FEEDBACK FROM REAL-TIME EXPERIMENTS

Camille MONIÈRE, PhD Student

Lab-STICC, CNRS UMR 6285
Université de Bretagne Sud, France

IMS, CNRS UMR 5218
Université de Bordeaux, France

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QCSP Meeting,
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1 CONTEXT
   - QCSP System Model
   - Implementation

2 EXPERIMENTS
   - Detection Critical Point: Threshold
   - Urban Area Experiments

3 CONCLUSION

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FEEDBACK FROM REAL-TIME EXPERIMENTS
Effective coding rate: \( R_{\text{eff}} = \frac{K \times m}{N \times q} \)

Message \( M \) (\( K \times m \) bits)

- NB-LDPC Encoder
- CCSK Modulation
- BPSK + Overmodulation
- Filter + DAC

Codeword \( C \) (\( N \times m \) bits)
CCSK Frame \( F_{\text{CCSK}} \) (\( N \times q \) bits)
QCSP Frame \( F \) (\( N \times q \) chips)

CAWGN Channel

Decoded Message \( M' \) (\( K \times m \) bits)

- NB-LDPC Decoder
- Synchronization
- Detection
- ADC + Filter

Synchronized Frame \( F' \) (\( N \times q \) chips)
Detected Frame \( B \) (\( 2N \times q \) chips)
Samples \( y(n) \) (\( 0 \) per chip)

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Feedback from real-time experiments
Implementation

Message $M$ (120 bits)

- NB-LDPC Encoder
- CCSK Modulation
- BPSK + Overmodulation
- Filter
- DAC

Effective coding rate: $R_{\text{eff}} = \frac{1}{32}$

Codeword $C$ (360 bits)

CCSK Frame $F_{\text{CCSK}}$ (3840 bits)

QCSP Frame $F$ (3840 chips)

Radio Channel
433.95 MHz
$F_s = \frac{1}{0.5}$ Msps

Decoded Message $M'$ (120 bits)

- NB-LDPC Decoder
- Synchronization
- Detection
- Filter
- ADC

Synchronized Frame $F'$ (3840 chips)

Detected Frame $B$ (7680 chips)

Samples $y(n)$ (8/4 per chip)

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Feedback from real-time experiments

- $K = 20$
- $m = 6$
- $N = 60$
- $q = 2^m = 64$
- $R_{\text{eff}} = \frac{1}{32}$
- $\mathcal{O} = 8$ or $4$
Effective coding rate: \( R_{\text{eff}} = \frac{1}{32} \)

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Feedback from real-time experiments
Detection Critical Point: Threshold

**Issue**

Score (function of $\Delta$ and $\omega$)

Threshold can be calculated from synthetic values but ...
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- Radio channel in urban area is not Gaussian,
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- oversampling was not considered.
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A criterion to set the threshold is needed:
Detection Critical Point: Threshold

Issue

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A criterion to set the threshold is needed:

**MTBFA:**
**Mean Time Between False Alarms**
Protocol: Measuring the MTBFA

Detection Critical Point: Threshold

No QCSP transmission,
uncontrolled environment
(ofice),
free running detector.
Detections (thus, false alarms) are
counted. After 100 false alarms or
5 hours elapsed, a new threshold is
tested.
Protocol: Measuring the MTBFA

- No QCSP transmission,
- uncontrolled environment (office),
- free running detector.

Detections (thus, false alarms) are counted. After 100 false alarms or 5 hours elapsed, a new threshold is tested.
Results for four different thresholds, receiver gain maxed-out

Threshold = 140.00 ⇒ MTBFA = 7.35 s

Threshold = 141.00 ⇒ MTBFA = 26.92 s

Threshold = 141.25 ⇒ MTBFA = 55.82 s

Threshold = 142.00 ⇒ MTBFA = 160.78 s
How does the QCSP communication system perform in an urban area?
Urban Area Experiments

How does the QCSP communication system perform in an urban area?

- Does it work?
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- Is it resilient to the channel evolution?
How does the QCSP communication system perform in an urban area?

- Does it work?
- Is it resilient to the channel evolution?

Best way to know is to test it in real conditions!
Transmitter

Standalone, embedded in a car moving through the town.

- Battery
- Raspberry Pi 4
- GPS Module
- USRP B205 mini-I

Vehicle

Vehicle roof

Feedback from real-time experiments
Feedback from real-time experiments

Receiver

![Diagram of receiver setup](image)

- **Power Grid**
- **USRP X310**
- **Linux Laptop**
- **Building (ENSIBS) roof**

**Notes:**
- **Context:** Urban Area Experiments
- **Experiments:**
  - Receiver
  - Power Grid
  - Linux Laptop
  - USRP X310
  - Sample stream
- **Conclusion:**
- **References:**

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Receiver

Feedback from real-time experiments
Sent Data

0  32  64  68  74  80  81  88  104  120
Urban Area Experiments

Sent Data

Latitude
(32 bits)
**Sent Data**

- Latitude (32 bits) and Longitude (32 bits) are sent within the range of 0 to 120.
Urban Area Experiments

Sent Data

Latitude (32 bits)  Longitude (32 bits)  Hours (4 bits)
Sent Data

Latitude (32 bits)  Longitude (32 bits)  Hours (4 bits)  Minutes (6 bits)
Sent Data

0 32 64 68 74 80 81 88 104 120

Latitude (32 bits) Longitude (32 bits) Hours (4 bits) Minutes (6 bits) Seconds (6 bits)
Sent Data

Latitude (32 bits)  Longitude (32 bits)  Hours (4 bits)  Minutes (6 bits)  Seconds (6 bits)  AM/PM (1 bit)
Sent Data

- Latitude (32 bits)
- Longitude (32 bits)
- Hours (4 bits)
- Minutes (6 bits)
- Seconds (6 bits)
- AM/PM (1 bit)
- Cents (7 bits)

Feedback from real-time experiments
Urban Area Experiments

Sent Data

- Latitude (32 bits)
- Longitude (32 bits)
- Hours (4 bits)
- Minutes (6 bits)
- Seconds (6 bits)
- AM/PM (1 bit)
- Cents (7 bits)
- SoC Temp. (16 bits)
Feedback from real-time experiments
GPS module is used to fetch latitude and longitude, while other information are given by the RPi4 SoC.

Note: The track is also recorded by an independent smartphone in the car, as redundancy.
Two experiments made:

1. Blue track:
   - 15/04/2022,
   - receiver’s antenna is disposed on a ground plane,
   - GPS module failed . . .

2. Magenta track:
   - 30/05/2022,
   - receiver’s antenna is plugged directly on the radio device,
   - transmitter antenna was damaged,
   - everything else was fine.
Locations retrieved from the time extracted from the frames crossed with the time-stamps of the smartphone GPS data, locations are coherent with the live tracking done by phone during the experiment, a maximum range of up to 1 km has been achieved.
Second Experiment

- Locations directly extracted from frames and frames logged by the transmitter,
- detection data are also logged,
- a maximum range of up to 500 m, expected due to antennas poorer quality.
Second Experiment: Frame examples

Frame N°45  ||  Good Frame  ||  Distance: 32.98m

Threshold: 140

Feedback from real-time experiments
Second Experiment: Frame examples

Frame N°44 || Good Frame || Distance: 50.77m

Threshold: 140
Second Experiment: Frame examples

Frame N°174  ||  Good Frame  ||  Distance: 306.24m

Threshold: 141.5
Second Experiment: Frame examples

Frame N°6 || Good Frame || Distance: 59.28m

Threshold: 140
Overall ranges

Range difference are related to the antennas.

Thus, a lower bound for the range of 500 m can be defined.

For a consumption lower than 1 \( \mu \)J per information bit, it is promising.

*Transmitter power have been measured to 4 dBm when transmitting a QCSP frame for the chosen settings, and for the given data rate, a frame takes 30 ms to be emitted.*
Conclusion

It Just Works™
Conclusion

- A full **real time** prototype is ready,

- not the sexiest (hybrid, not fully embedded, **Matlab**)  

- but already good enough to draw attention.

- Bonus: logged data already allow further explorations.
Conclusion

- A full real time prototype is ready,
- not the sexiest (hybrid, not fully embedded, \texttt{MATLAB})
- but already good enough to draw attention.
- Bonus: logged data already allow further explorations.

Yay!
Futur Points of Interest

→ A retro-engineered LoRa-like communication stack will be tested following the same protocol, to make comparisons.

→ The hardware detector is nearly there (and can theoretically achieve throughput up to 200MChip/s, with the resources).

→ TO CHECK: QCSP reception seems to be more resilient to saturation than (for example) LoRa-like transmissions.
References


Thank you, have you any question?