“Where the Wi-Fi sucks” is where a new wireless protocol does its magic

Enlarge / BYU assistant professor of computer engineering Phil Lundrigan is looking at an ONPC heartbeat on an RF signal analyzer.

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Researchers at Brigham Young University have created a new RF protocol that runs on top of existing consumer Wi-Fi at significantly greater range. But before you get too excited, the protocol’s bandwidth is extremely low—so much so that it makes LoRa look like an OC-24. The protocol, called ONPC—short for On-Off Noise Power Communication—currently only specifies a single bit per second.

Although ONPC only conveys one bit per second of data, its range is 60m or more beyond Wi-Fi—and it runs in software alone, on unmodified Wi-Fi hardware. An ONPC device can connect to standard Wi-Fi when range permits, fall back to ONPC mode if the connection drops, and then re-connect to the Wi-Fi when it becomes available again.

Disconnected versus unpowered

BYU Associate Professor of Computer Engineering Phil Lundrigan told Ars that ONPC was inspired by problems in an otherwise

unrelated health care research project he'd worked on. The project required placing IoT sensors in the homes of study participants so that BYU's control over the environment was minimal to nonexistent. The project also required the sensors to report back to the researchers over the Internet, using whatever Wi-Fi the study participants had in place.

Unsurprisingly, participants' home Wi-Fi tended to have problems. The sensors didn't need much of a connection, since they only needed to report small amounts of data over a time series—so placing them at the dubious edges of coverage was basically OK. The problem the researchers ran into was that at the edge of coverage, their sensors would frequently drop off the Wi-Fi for hours or even days at a time.

Dropping off the Wi-Fi wasn't necessarily a big problem. The sensors were perfectly capable of continuing to store data locally, and they would send all the collected data in a batch whenever they managed to reconnect to the Wi-Fi again. But if the sensor was truly powered off or broken—and thus not collecting data—this posed real problems for the study.

This left researchers balancing the need to make sure sensors worked against the likelihood of annoying participants badly enough that they might drop out of the study. In one memorable case, a basket of laundry in front of a sensor was all that kept it from transmitting its data to the researchers. When the laundry basket was moved, the device almost immediately reconnected to the house's Wi-Fi and began transmitting its stored data.

Shave and a haircut, two bits

The desire to know whether their sensors were *working*, even if they weren't connected, led the researchers to the idea of ONPC. 802.11 Wi-Fi requires a bi-directional signal strong and clean enough to establish a 1Mbps PHY rate, and if such a signal can't be established, the client device and Wi-Fi

infrastructure are effectively invisible to one another.

Although a Wi-Fi AP (Access Point) can't actually receive frames sent by a STA (Station, or Wi-Fi client device) outside its range, it's still possible for it to detect them by looking for changes in the RF noise floor. When a STA outside the AP's range transmits a frame, the noise floor increases. When the STA stops transmitting, the noise floor decreases.

- This is an overview of an ONPC-capable Wi-Fi network. Whenever possible, the devices just use normal Wi-Fi. When the network isn't available, they transmit ONPC frames instead.
- By looking for patterns in the RF noise floor, an ONPC receiver can detect the presence of individual ONPC devices.
- Wi-Fi puts data inside the frames—ONPC puts it in the presence or absence of the frames themselves.

ONPC isn't looking for data inside Wi-Fi frames at all—it deduces its data from the presence or absence of the frames themselves, much like plugging and unplugging a device into a switch. ONPC also looks for Morse Code in the pattern the link-light blinks in.

A Wi-Fi AP configured as an ONPC receiver has pre-configured and shared pseudo-random patterns which associate it with STAs configured as ONPC transmitters. When the AP detects a matching pattern in the RF noise floor—like Roger Rabbit hearing a famous ditty knocked on the wall of his hideout—it knows it's receiving a communication from one of its ONPC partners.

In the BYU researcher's testing, ONPC transmissions had minimal effect on the Wi-Fi network they rode. Test laptops near the edge of the Wi-Fi network saw no distinguishable drop in speed, as the lost-frame overhead was greater than the impact of the ONPC transmitter. Test laptops very near the AP,

with near-flawless signal, might see throughput drop by 20% due to CSMA interruptions caused by ONPC transmission.

The 20% decrease BYU measured is as compared to no transmission at all—not compared to a Wi-Fi device connected to the same AP and moving data at extreme range. It's not unreasonable to suspect that the ONPC transmission still consumes no more airtime (and therefore impacts performance no worse than) an actual Wi-Fi connection would have.

- Even the closest of these ONPC test locations is well over a football field away.
- ONPC isn't perfect—even at one bit per second, it occasionally makes a mistake—but it's more than good enough for monitoring device health.
  Brigham Young University
- At long range, the effects of ONPC transmission on normal Wi-Fi are effectively zero. Overhead in missed frames greatly outweigh the impact of the ONPC symbols.
  Brigham Young University
- ONPC transmissions may decrease very close-range devices' maximum Wi-Fi throughput by up to 20%. This is still probably less impact than normal Wi-Fi transmissions from the same ONPC device would have.
  Brigham Young University

Stayin' Alive

Since ONPC is designed to supplement standard 802.11 Wi-Fi, not replace it, there's one more piece to the puzzle—a controller that decides when to fall back from Wi-Fi to ONPC. The BYU team named that controller "Stayin' Alive."

When an ONPC-capable STA gets disconnected from the Wi-Fi network, it begins transmitting its ONPC identifying symbol. Similarly, when a controller realizes that it hasn't received

data from that STA for a longer than normal interval, it turns on the ONPC receiver functionality and looks for that missing device’s symbol on the noise floor. If the missing device’s symbol is present, the controller knows the sensor is OK; if the symbol is missing, the controller can set an alarm condition to notify a human to investigate.

Why ONPC?

Numerous alternatives are competing for low-rate, long-range RF data transmission, including but not limited to LoRa, cellular broadband, HaLow, and White-Fi. However, these protocols achieve their long range in large part by operating at lower frequencies than consumer Wi-Fi, and they require an entirely separate infrastructure to operate.

ONPC allows for much greater economy through the use of existing, widely mass-marketed consumer Wi-Fi gear. Ars spent $46 apiece on a pair of LoStik LoRa radios; the ONPC project used Wemos D1 mini WLAN boards, which cost about $3 apiece.

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