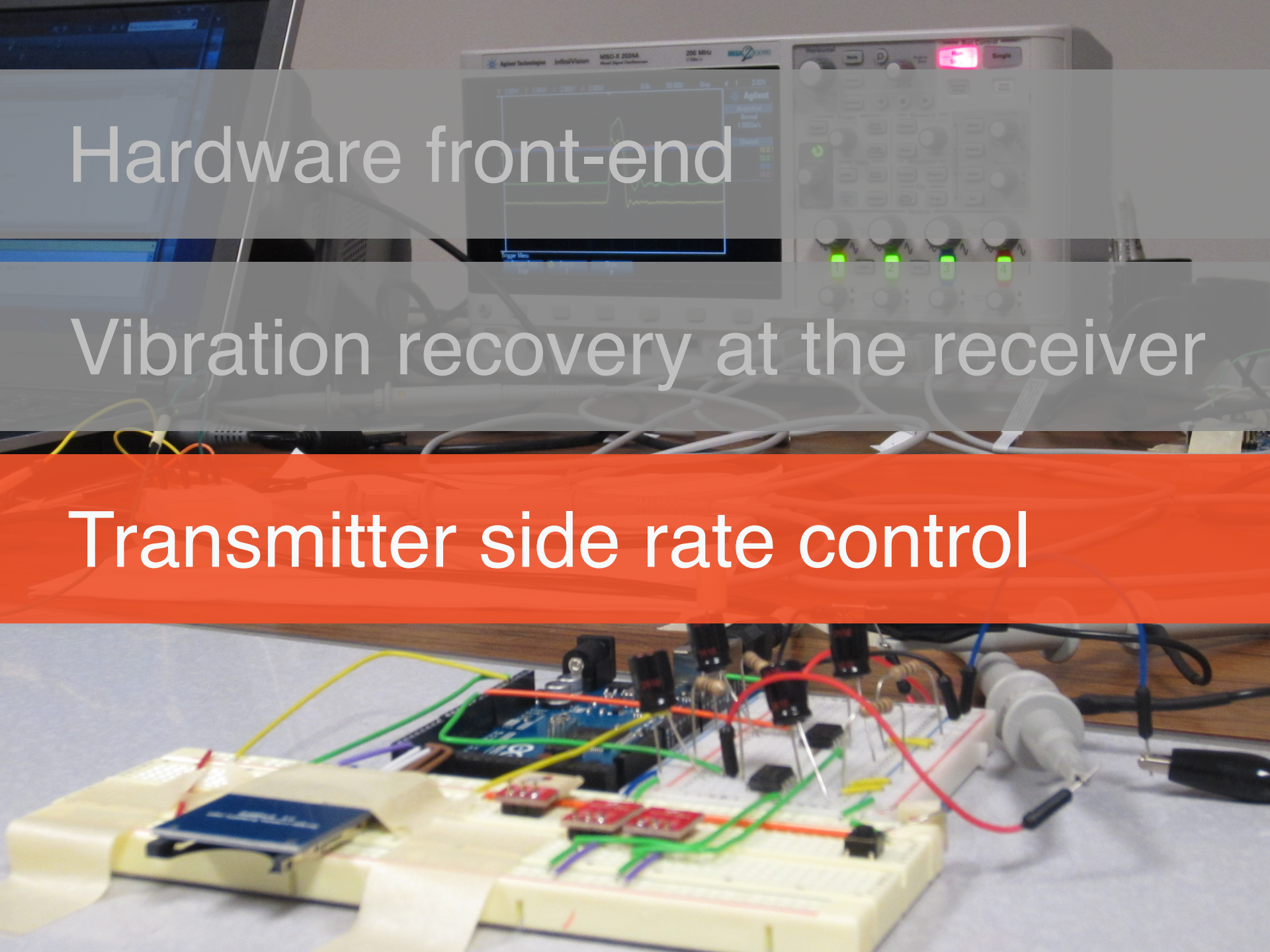


Vibration recovery at receiver



Vibration recovery at receiver




Hardware front-end
Vibration recovery at the receiver
Transmitter side rate control

MAC layer rate control

1

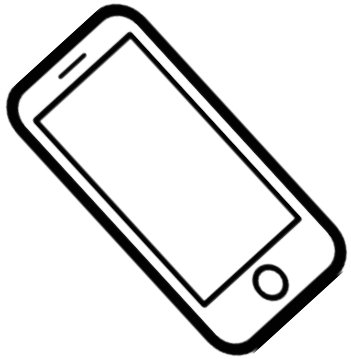
Packet 02

Packet 01

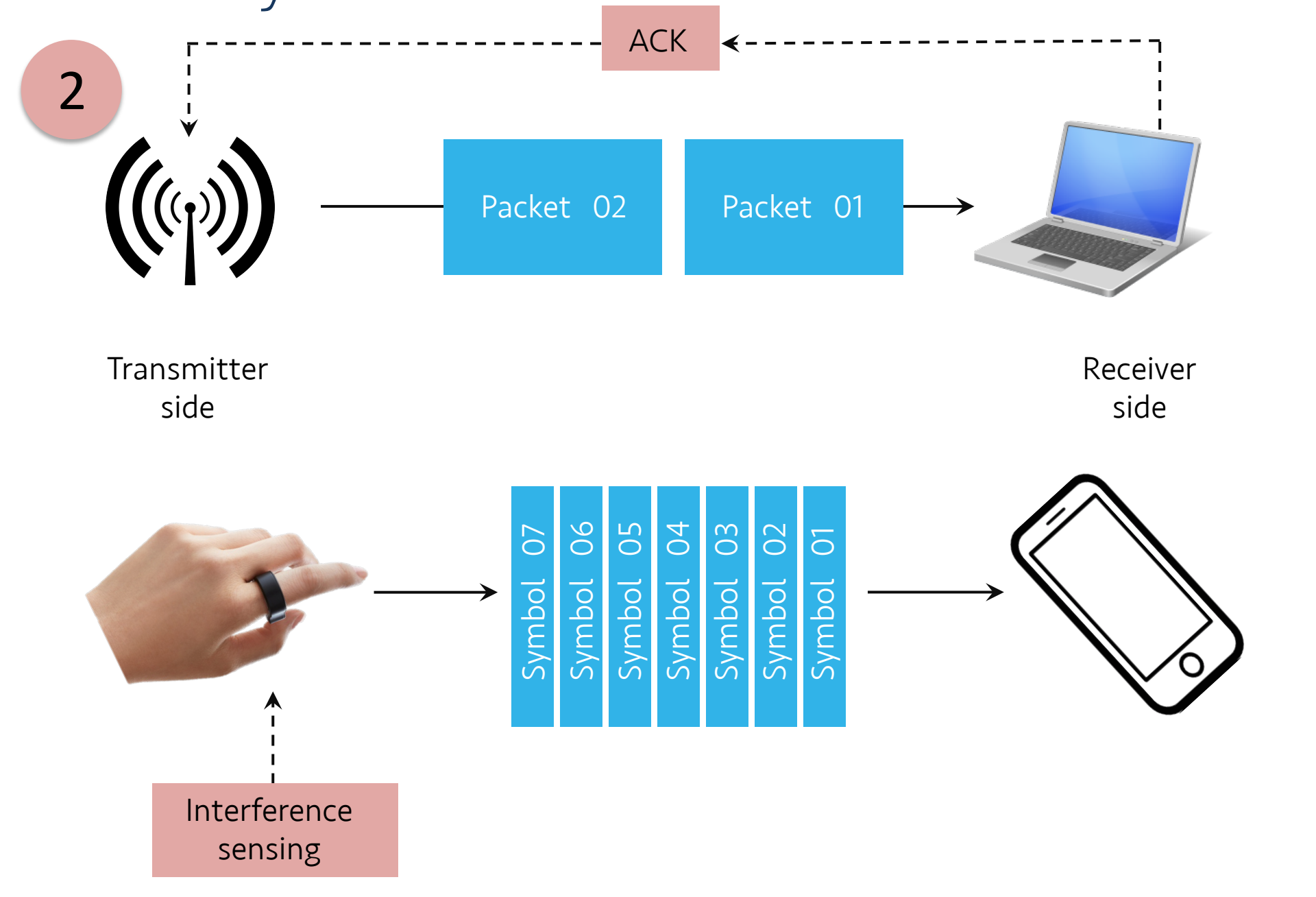
Transmitter side

Receiver side

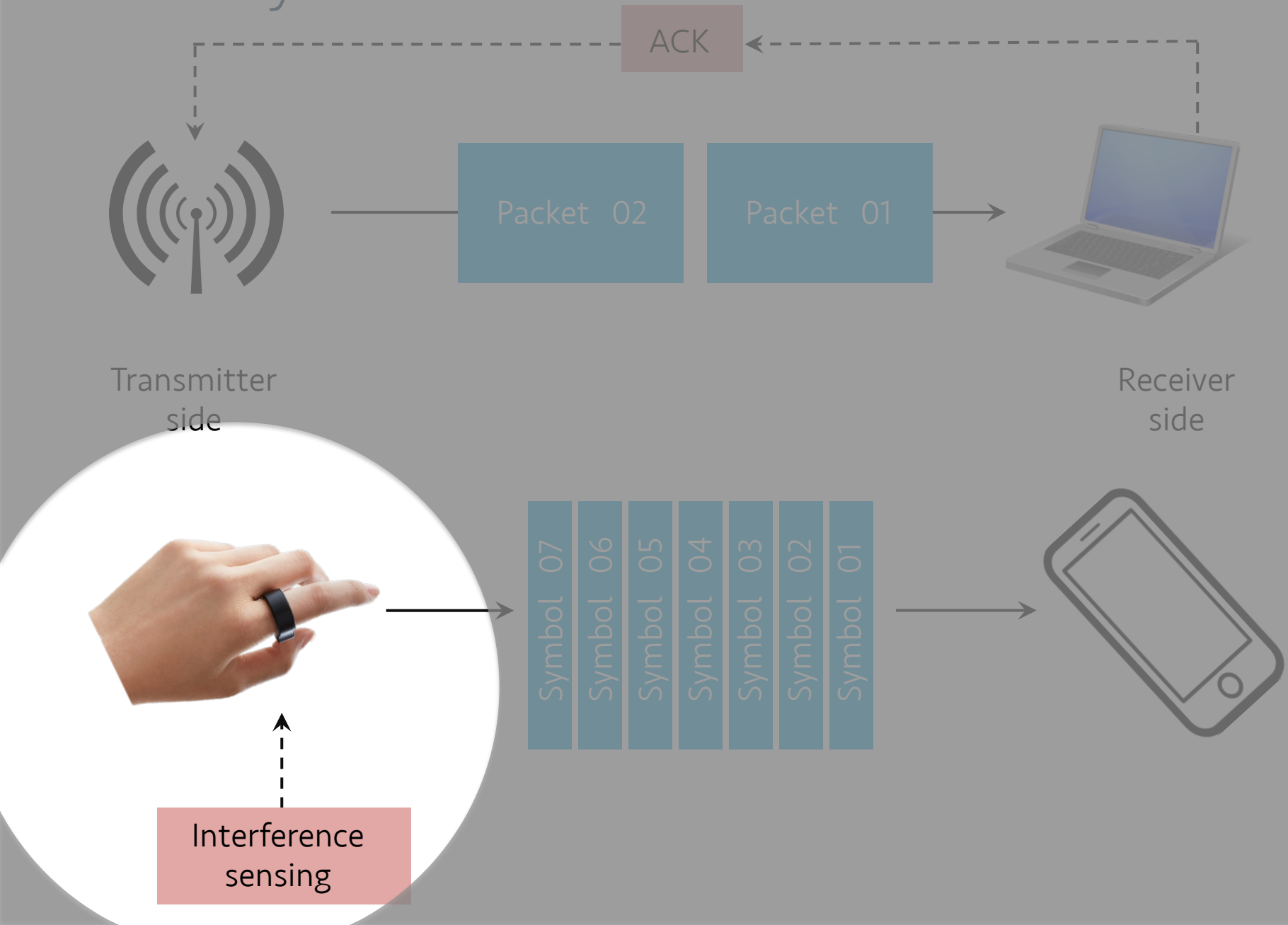
Symbol 07 | Symbol 06 | Symbol 05 | Symbol 04 | Symbol 03 | Symbol 02 | Symbol 01



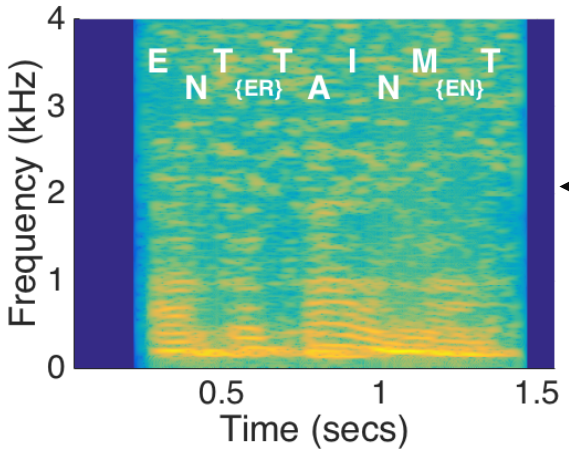
MAC layer rate control

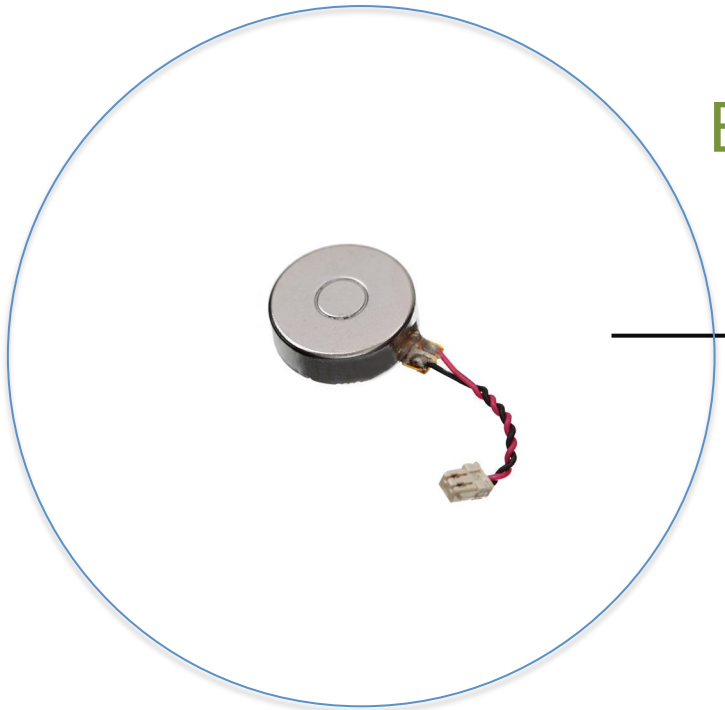


MAC layer rate control

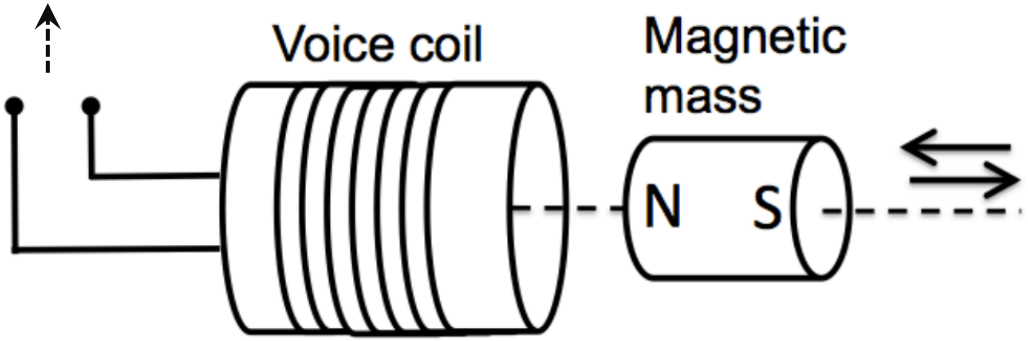


MAC layer rate control

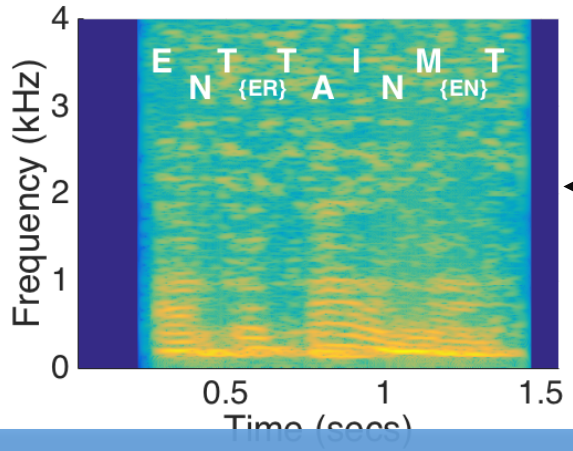




Back-EMF

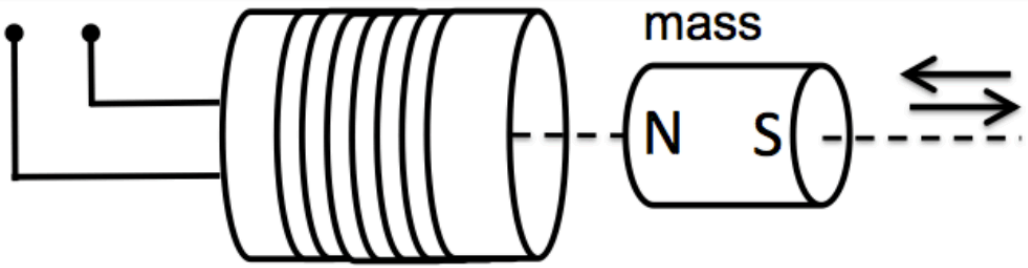


MAC layer rate control

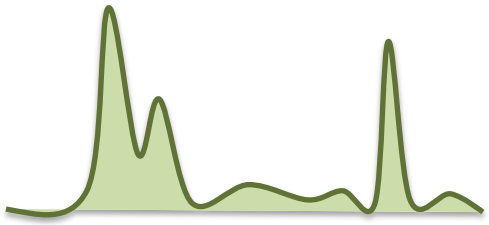


"Listening through a Vibration Motor"

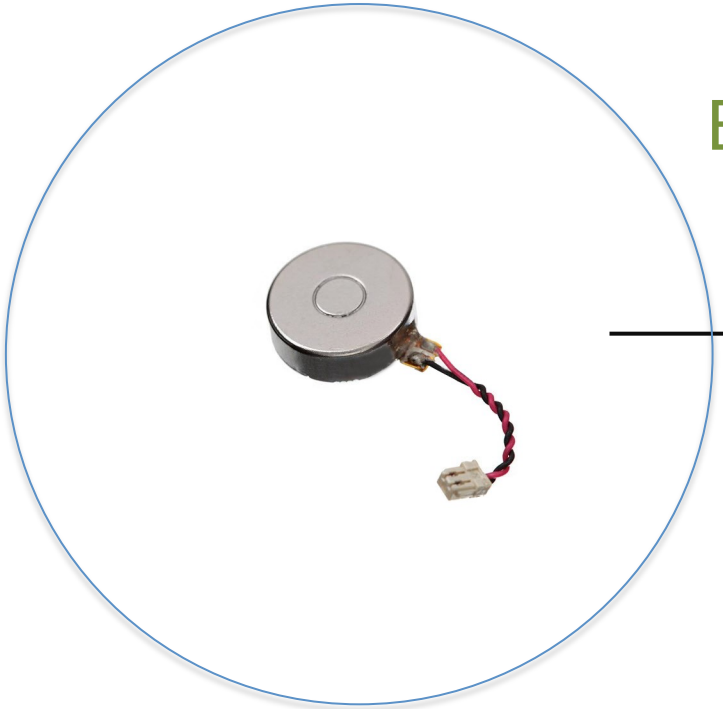
Nirupam Roy, Romit Roy Choudhury [MobiSys 2016]

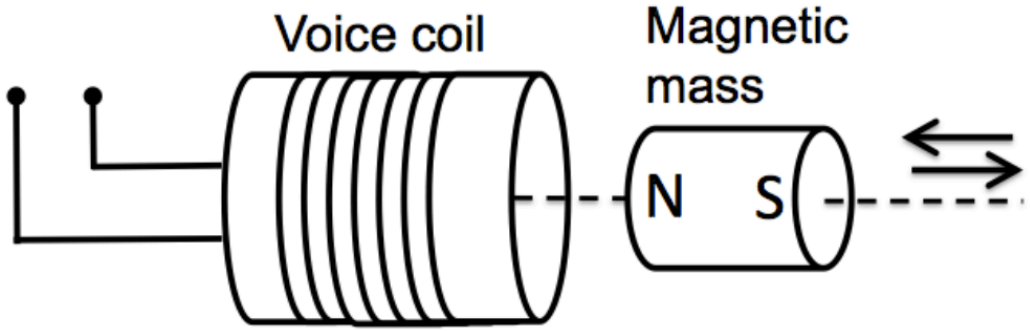


MAC layer rate control

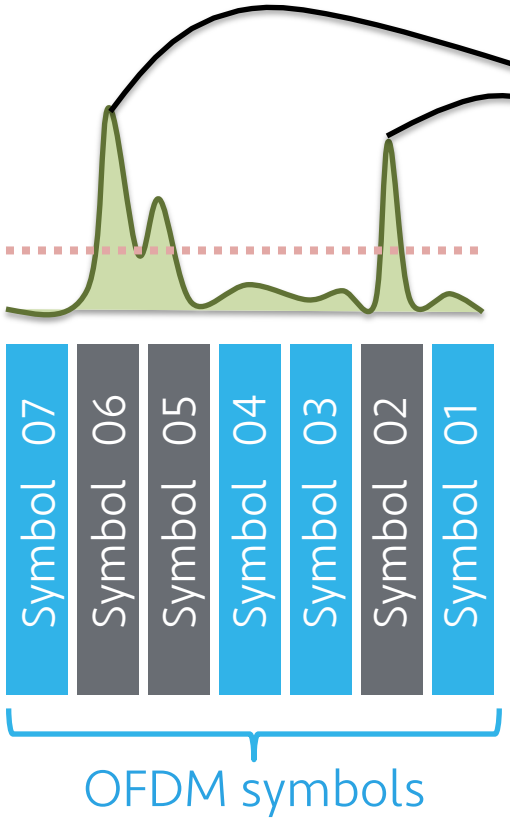


Back-EMF



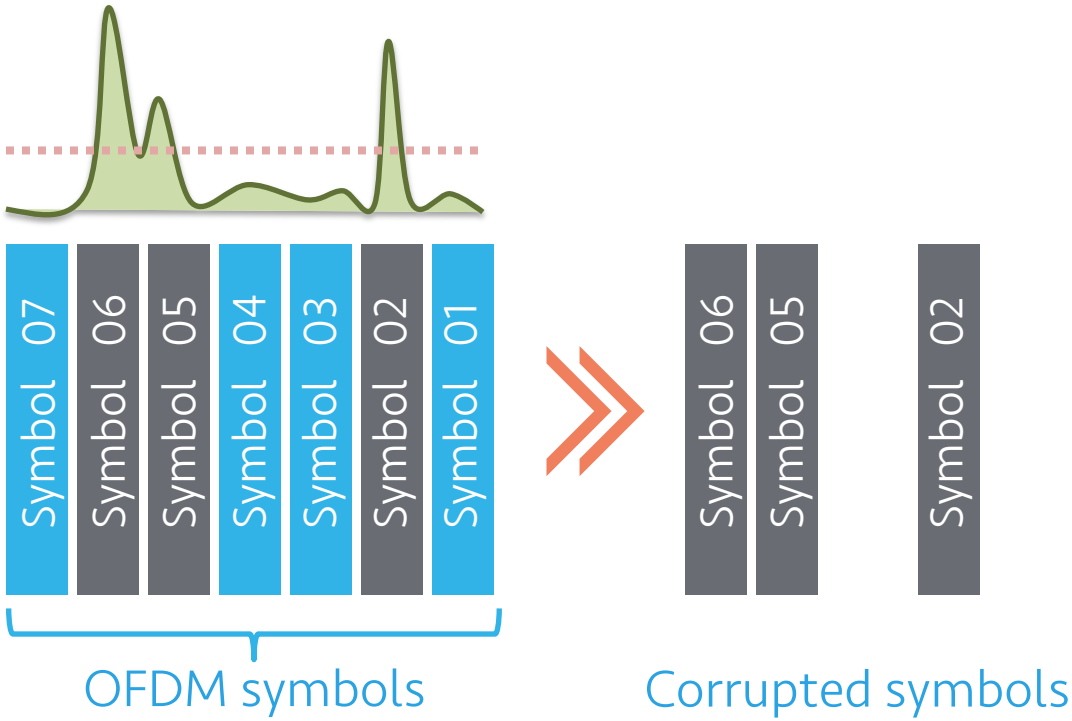


MAC layer rate control

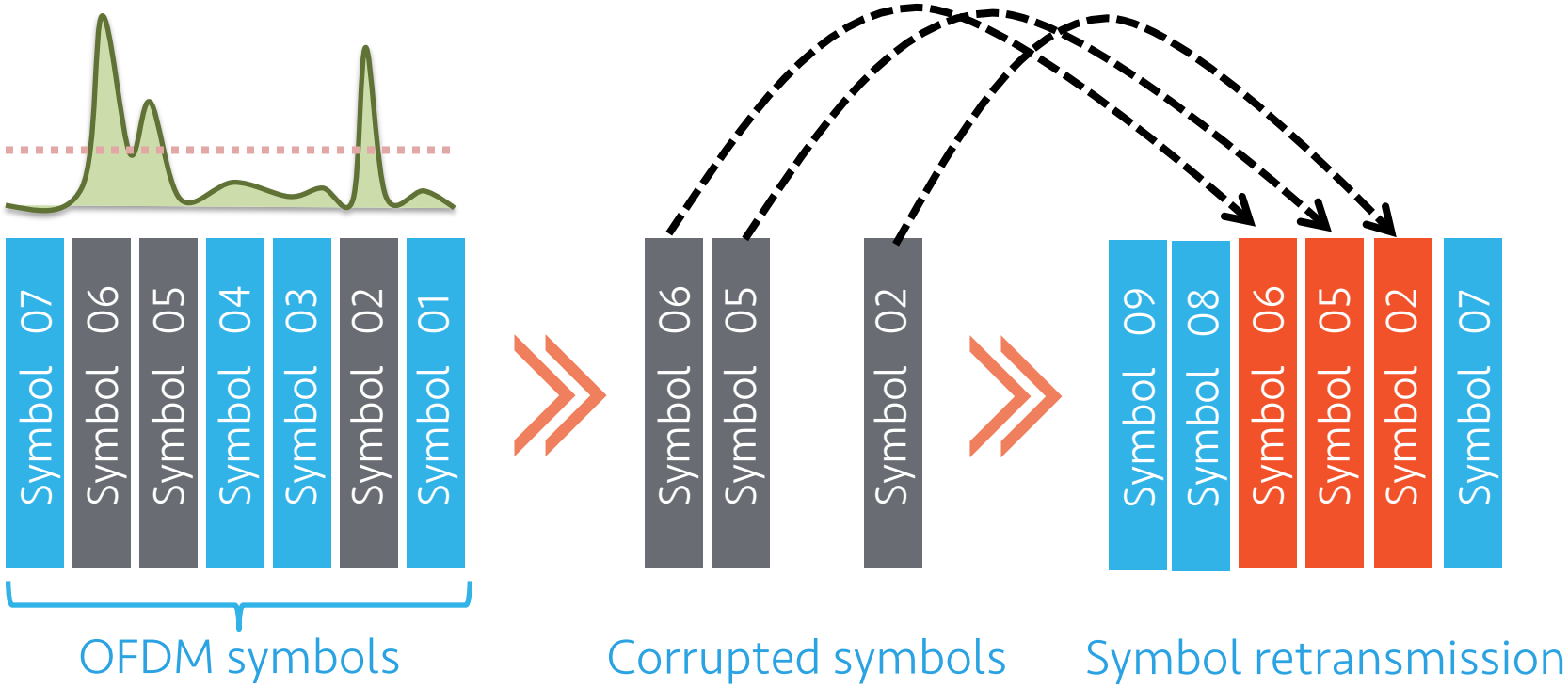


Low “Signal to Interference and Noise Ratio” (SINR)

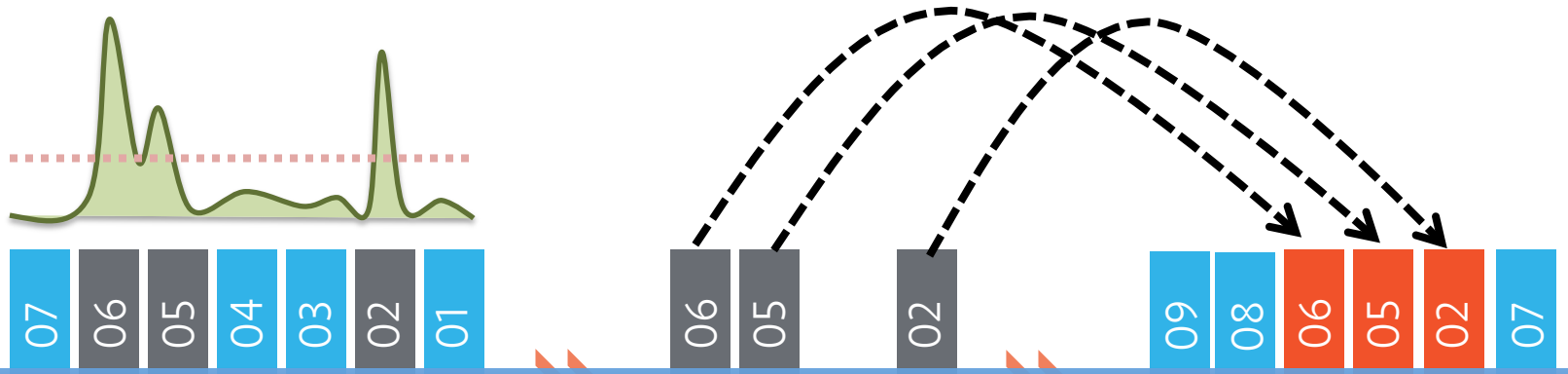
MAC layer rate control



MAC layer rate control



MAC layer rate control



What is the data-rate of the duplicate symbol?

How can the receiver detect a duplicate symbol?

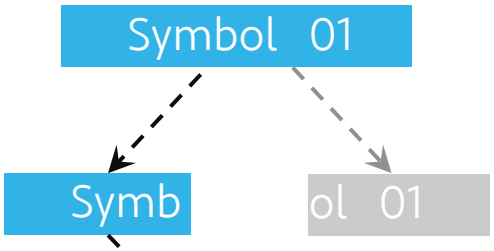
OFDM symbols

Corrupted symbols

Symbol retransmission

MAC layer rate control

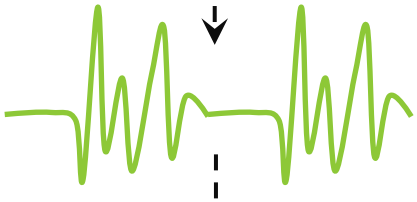
Half of the symbol per retransmission



Doubles per bit energy

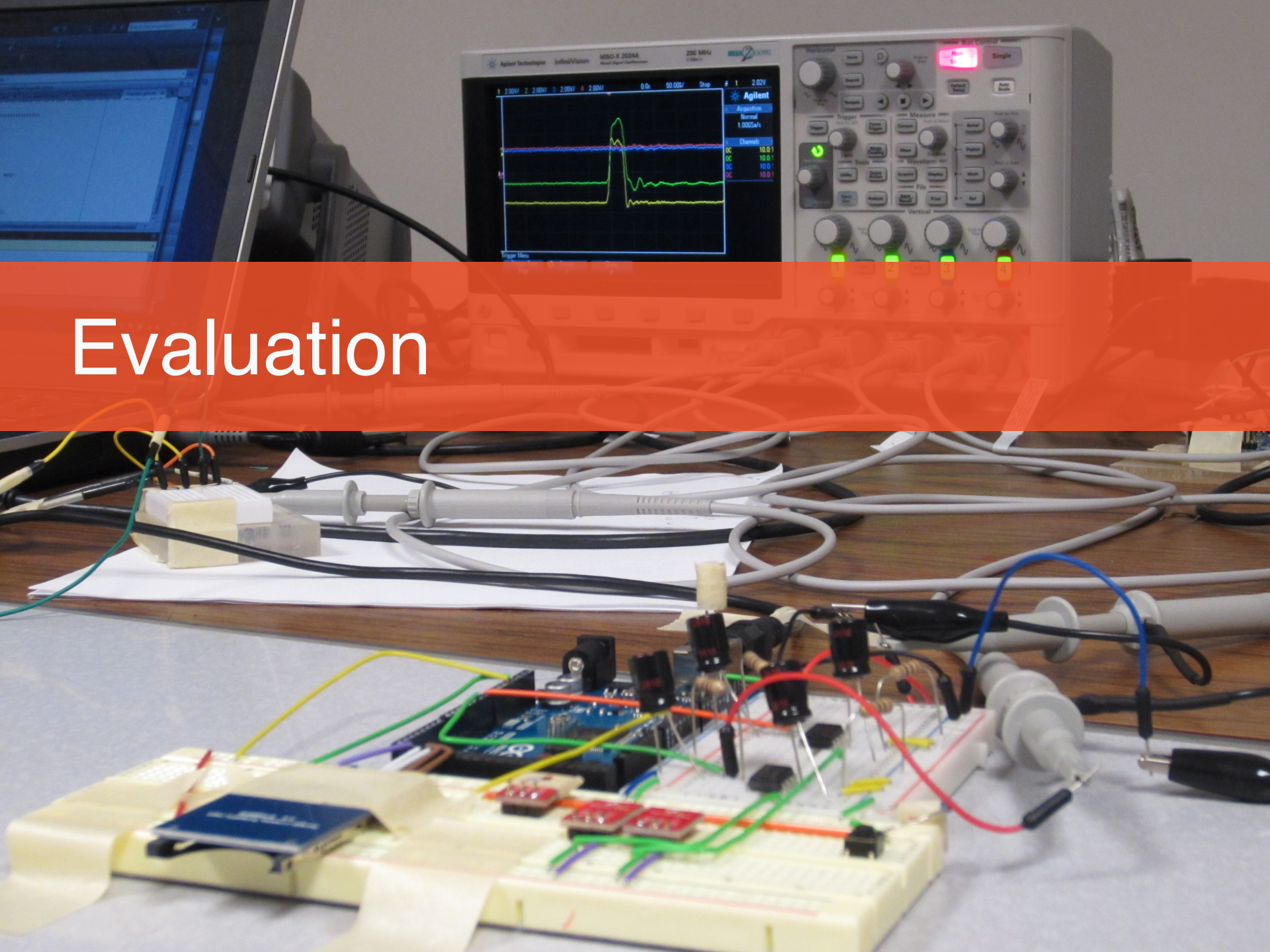
Data in alternate frequency bins

Identical halves in the time domain signal

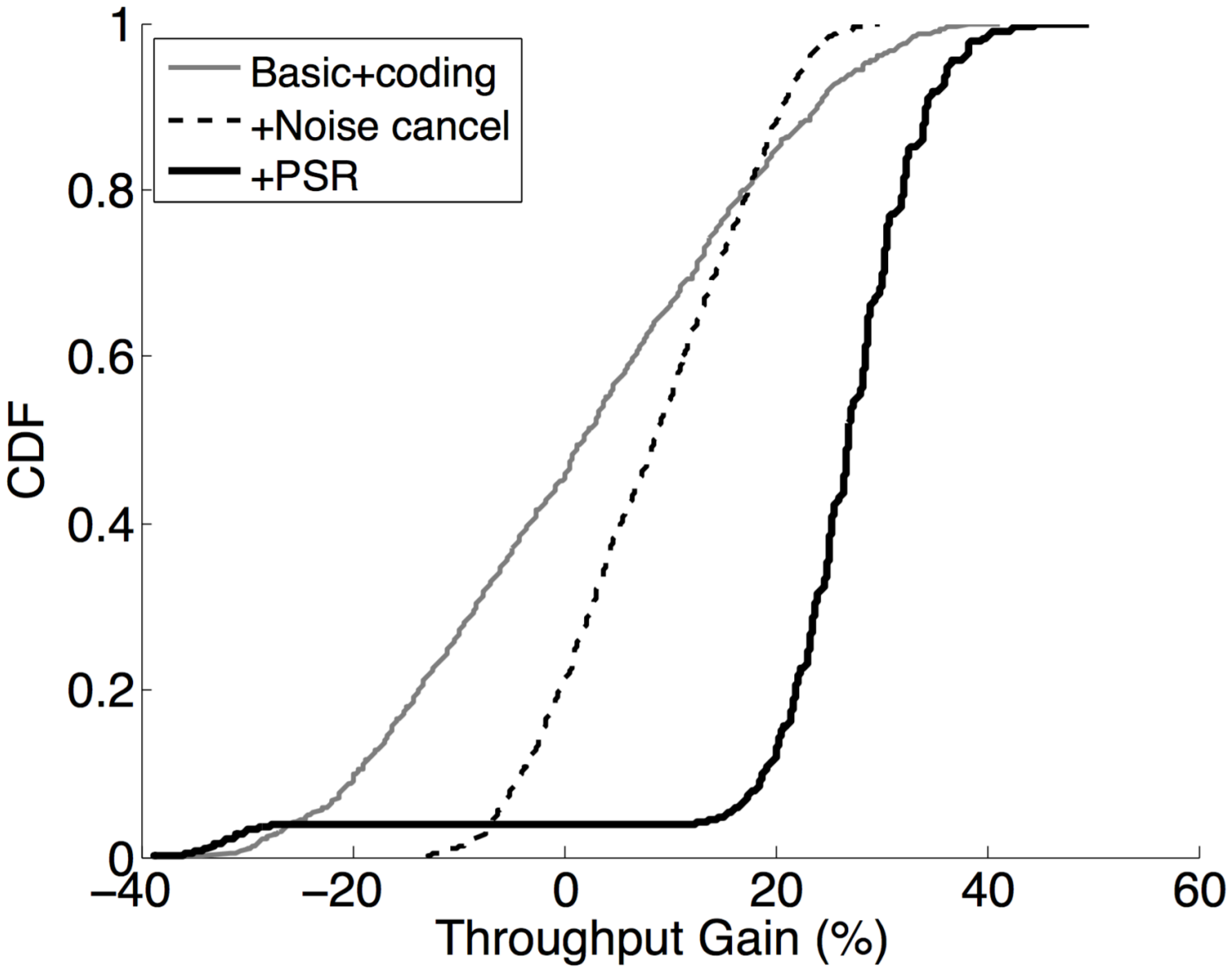


Algorithm detects this special symbol at the receiver

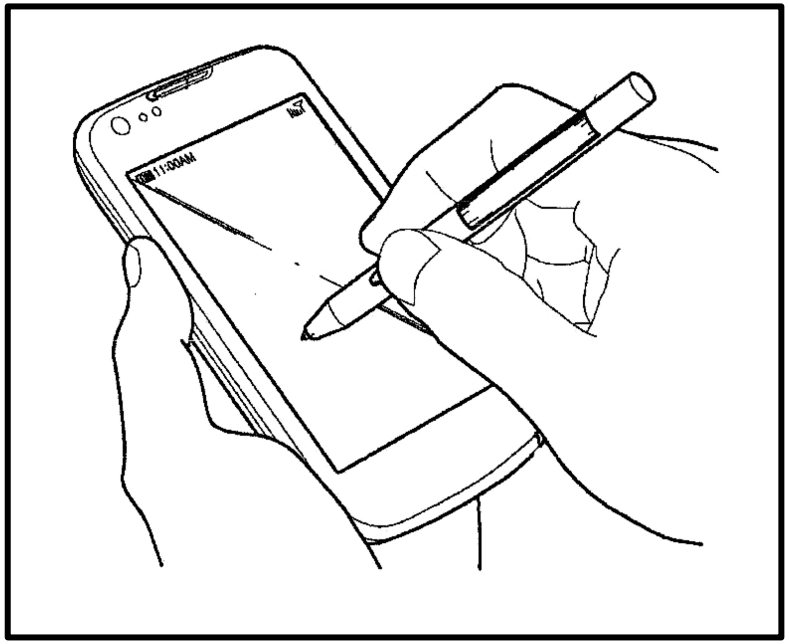
Evaluation

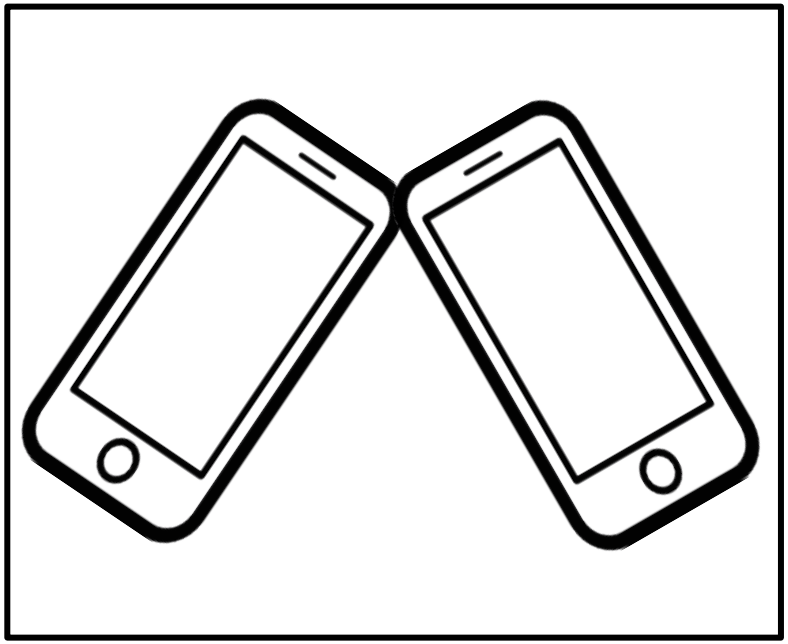


Evaluation


Basic+coding
+Noise cancel
+PSR
CDF
1
0.8
0.6
0.4
0.2
0
–40
–20
0
20
40
60
Throughput Gain (%)

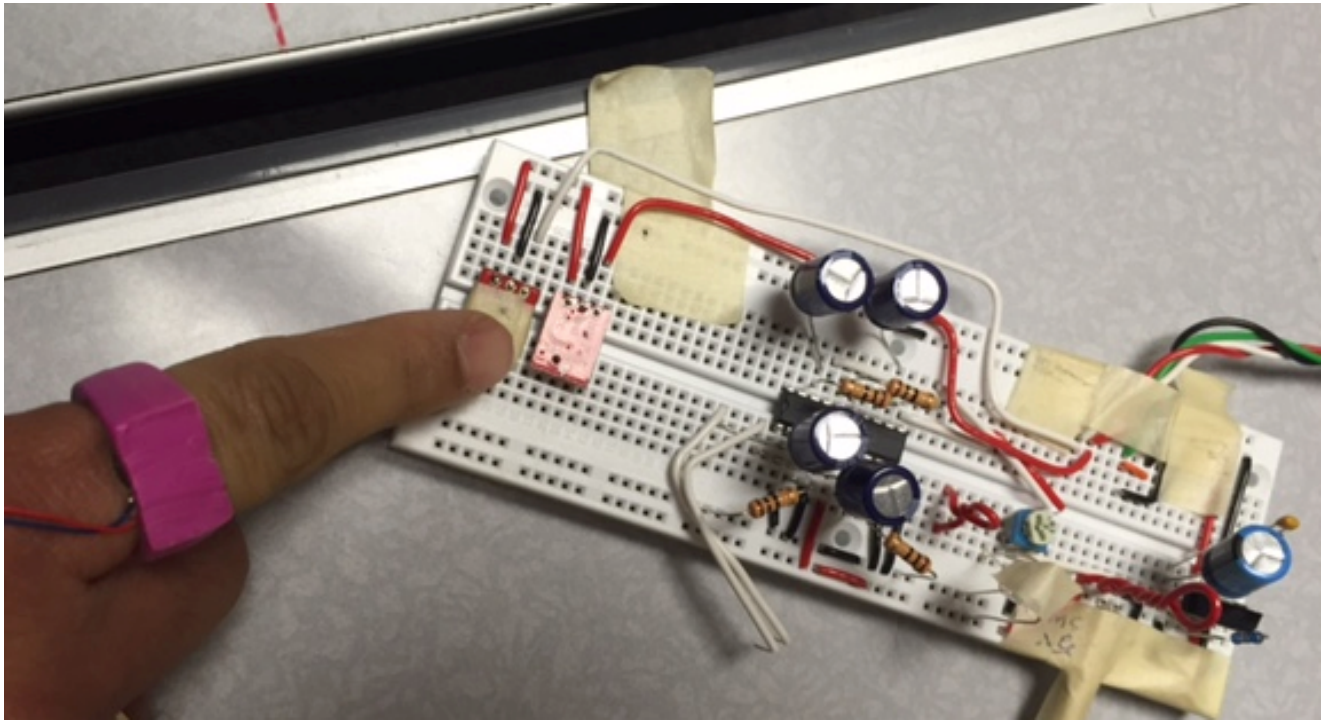
Evaluation





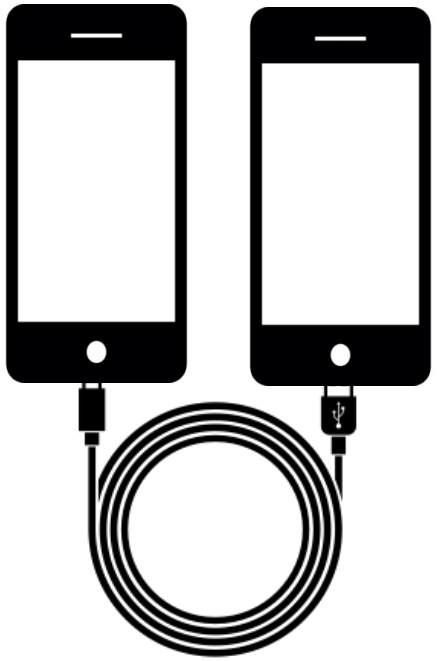
	Bandwidth	Modu.	Code	Tput:Kbps
Stylus	12 KHz	16 QAM	2/3	29.19
Phone	12 KHz	16 QAM	2/3	26.13

Evaluation



	Bandwidth	Modu.	Code	Tput:Kbps
Ring	8 KHz	QPSK	1/2	7.41
Watch	3 KHz	QPSK	1/2	2.23

Applications



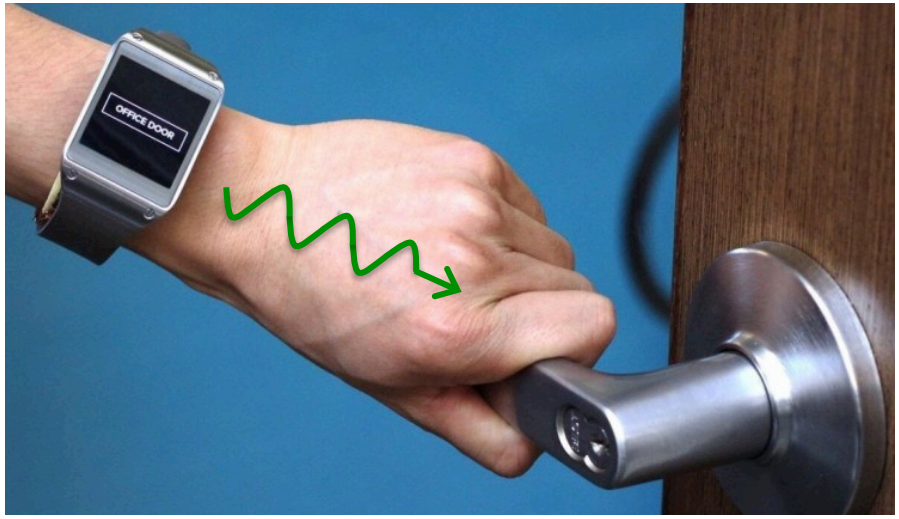
Vibrations do not **tether**

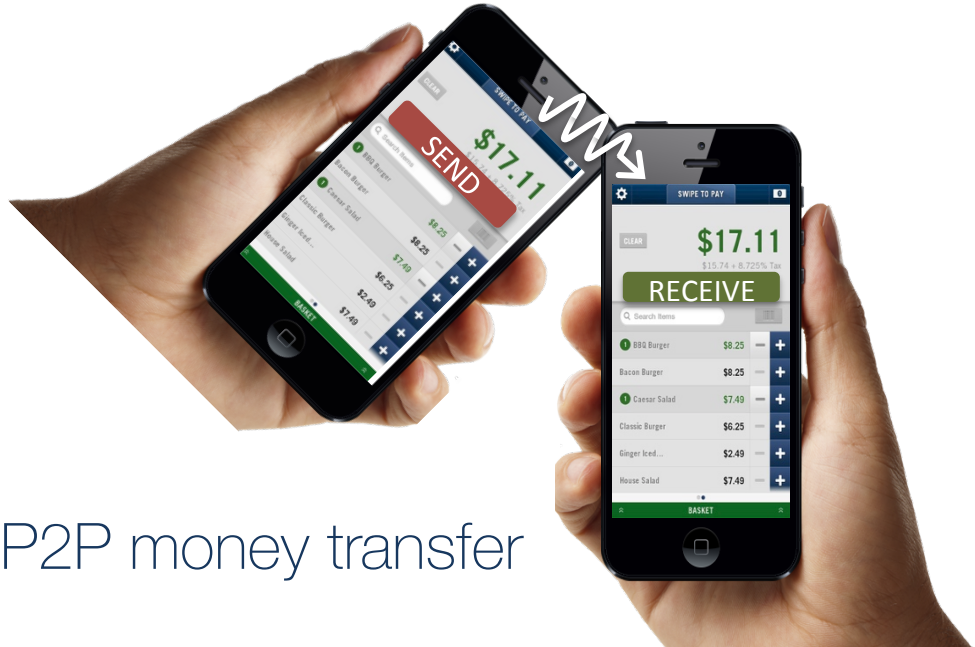
Vibrations do not **broadcast**

Vibratory communication

Applications

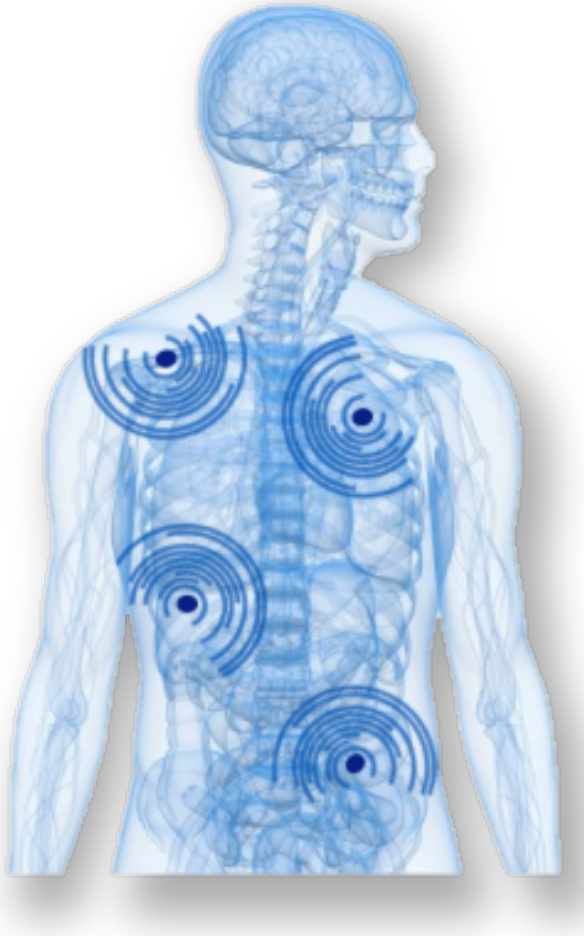
Touch activated smart-lock

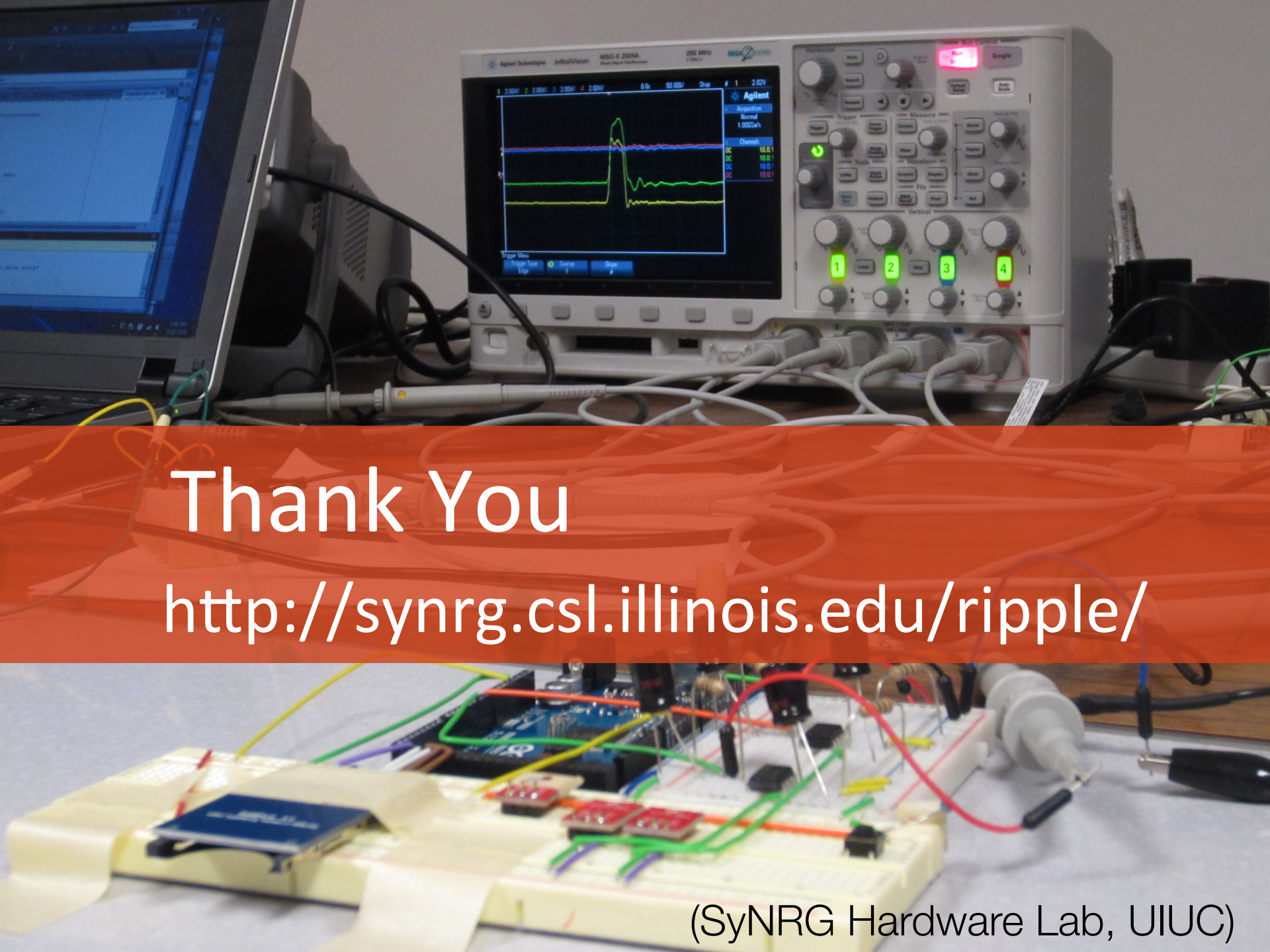




P2P money transfer

Communication through bone conduction





Thank You

http://synrg.csl.illinois.edu/ripple/

(SyNRG Hardware Lab, UIUC)