A Platform for Experimental Research in Critical Voice Communications

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https://irtlab.gitlab.io/mcv-testbed

Introduction

How does the quality of the communication channel affect first responder communications?

Quality of Experience (QoE) Measures:

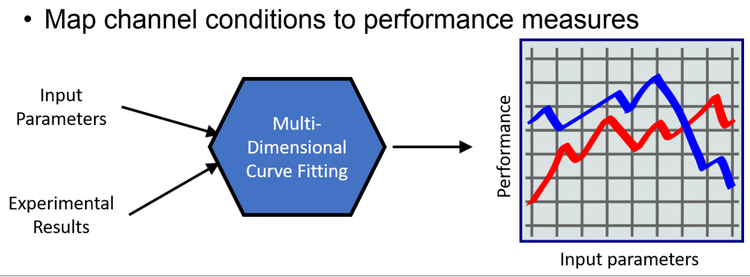
- Comprehension errors
  - ▸repeat transmitted messages
- Task errors
  - ▸wrong information recorded
- Usage errors
  - ▸pressing PTT button too early or too late
- Length and latency of responses
  - ▸pauses between requests and start of transmissions
- Subjective ratings of user experience
  - ▸rated frustration with radio operation

Evaluate in experiments with volunteer human subject in a controlled environment

Approach

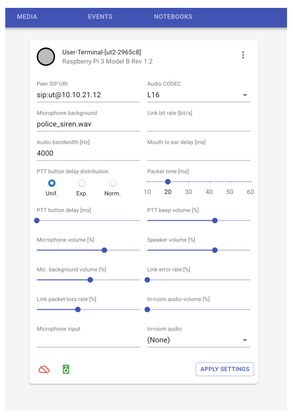
Four-phase approach:

1. **Design and build a communication testbed**
   - Emulate real mission critical voice (MCV) systems
   - Configurable audio and network impairments
2. **Experiment with trained first responders**
   - Communicate using the testbed in a controlled environment
3. **Measure communication performance**
   - Analyze data collected during experiments
4. **Build mathematical models**
   - Map channel conditions to performance measures

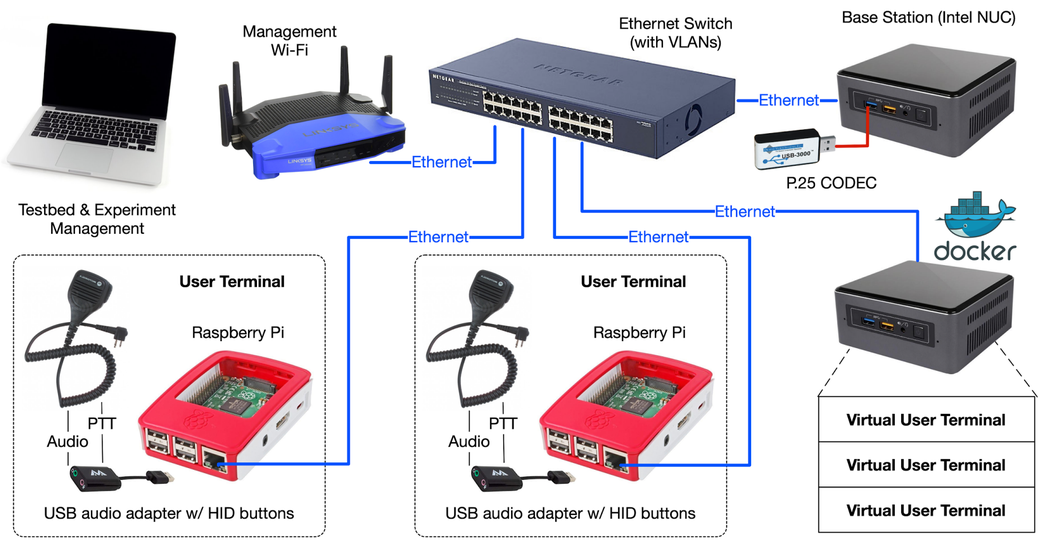


Experimental Testbed

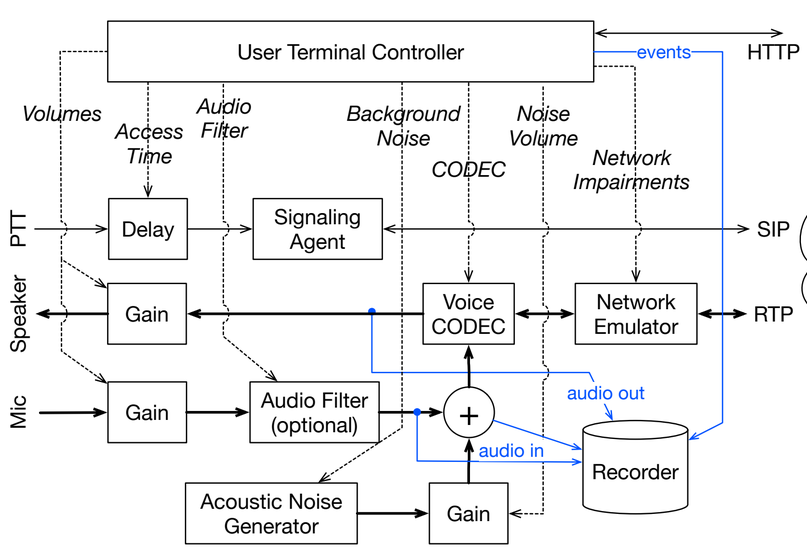
- Open hardware & software
- Affordable off-the-shelf components (Raspberry Pi)
- Emulates analog & digital MCV systems (P.25 Phase 1 & 2)
- Programmable audio & network impairments
- Support for interactive and listening (at-home) experiments



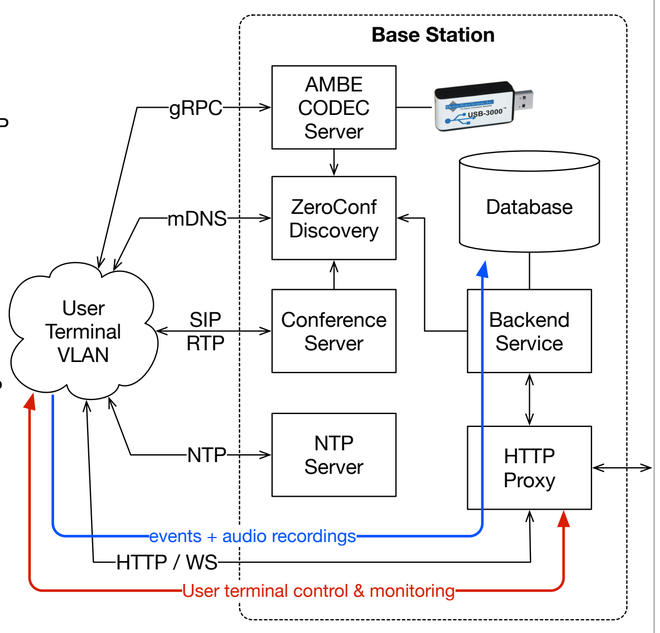
Testbed Architecture



Network architecture diagram



User terminal architecture

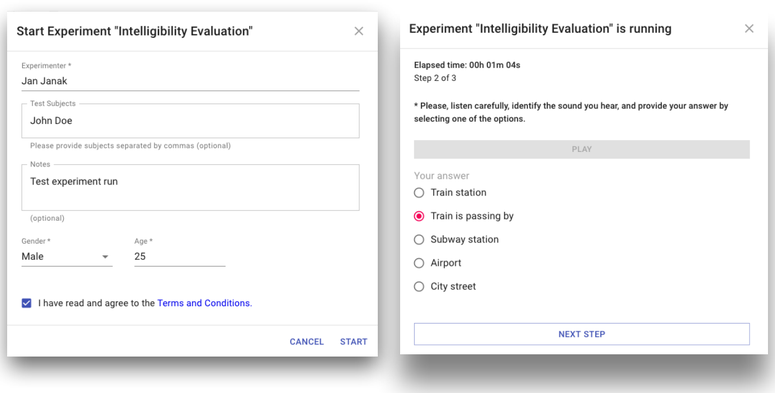


Base station architecture

Listening Experiments

- A series of impaired audio recordings (via text-to-speech)
- Browser UI for playback & data collection
- Anti-cheat design (play once only, no pause)
- Accessible from test subjects' homes

Automated experiment and impaired audio recording generation



License Plate Transcription Experiment

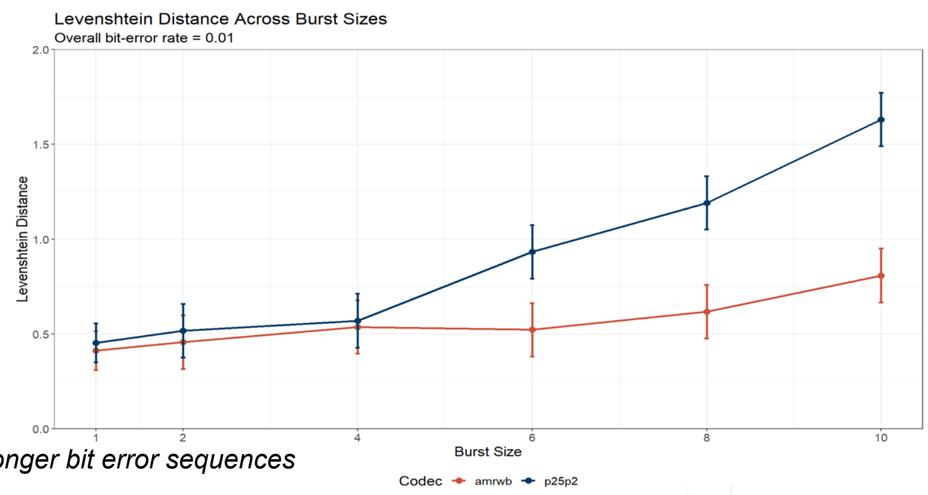
Evaluation by Lauren Berny, John Jay College

- New Jersey license plates using NATO alphabet
- 48 participants x 72 trials = 3,456 total trials
- Correlated (Gilbert-Elliot model) frame loss and bit errors
- Levenshtein distance to measure license plate recording error
- Compare codec performance: P.25 Phase 2 versus AMR-WB

Results:

- Comparable performance until clustering factor 4
- Levenshtein distance (error measure) grows faster for P.25 with longer error bursts

Codec	Condition	Levenshtein Distance
amrwb	Condition 1 - p0k1	0.344
p25p2	Condition 1 - p0k1	0.394
amrwb	Condition 2 - pgb001p001k2	0.403
p25p2	Condition 2 - pgb001p001k2	0.442
amrwb	Condition 3 - pgb001p001k4	0.479
p25p2	Condition 3 - pgb001p001k4	0.500
amrwb	Condition 4 - pgb001p001k6	0.462
p25p2	Condition 4 - pgb001p001k6	0.865
amrwb	Condition 5 - pgb001p001k8	0.536
p25p2	Condition 5 - pgb001p001k8	1.144
amrwb	Condition 6 - pgb001p001k10	0.745
p25p2	Condition 6 - pgb001p001k10	1.566



P.25p1 exhibits worse intelligibility than AMR-WB with longer bit error sequences

Interactive Experiments with EDGE*

Experiment design by Kahlil Dozier, Columbia University

Study the influence of delays on task and usage errors
(work in progress)

- Human test subjects perform tasks in EDGE
- Two-way communication with a dispatcher via MCV testbed
- Variables: MtE delay, PTT delay, channel access time

Charles Jennings during a practice experiment

** The Enhanced Dynamic Geo-Social Environment (EDGE): https://www.dhs.gov/science-and-technology/EDGE*

Ongoing and Future Work

Human Subject Experiments

- Ongoing experiments with volunteers at Columbia University
- Involve trained first responders in interactive lab experiments
- QoE: measure communication time, accuracy, impact on other tasks

Modeling

- Produce mappings from input parameters (delay, noise, loss) to output parameters (communication time and accuracy)

References

1. David J. Atkinson and Andrew A. Catellier, Intelligibility of Analog FM and Updated P25 Radio Systems in the Presence of Fireground Noise: Test Plan and Results, NTIA Report 13-495, May 2013.
2. Jesse Frey, Jaden Pieper and Tim Thompson, Mission Critical Voice QoE Mouth-to-Ear Latency Measurement Methods, NIST, Feb 2018.
3. Wenyu Jiang, K. Koguchi and H. Schulzrinne, "QoS evaluation of VoIP end-points", *IEEE International Conference on Communications*, 2003

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