



SenSys 2026



Longan

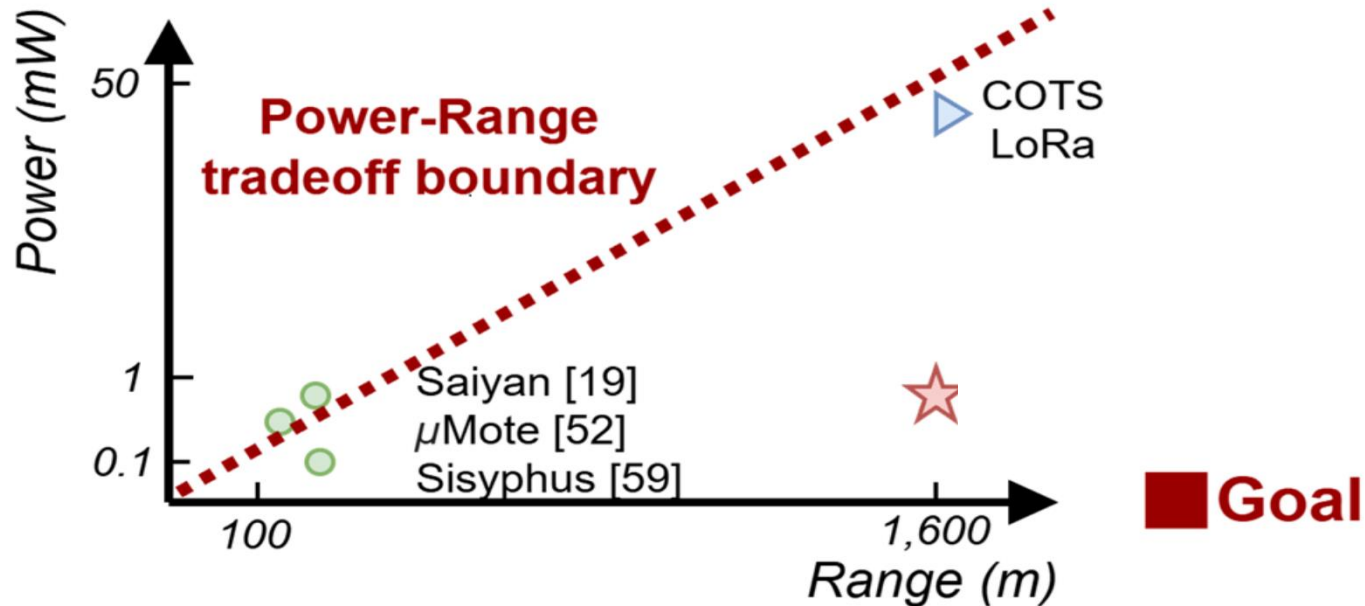
Ultra-Low-Power, Long-Range LoRa Receiver for LPWANs

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But there is a power-range tradeoff



COTS LoRa

25–42 mW · km range

2× AA → only ~6 days

SOTA low-power

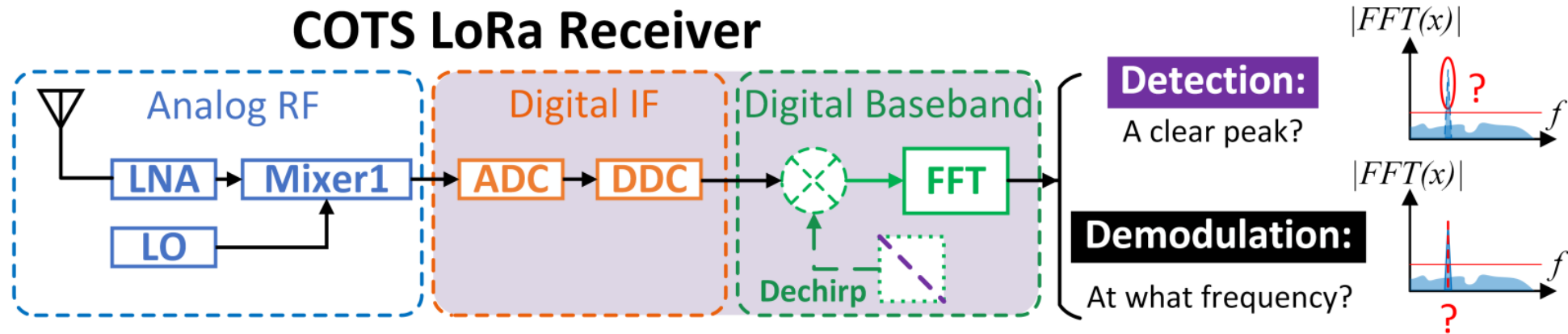
<1 mW · 100–400 m only
(Saiyan, μMote, Sisyphus)

Our goal ★

≈ 1 mW & km-scale

Can we have BOTH *low power* AND *km-scale* range?

Where does the power go in a COTS receiver?



Sink #1: Analog RF

Low-noise amplifier (LNA) + Mixer
+ Local oscillator (LO)

~25 mW, always on

Sink #2: Digital baseband

ADC + dechirp + FFT

10+ mW, always on

Two independent power sinks → must address BOTH

Longan: two ideas, one for each sink

Idea1 TD-based RF front-end

- Replace BJT with **tunnel diode (TD)**
- Exploit TD's **negative-resistance** region
- Reflection-mode amplification
- Same idea → low-power LO
- **Analog RF chain < 0.5 mW**

Idea2 Decouple detection / demod

- **Always-on: cheap LF detector (AS3933)**
- On-demand: wake the COTS LoRa demod
- Idea: 4-phase shifting LO2 to align CSS
- Avoids ADC + FFT power during idle

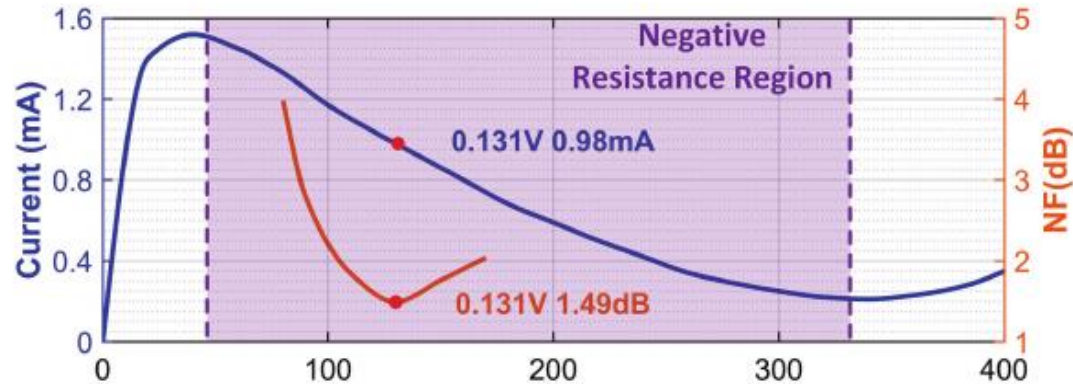
Baseband detection \approx 0.66 mW

Combined: total receiver power = 1.16 mW

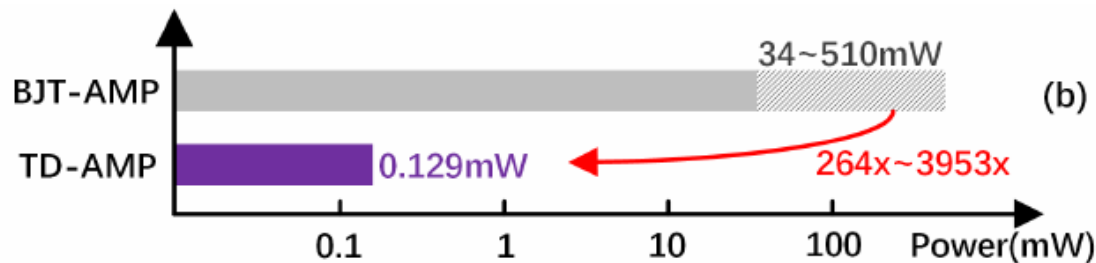
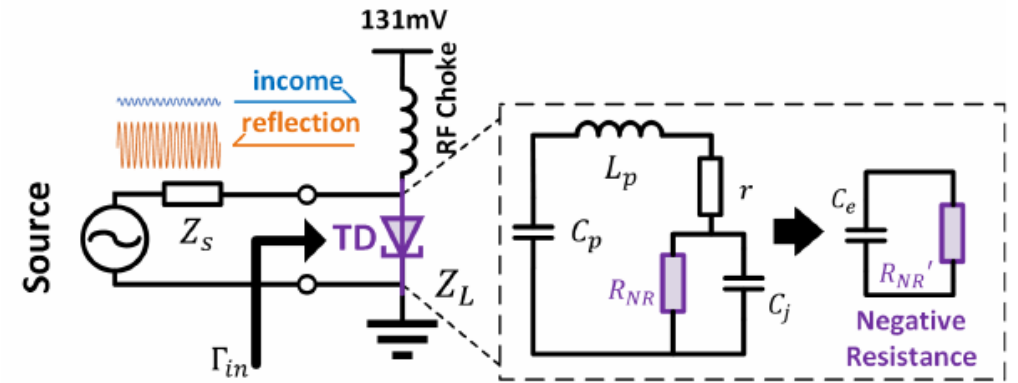
COTS: > 35mW

Design 1: Amplify with a Tunnel Diode (TD)

I-V curve: negative-resistance region



Reflection-mode amplification



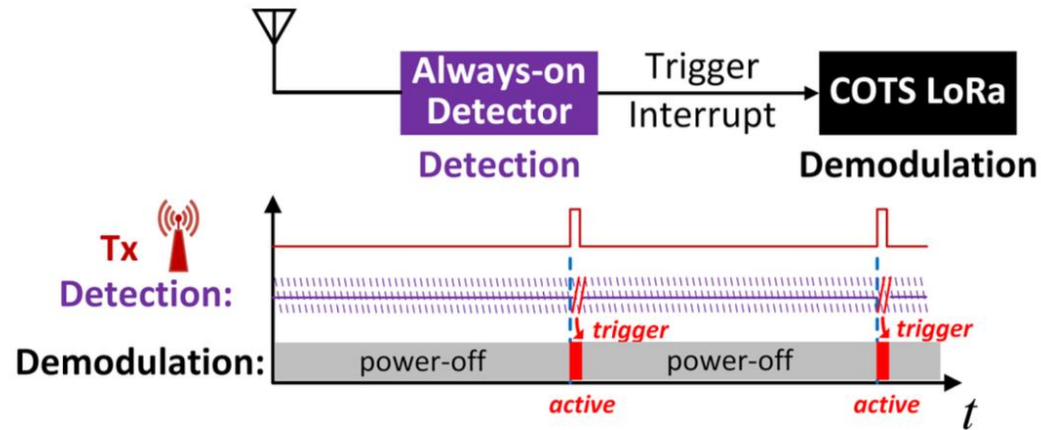
Same TD idea for:

- low-power local oscillator (TD-LO)

42 dB gain @ 0.129 mW: 264~3953× lower power than BJT

Design 2: Detection-triggered Demodulation

Inspired by wake-up receivers

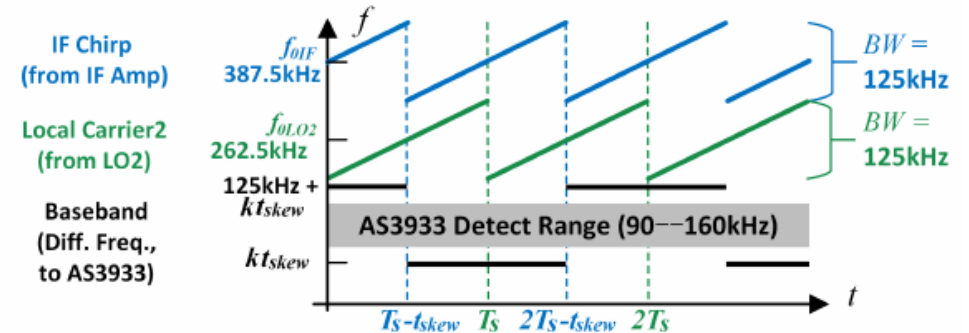


Always-on AS3933 wake-up chip

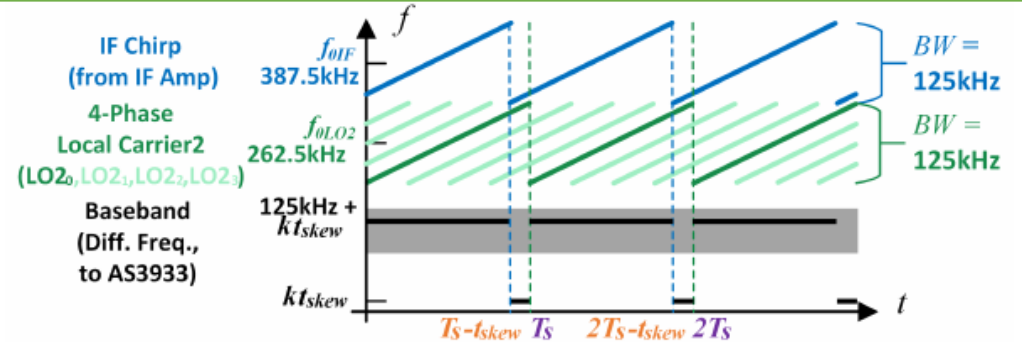
- 5.75 μW only (vs >30 mW for ADC+FFT)
- Sensitivity -69 dBm (vs ~ 40 dBm of envelope detectors)

Detection chain stays ON @ ≈ 0.66 mW

Challenge: chirp drifts out of detector window



Solution: 4-phase shifting LO2

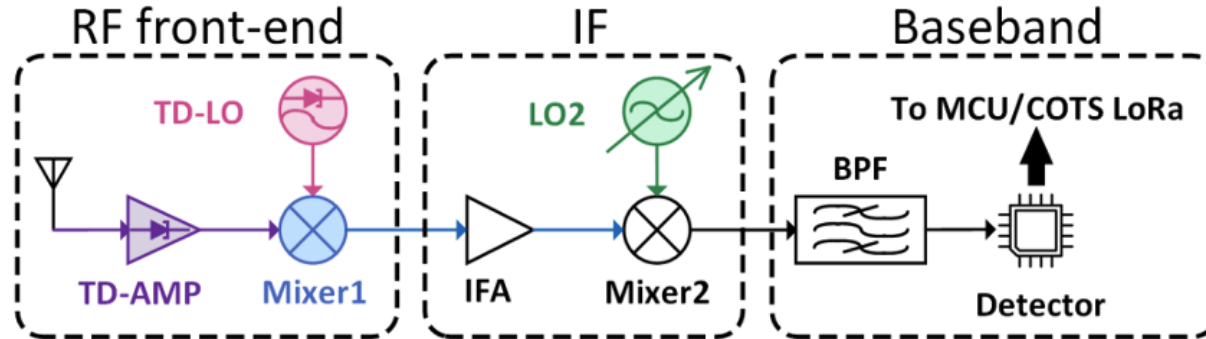


- Periodically rotate LO2 phase: ≥ 1 alignment per chirp

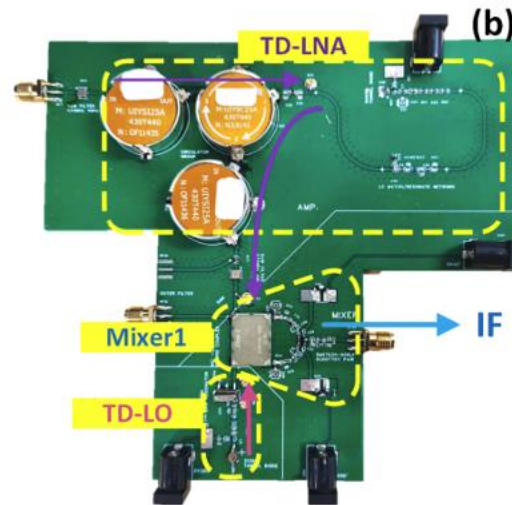
Demodulation works only on trigger

Longan Prototype

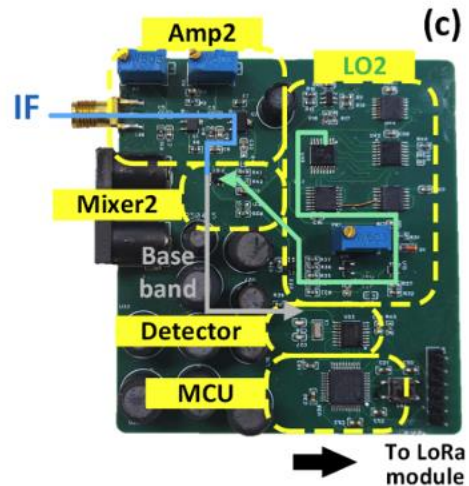
System architecture



Two FR4 boards: plug-and-play with COTS LoRa transceivers



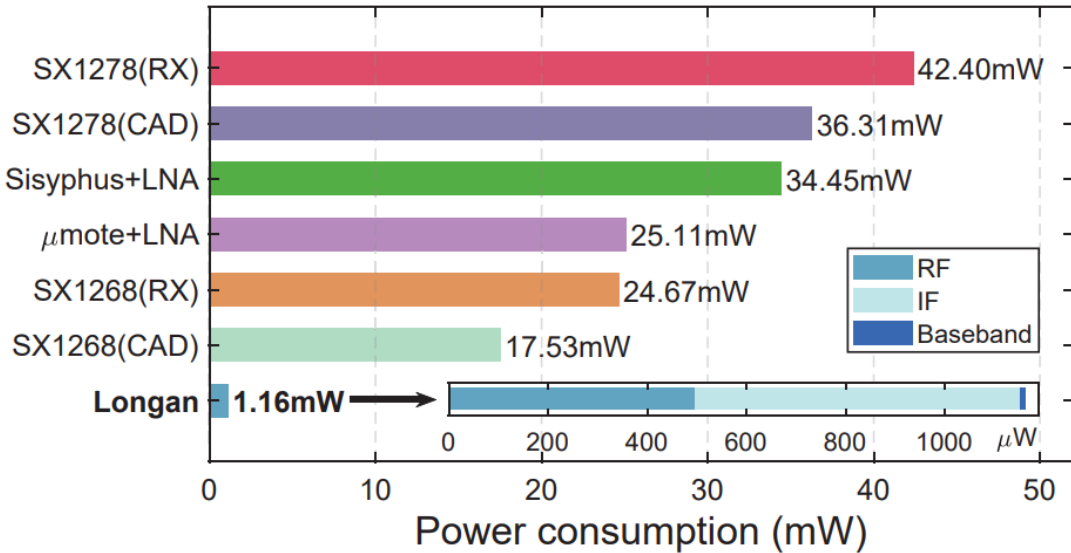
14.6 × 15.7 cm RF front-end board



7.0 × 7.7 cm IF/baseband board

Result: 36× lower power, comparable sensitivity

Power consumption (mW)



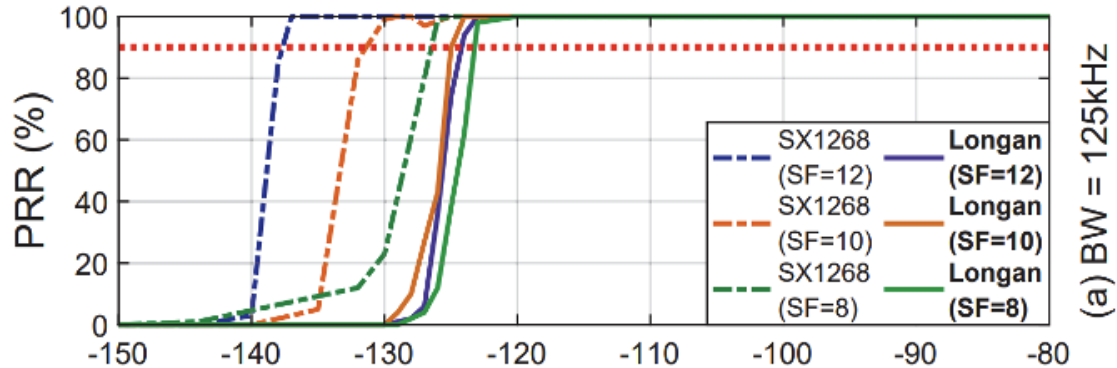
1.16 mW

total power

36×

lower than COTS

PRR vs. RSSI (BW = 125 kHz)

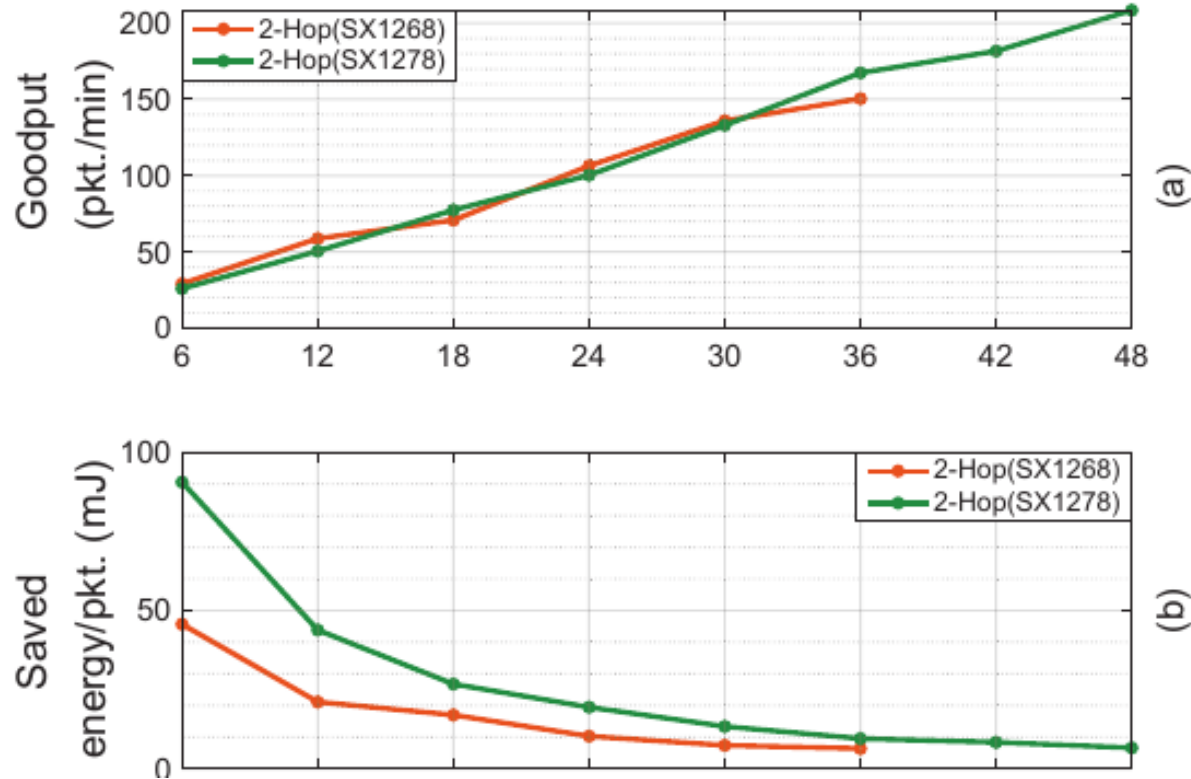


< -120 dBm

Sensitivity

Network impact: enables always-on Class C on battery

2-hop network: goodput & energy saved per packet



Same power budget

- COTS receivers must duty-cycle (limited Class A/B operation)
- Longan stays ON: full Class C on a battery node

Per-packet energy

10.3 ~ 90.6 mJ saved per packet vs always-on COTS receiver

Network unlocks

- Energy-efficient CSMA (LMAC)
- Scalable multi-hop topologies

Take-away

- 1 First** LoRa receiver to cross the power-range tradeoff boundary
- 2 Two ideas:** TD-based RF amp + detection-triggered demodulation
- 3 1.16 mW @ km-scale** → always-on Class C, CSMA, multi-hop

More circuit details and evaluation in the paper.

Thank you!

Q & A

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