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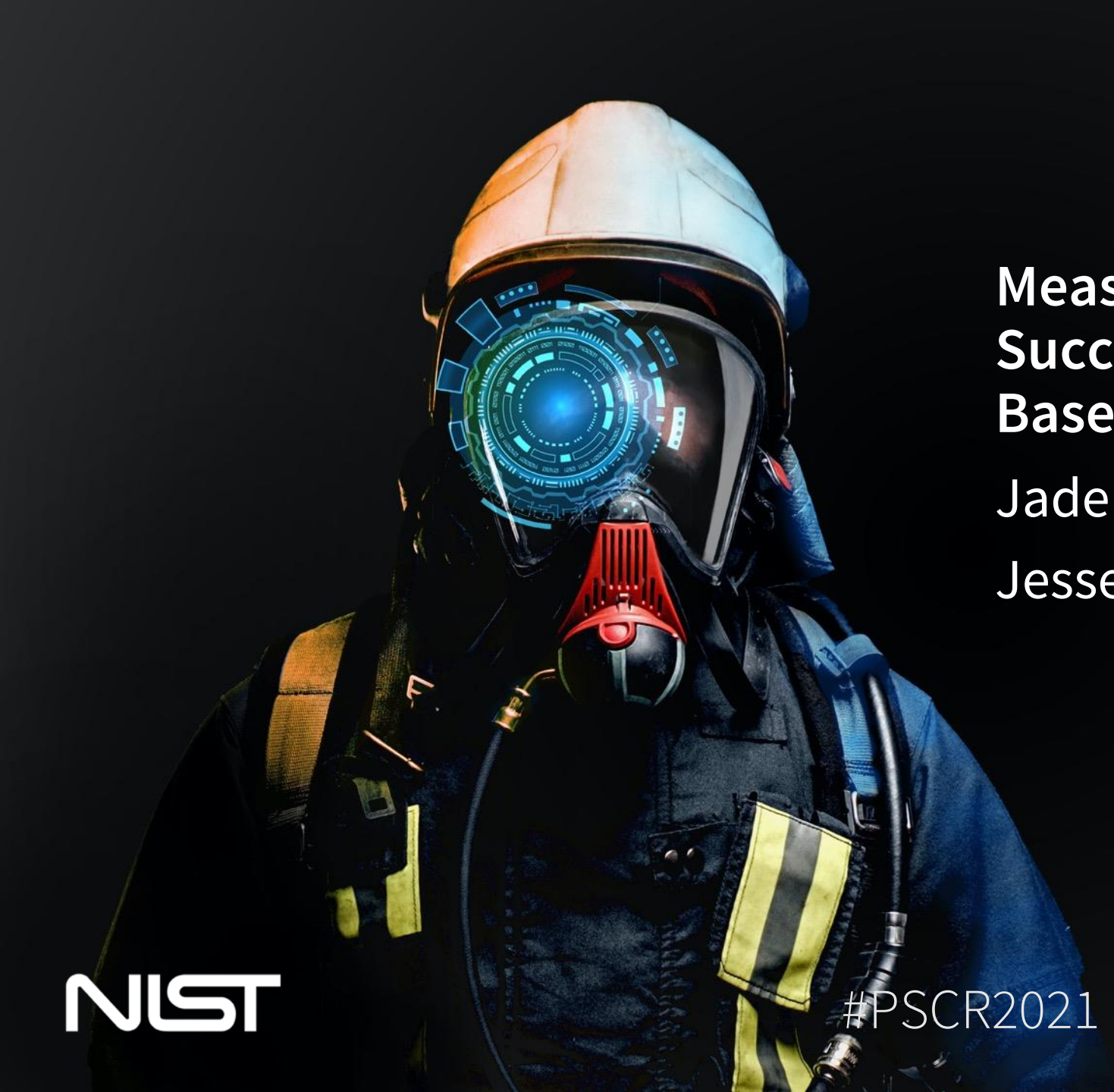

Measuring the Probability of Successful Delivery: a QoE Based Approach

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Overview

- Quality of Experience Based Measurements
- Probability of Successful Delivery Definition
- Intelligibility
- Measurement Technique
- Validation
- Future Work

Quality Of Experience (QoE) Based Measurements

- QoE KPIs for Mission Critical Voice (MCV)
  - Mouth-to-Ear Latency
  - Access Time
  - Voice Quality/Intelligibility
  - Probability of Successful Delivery (PSuD)

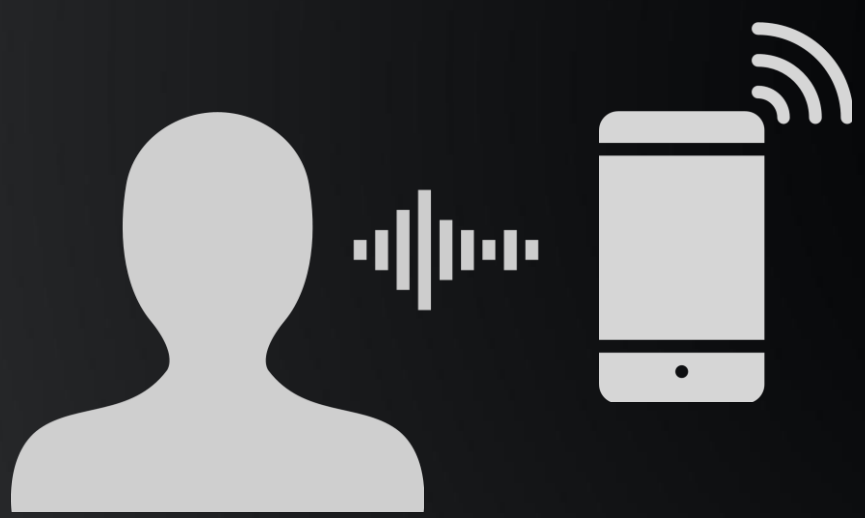
The User Experience: PTT Communications

- Press the Push To Talk (PTT) button and speak into a device
- Listening to speech output from a device
- It is all about speech

- Goal - Create measurement systems that are:
  - Based upon the user experience -- speech
  - Comparable and fair across technologies
- This is not:
  - Analyzing internal system design/construction

Technology Agnostic Measurements

Communications System



KPIs:

- Mouth-to-ear Latency
- Access Time
- Intelligibility
- Probability of Successful Delivery

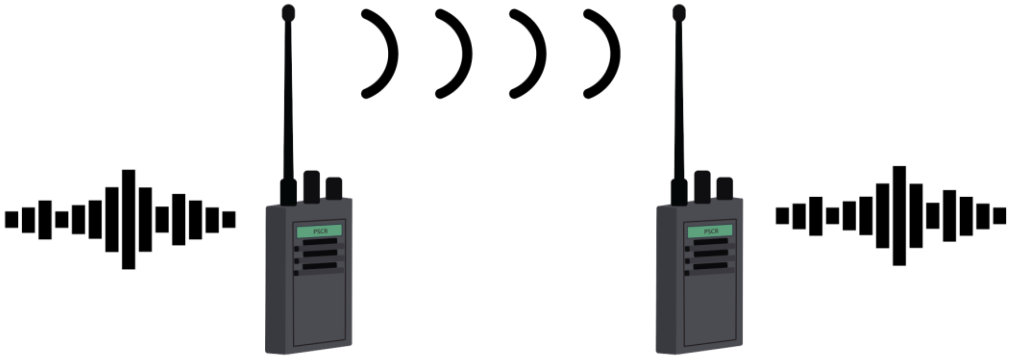
Probability of Successful Delivery

- Probability of Successful Delivery (PSuD)
  - **Definition:** The probability of successful delivery, $P_S(T)$, is the probability of successfully transmitting and receiving a message of length T.
- Encompasses probability of access and retention
  - Hard to separate
  - Roll into one
- Length of your message matters
- What is success?
  - Achieves an intelligibility threshold

Probability of Successful Delivery

Send the same message 5 times

Radio



Full message intelligible?

Examples of received messages:

Radio | Ra...o | ...dio | Radio | Radi...

Probability of Successful Delivery of "Radio" = 2/5 = 40%

Intelligibility

- Modified Rhyme Test (MRT)
  - Batches of six words
    - *went, sent, bent, dent, tent, rent*
    - Words within a batch rhyme
    - 50 batches total, 300 MRT keywords
  - MRT Trial
    - Carrier phrase + word
    - “Please select the word *went*”
    - Success (identified) or Failure (mis-identified)
- ABC-MRT16
  - Objective algorithm to estimate MRT scores
  - Get results “on demand”
- For more information, view the on-demand session:
  - Designing Remote Listening Experiments for the Partially Muted Word Impairment

Measurement Strategy

- Send strings of MRT keywords through a system
  - From ABC-MRT16 database[1]
  - No carrier phrase, keywords only
- Measure intelligibility of each word
- Determine if message was a success or not
- Do this over lots of trials

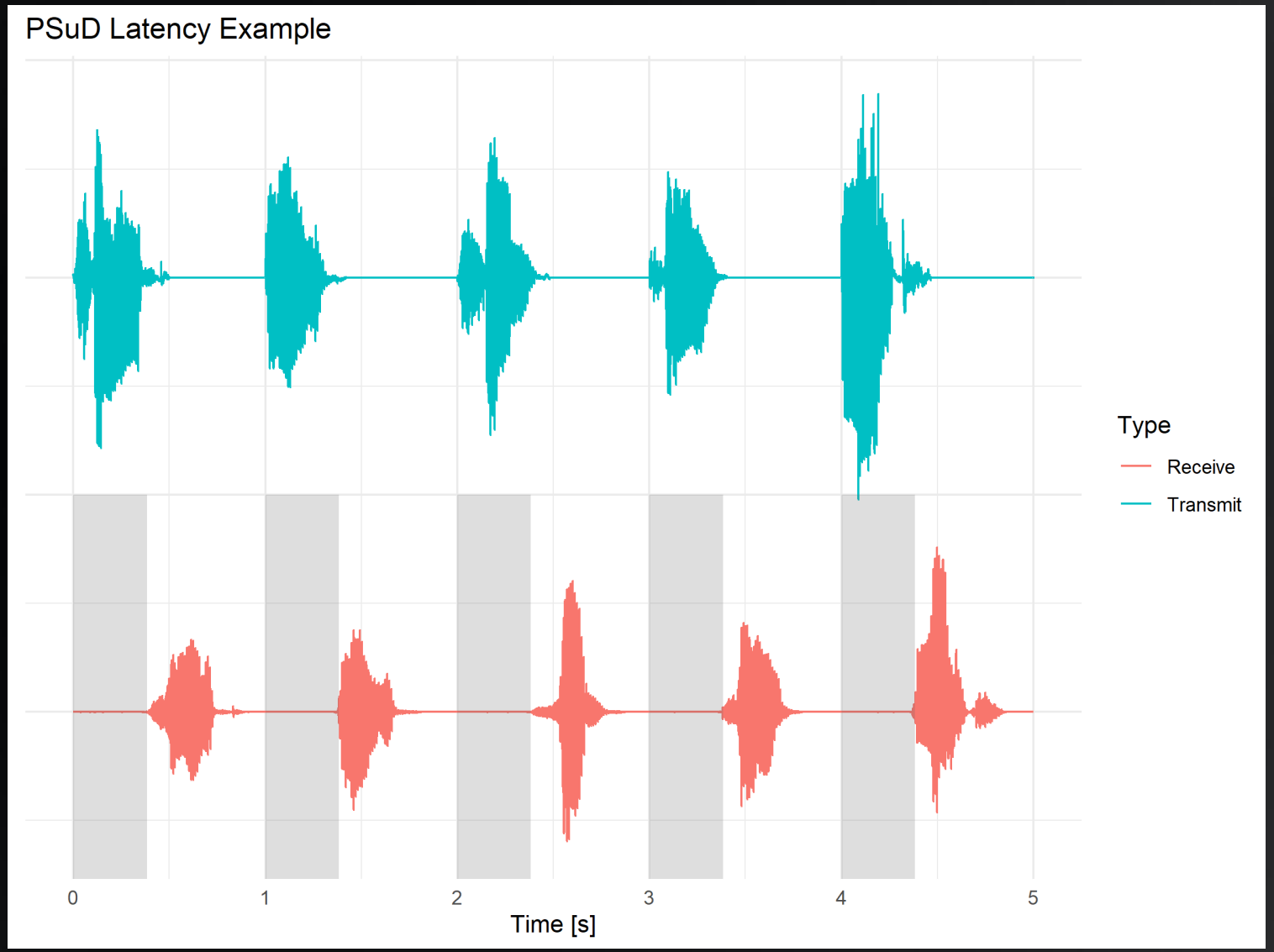
1: Voran SD (2017) A multiple bandwidth objective speech intelligibility estimator based on articulation index band correlations and attention. 2017 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), pp 5100–5104.doi: 10.1109/ICASSP.2017.7953128

Audio Clip Structure

- 10 second clips, one MRT keyword every second
- Highly structured, know where words should be
- Good neighbors
  - No keywords near keywords from shared batches
  - “look” is not next to “hook”
  - Prevents poor alignment causing estimate errors
- MRT Coverage
  - Broad sense of system performance
  - 10 words per clip
  - 30 clips is full coverage for a talker
  - 4 orderings to minimize additional vocoder effects
  - 120 clips per talker, 480 total (4 talkers)

Latency Estimation

- Need to know what word is where
- Challenging when lots of audio is missed
- Clip structure alleviates this
- Can eyeball latency



Classifying Success

- Intelligibility thresholds
- What about context?
  - Normal speech tends to have it
  - Special cases do not
    - Phone numbers, license plates
    - Addresses if you do not know the area
- No context is worst case scenario for PSuD
  - Cannot miss a single word
- MRT strings lack context
  - Simulates special no-context cases perfectly!
  - How do we simulate context?
  - PSuD needs to be more robust than the worst-case scenario

Simulating Context

- Every Word Critical: EWC
  - Worst case
  - No context
- Average Message Intelligibility: AMI
  - Best case
  - Context distributed uniformly through a message
- Autoregressive Filter: AR(1)
  - Somewhere in the middle
  - Filter weight gives us a dial to play with
  - Simulates message context memory

Every Word Critical (EWC)

- Success – every word of the message achieves the threshold intelligibility
- No context in the message
- Worst case scenario
  - Lose one word, the rest of the message fails

Example Data - P25 Direct
Threshold = 0.7

Word	W0	W1	W2	W3	W4	W5	W6	W7	W8	W9
Word Intelligibility	1	0.4375	0.75	0.875	1	1	1	1	1	1

Average Message Intelligibility (AMI)

- Success – average intelligibility over the whole message exceeds a certain threshold
- $\text{Output}(k) = \frac{1}{k+1} * \sum_{j=0}^{k} \text{Input}(j)$
- Context is uniformly distributed throughout the message
- Best case scenario: lose one word, every other word provides context

Example Data - P25 Direct
Threshold = 0.7

Word	W0	W1	W2	W3	W4	W5	W6	W7	W8	W9
Word Intelligibility	1	0.4375	0.75	0.875	1	1	1	1	1	1
Filtered Intelligibility	1	0.7188	0.7292	0.7656	0.8125	0.8438	0.8661	0.8828	0.8958	0.9063

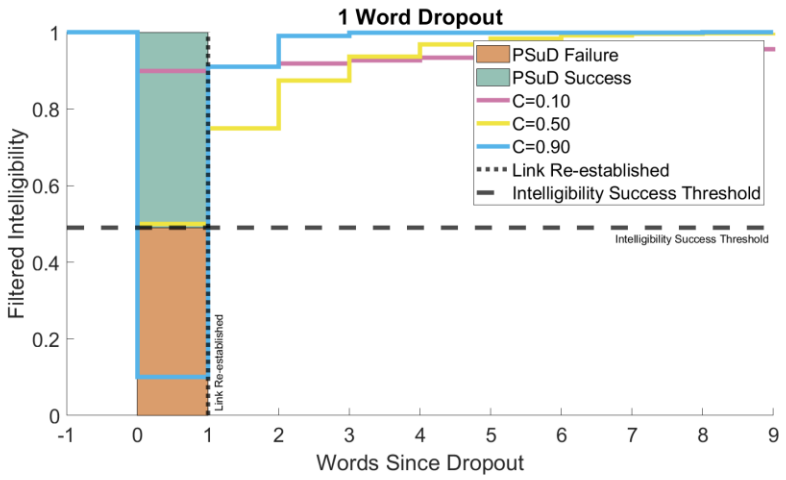
Autoregressive Filter - AR(1)

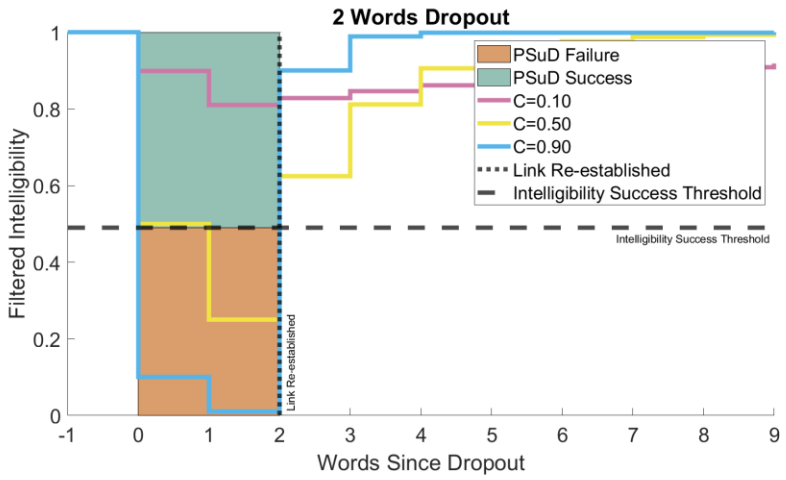
- Success – Filtered intelligibility for each word of the message exceeds a certain threshold
- $\text{Output}(k) = c * \text{Input}(k) + (1 - c) * \text{Output}(k - 1)$
- Context decays as you move away from a previous word
- Middle ground
  - Filter parameter controls decay rate

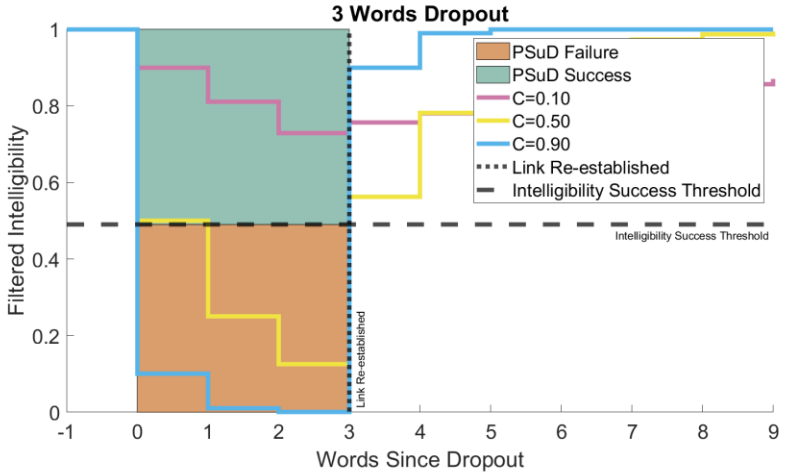
Example Data - P25 Direct
Threshold = 0.7
$c = 0.5$

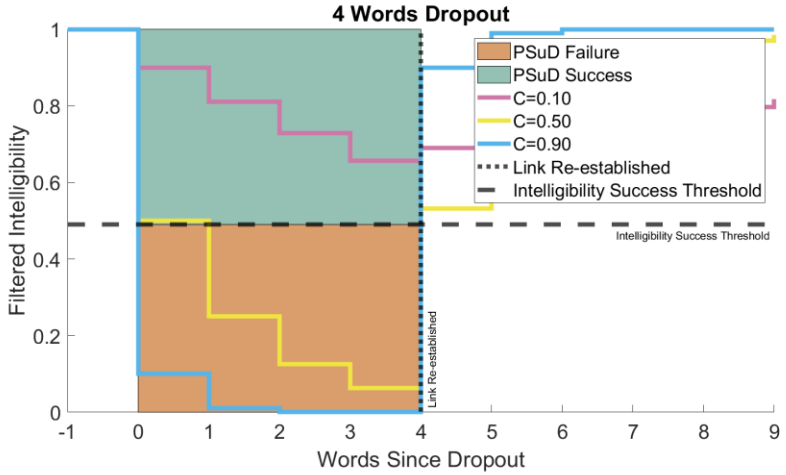
Word	W0	W1	W2	W3	W4	W5	W6	W7	W8	W9
Word Intelligibility	1	0.4375	0.75	0.875	1	1	1	1	1	1
Filtered Intelligibility	1	0.7188	0.7344	0.8047	0.9023	0.9512	0.9756	0.9878	0.9939	0.9969

Autoregressive Filter – AR(1)

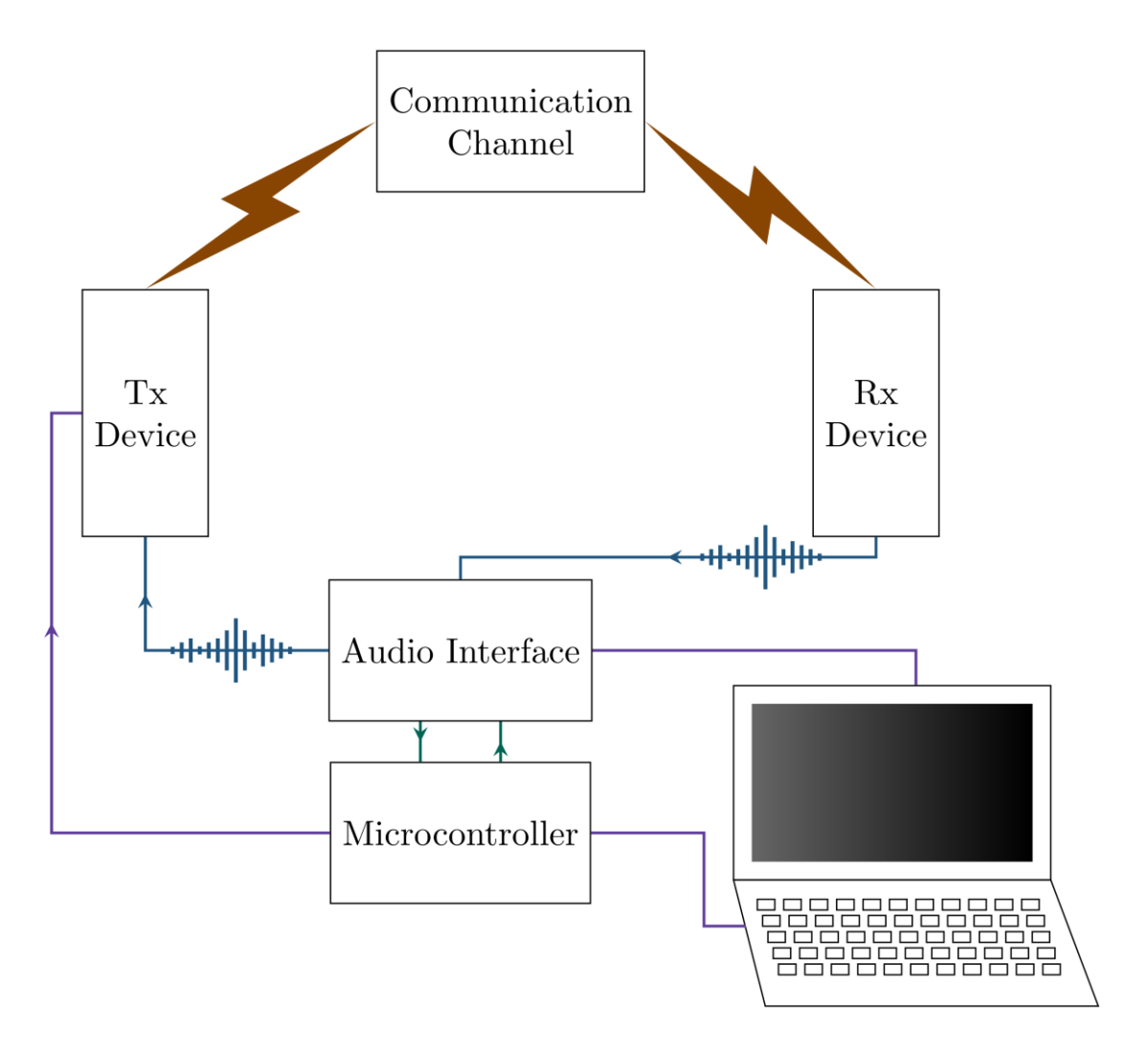








System Diagram



Measurement Software

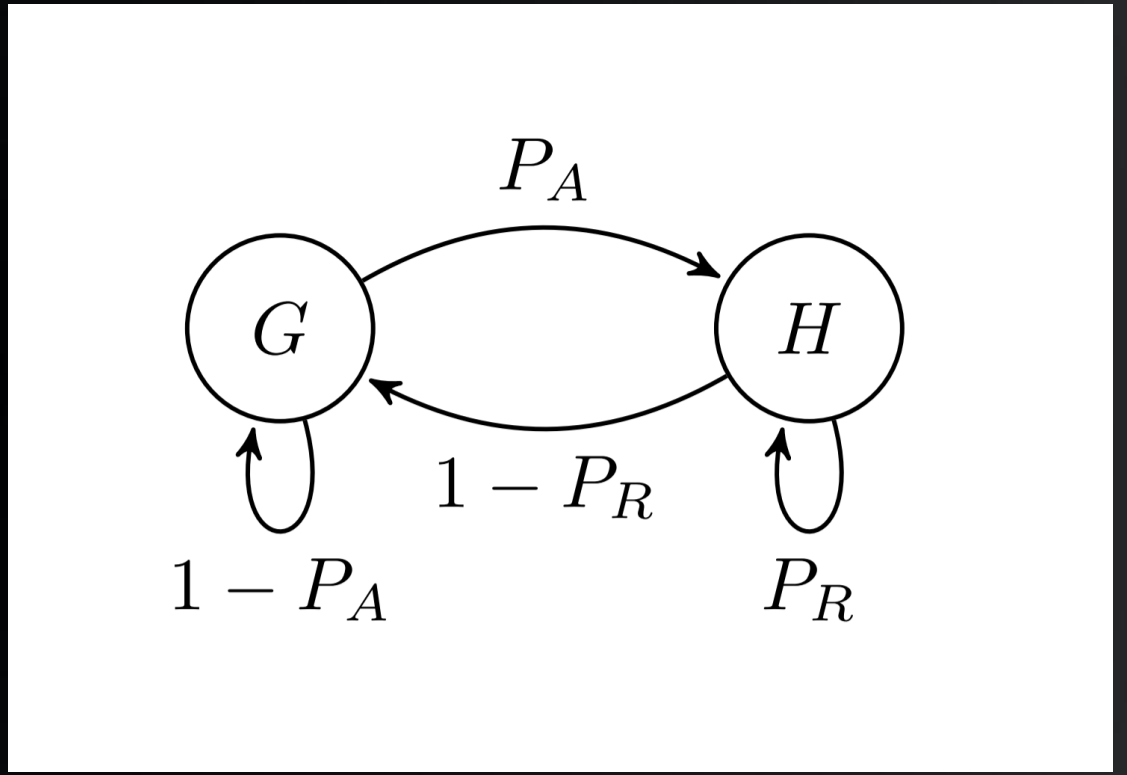
- Developed in Python
  - MCV shared code modules
- Improved simulation features
- For more information, please view the on-demand session:
  - QoE Software and Hardware Packaging

Validation

- Need to know measurement is accurate
- Simulated measurements
  - Software implementations
    - Radio interface
    - Audio interface
- Control impairments directly
- Verify results match expectation

Validation

- Model
  - G - communication links not established
  - H - communication link established
  - P_A - probability of establishing communication link
  - P_R - probability of retaining communication link
- Markov Model
  - Every word critical (EWC) case
  - PSuD of T second long method, state changes every c seconds.
  - $P_S(T) = \frac{P_A}{1+P_A+P_R} * P_R^{\left(\frac{T}{c}\right)-1}$



Future Work

- Continue developing context methods
- Validating measurement strategy is successful on more technologies
- Radio frequency (RF) channel impairments
- Two-location measurements

Related PSCR 2021 On-Demand Sessions

- Mission Critical Voice Quality of Experience Measurement Methods Overview
- Introducing a Start of Word Correction for Access Delay Measurements
- Designing Remote Listening Experiments for the Partially Muted Word Impairment
- Optimal Transmit Volume Conditions for MCV QoE Measurement Systems
- QoE Software and Hardware Packaging
- QUARC: Quality Under Adjustable Realistic Conditions for Communication Systems
- Lab from Home: Distributed QoE Testing for Mission Critical Voice

Questions

- Looking forward to answering questions at our live Q&A session!

THANK YOU

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