A classification of single-channel communication concurrency

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IWCMC conference
1–6/06/2026, Shanghai, China

Concurrent communication without hindering each other

Motivations

Some excerpts from random articles using concurrent communications:

- "*Multipath TCP provides the ability to simultaneously [concurrently] use multiple paths*" [5]
- "*TS-OOK enables robust and concurrent communication among nano-devices*" [3]
- "*PiP exploits packet concatenation to achieve concurrent data collections from multiple neighboring nodes in a single transmission slot*" [2]
- "*provide a scalable concurrent ranging solution that can be practically implemented on off-the-shelf UWB devices*" [4]

We noticed that the word concurrency above has different meanings

- What does the word concurrency in these sentences mean?
- What does concurrent (or simultaneous, or parallel) communication mean for you?
- Many communications happen right now in this room, at the same time, without hindering each other, how is concurrency possible?

Concurrent communication without hindering each other

Context and contribution

This talk is not about:

- Concurrent communications in different geographical zones, because such communications do not interfere each other (they are too far away)
- Different frequencies (5G, sound, visible light), since there is no interference either

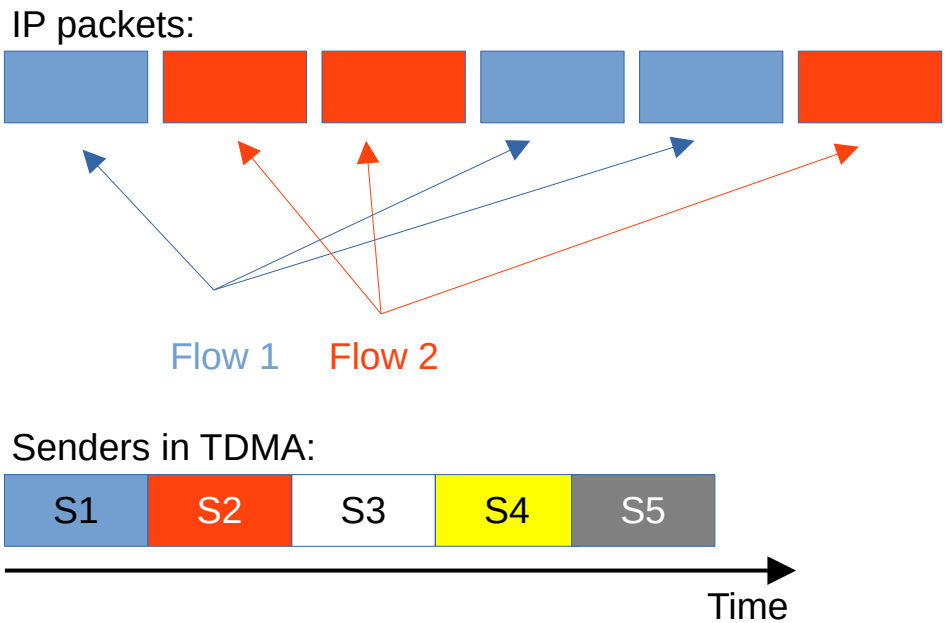
This talk is about:

- 1-channel case (for ex. same place, same frequency), where if two machines send data at the same time, there is interference

- How is interference mitigated?
- What kinds of concurrency does 1 channel support?
- This talk does not present experiments, nor simulations, instead it explores the forms of concurrency in 1 channel
- It fills the gap in existing terminology in literature
- It contributes to a better scientific understanding of the concurrency concept and its diversity

Flow-level concurrency

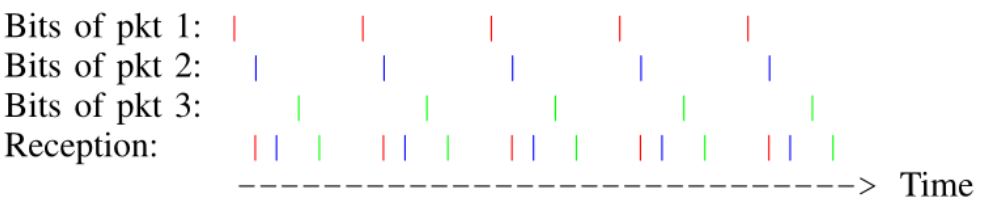
- Most popular type of concurrency
- Examples:
  - Internet Protocol (IP): a flow (e-mail, file, video etc.) is cut in packets (of length 1400 bytes for ex.); packets from several flows travel the same channel sequentially; right now we use Wi-Fi, our concurrent communications are possible because they are cut in IP packets, sent sequentially
  - TDMA (Time-Division Multiple Access): channel is divided in time slots, and each flow can send only in its time slot
  - LoRa: time-slotted, duty-cycling, spreading factor
- Concurrent flows, but sequential packets (i.e. packet interleaving); can packets too be concurrent?



Packet-level concurrency

- Concurrent packets, but sequential bits (i.e. bit interleaving); how is this possible??
- Conventional wireless technologies use a carrier at a specific frequency, and adds information on top of it (uses "one frequency, all the time")
- Instead, pulse-based technologies send data through pulses of energy on a wide band (uses "all frequencies on a time slot only")
- For ex. each pulse is a bit, and pulses are more or less spaced in time
- Examples: UWB (Ultra Wide Band), TS-OOK (Time Spread On-Off Keying)

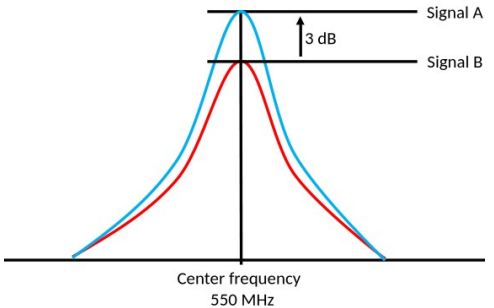
Bit 1 is sent as a pulse, bit 0 is silence



Concurrent packets, but sequential bits

Bit/symbol-level concurrency

- Concurrent bits from several packets
- Glossy, simultanous transmission of the same packet, uses constructive interference (signals add), correctly received if time difference between receptions <.5µs
- PIP, if synchronisation is not accurate, uses capture effect, where receivers extract only the strongest signal and ignore the others
- SAR protocol uses successive interference cancellation, decoding the strongest signal and removing it, several times recursively to get all the signals

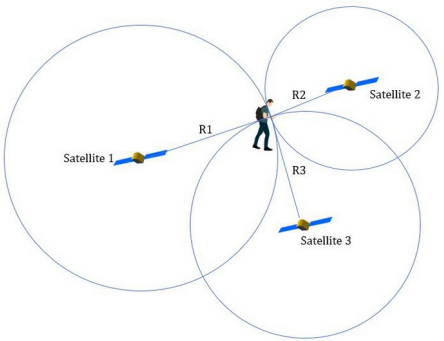


Capture effect, extracting the strongest signal

Pulse-level concurrency

Pulse injection (or interleaving)

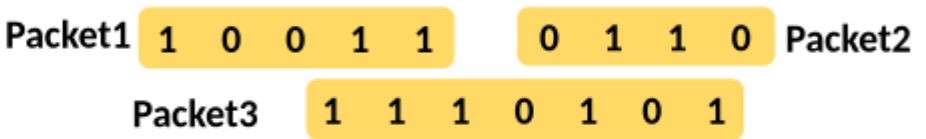
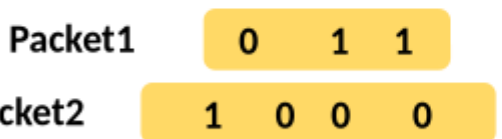
- Chorus: UWB ranging (localisation), where several localisation anchors at known positions send a pulse at the same time; the target device computes the distance using the time difference of their arrival time (like in GPS)



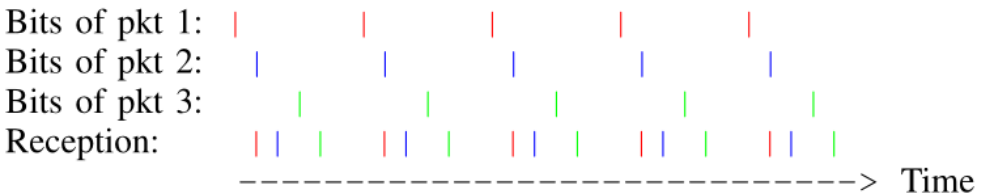
Pulse shape changing

- DW1000 chip can create pulses with different shape widths, and receiver can sometimes differentiate them

Summary table

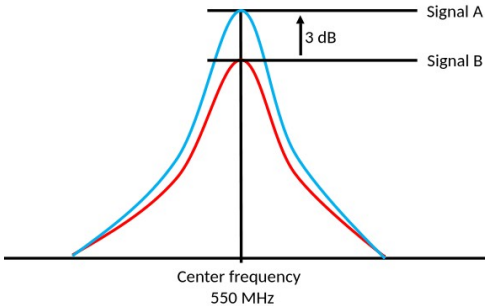
Concurrency level	
Flow-level	
Packet-level	
Bit-level	
Pulse-level	

Parameters affecting the amount of concurrency



Node capability: small nodes lack resources to decode more than K concurrent packets

Time: the larger the time between bits, the higher the amount of concurrency



Signal strength: the higher the differences between overlapping signals, the higher the amount of concurrency

Pulse shape: the number of unique pulses determines the amount of concurrency

Conclusions and perspectives

- Concurrency is an ambigous concept in computer networks, because it may occur at various levels
- Concurrency levels: flow (IP, LoRa), packet (TS-OOK), bit/symbol, pulse
- This talk allows to understand the meanings of the word concurrency in papers on right →
- Perspective work: empirical validation to identify instances of each concurrency level in practice, in real traffic traces + benefits of packet-level concurrent communications compared to sequential ones

Some excerpts from random articles using concurrent communications:

- "*Multipath TCP provides the ability to simultaneously [concurrently] use multiple paths*" [5] => multi-channel (out of scope of our talk)
- "*TS-OOK enables robust and concurrent communication among nano-devices*" [3] => packet-level concurrency
- "*PiP exploits packet concatenation to achieve concurrent data collections from multiple neighboring nodes in a single transmission slot*" [2] => bit-level concurrency
- "*provide a scalable concurrent ranging solution that can be practically implemented on off-the-shelf UWB devices*" [4] => pulse-level concurrency