Design and Development of a Client Relay System Level Simulator

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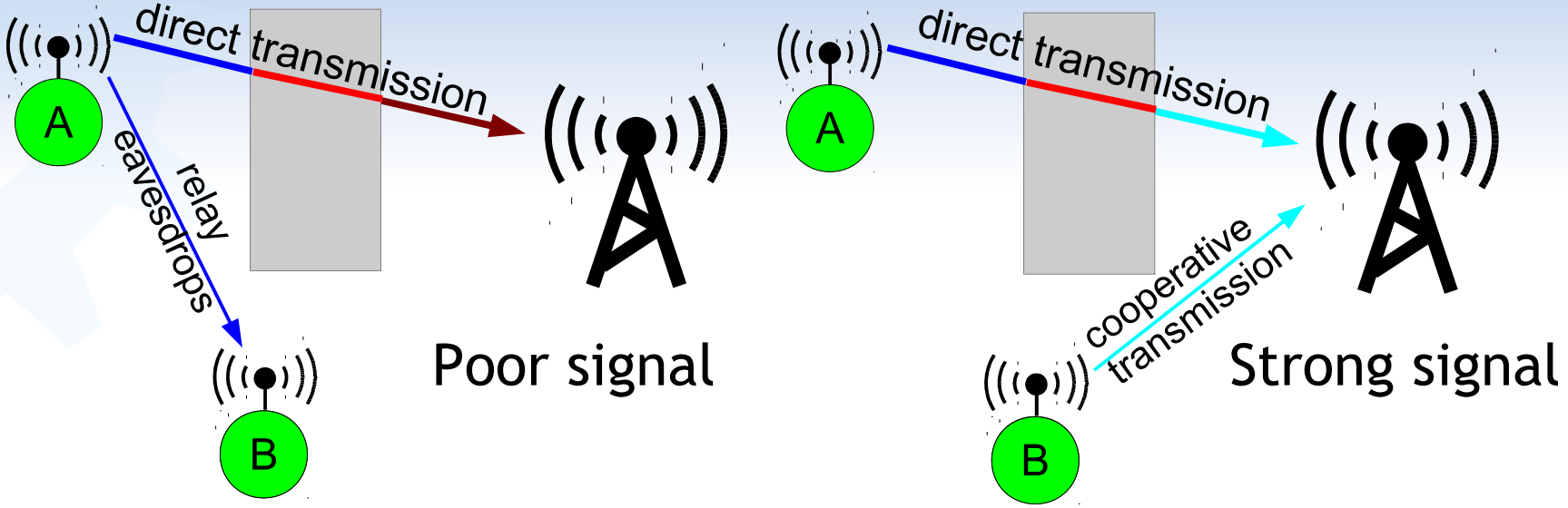
Why do we need relays?

- Operators want to provide **more bandwidth**
- New best practice – **no frequency reuse**
- Classic network planning shows it can not work
  - **Yet it does...**
  - Well **not exactly...**
- **Relays** can improve situation → **expensive!**
- **Go around it –** make **users relay data** for each other → cheap
- Recall: **cognitive radio, RIP**

Client relay concept 1 on 1



- **Every client** of the network may receive the **data packets**, transmitted by **other clients** to base station, becoming a **relay node** (node B)
- Relay nodes may **join** subsequent transmissions of the packet to improve the delivery probability

Project motivation

- Currently there are **no models** to analyze and optimize client relay networks
  - Most simulation platforms were not designed for client relay scenarios
- The implementation of client relay is an open question, there are **no standards**
  - **Yet everyone wants it done anyway**
- The assumptions about operating environment should be reasonable and match real deployment

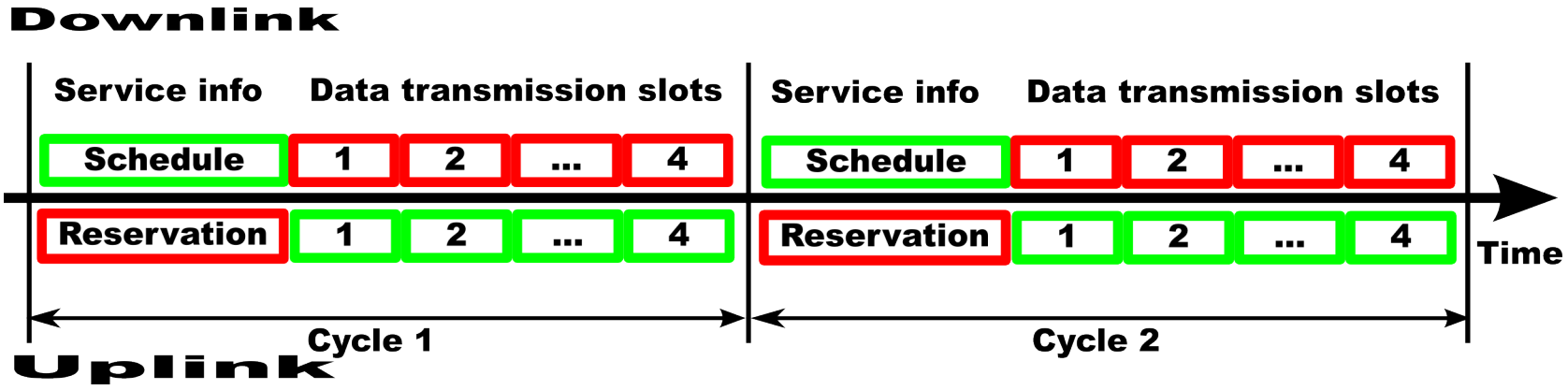
So how do we study it?

What we are going to do

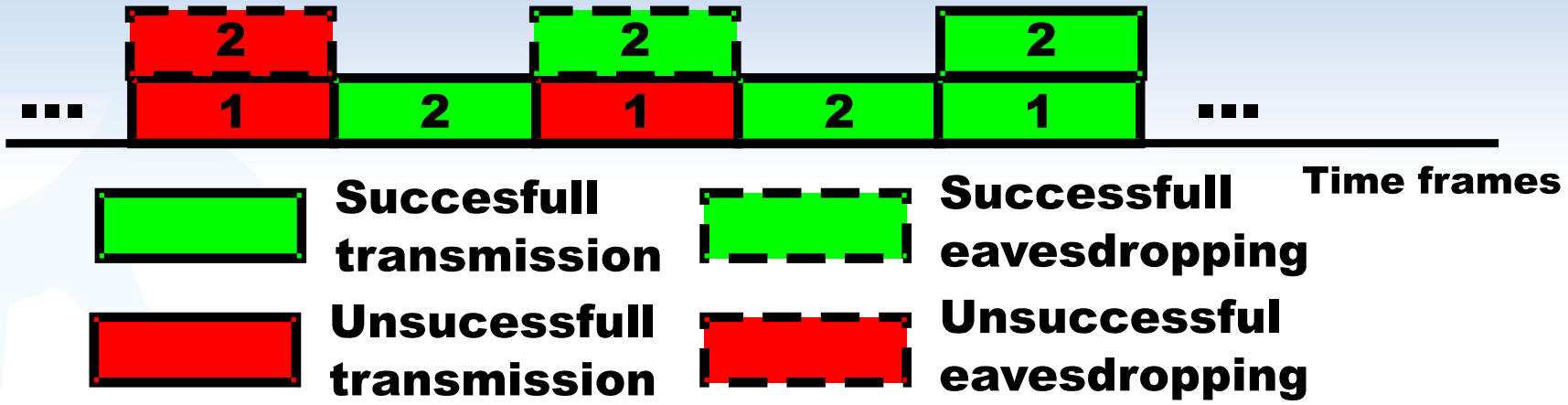
1. Review the assumptions made about cellular network
2. Choose proper approaches for modeling and simulation of client relay
3. Try to keep it simple...
4. Consider some scenarios
5. Highlight the perspectives

1.1 System assumptions we make

- Slotted time, synchronous operation
- Frequency division duplex
- BS handles scheduling
- Perfect packet integrity check
- Finite buffers and retransmission counters
- We ignore downlink traffic and assume proper reservation



1.2 Our client relay “protocol”



- Benefits:
  - **No explicit signaling** involved
  - Only **minor modifications** of existing protocols needed
  - Full **backwards-compatibility**
- Implications
  - The solution is **not optimal** in terms of **energy efficiency**
  - The relay link **can not be guaranteed**

2.1 Modeling the network

- For a fixed system model there are known trade-offs:
- More speed = less details = poor accuracy
- High accuracy = more detail = less speed
  - What shall we do?
- Another performance metric – reliability.
  - Get the result that has a predictable accuracy
- Implementation – has to be fast and accurate
  - General idea – model only things that seem to affect
  - Use simple PHY model
  - Do not oversimplify

2.2 Hacking the code

- Is generally a **bad** idea… But we can:
- Use something instead of ~~Matlab~~
- Avoid data protection (OOP) on low level
- **Avoid scripting** in critical sections
- Allocate once, use forever

  Total performance ≈50000 frames/s on average laptop

  This means it can simulate 50 LTE channels in real-time

  And no hacker-style code

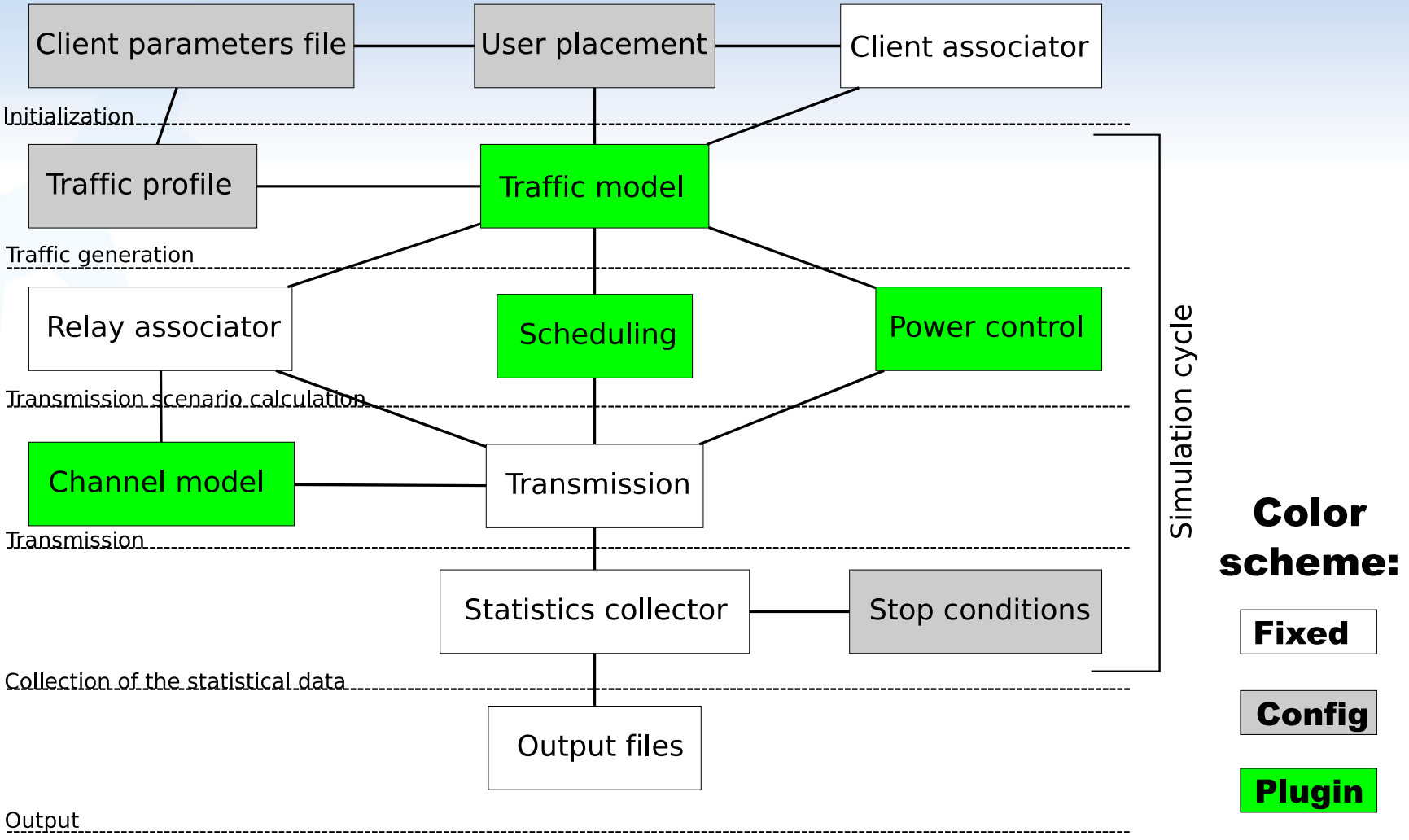
3.1 Our path

- Each project has a development path
- We have first started with a primitive model of 2 users in single cell → too simple
- Many users in the same cell → again too simple
- Many users in many cells randomly roaming with realistic channels and real reservation protocols → too complicated to be fast
- Our compromise:
  - Multiple users
  - A single cell with interference looped back inside
  - Simplified channel models (ITU, empirical)

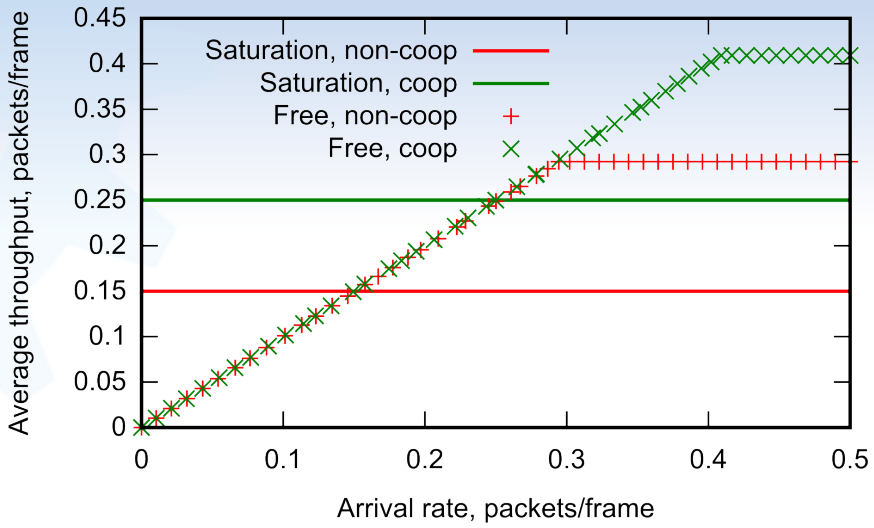
3.2 What we have?

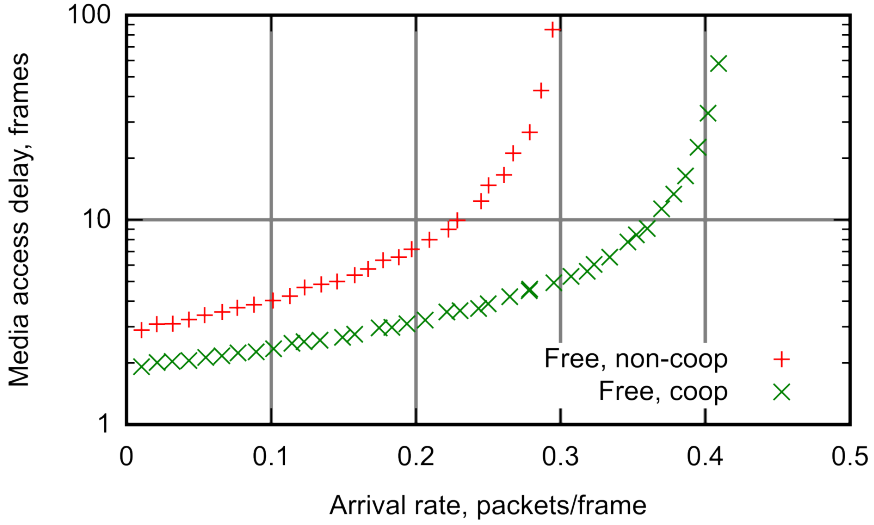
- PHY model for P2P links and for BS communication
- Fast fading and shadowing
- User mobility
- Different traffic patterns
  - Their effect is not so huge though...
- Noise and interference measurement
- Adaptive power control
- Adaptive modulation schemes
- Much more...

3.3 Simple it is



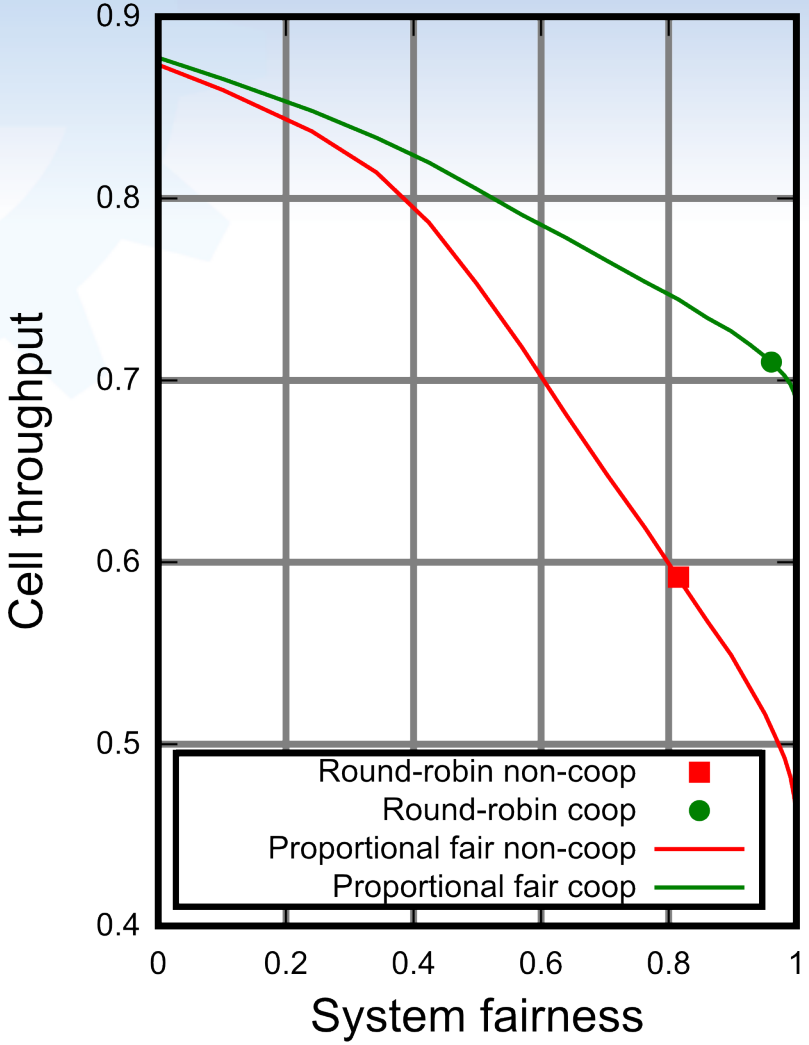
4.1 Very trivial results





- Two client nodes and a BS – as simple as it gets
- Improved peak throughput
- Decreased media access delay under similar conditions
- Increased system throughput under all conditions

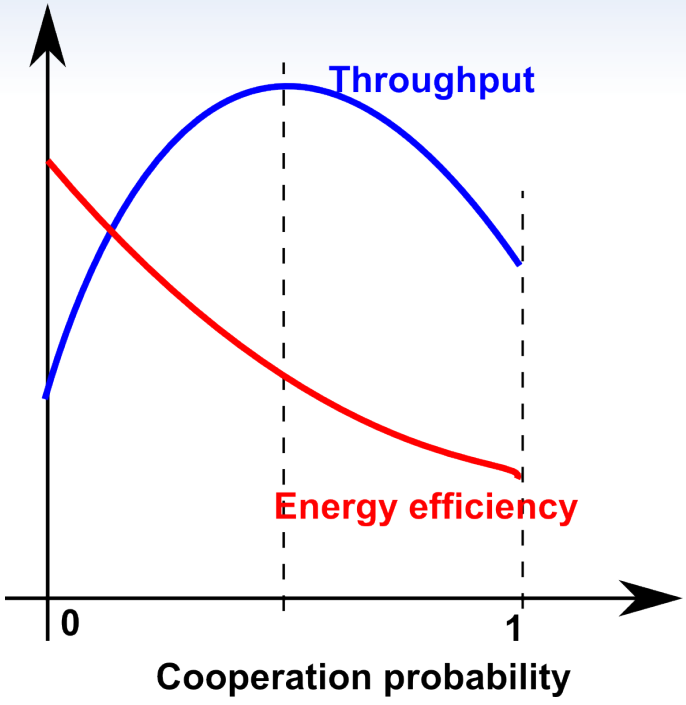
4.2 How not to make schedulers



- Network of 25 nodes with AWGN channel and Poisson arrivals
- Common schedulers might not be so effective in client relay network...
- Primitive scheduling might provide better results for both fairness and throughput with adaptive transmission

4.3 Everything has a limit

- More relays → more bandwidth (10%)
- Also less latency (30%)
- There is a saturation point, however
- Worse power efficiency of the cell (like 30%)
- Is it possible to keep both the bandwidth AND power efficiency at the same time? We do not know so far



5.1 Current work

- Better schedulers and relaying disciplines
- Provide handover simulation
- Introduce beamforming transmissions on MS
- Variable conditions (weather) and adaptive system

5.2 Open issues

- Different HARQ?
  - Client relay can work with HARQ, but the **question is if it is still the best option**
- Prefer relay over direct channel?
  - What if MS would use relay channel even if it could reach BS directly?
- Handover between cells
  - Perfect conditions for cooperation are **not so perfect for signalling traffic**
  - It is very hard to **relay signaling traffic** without sacrificing security

5.3 Conclusions

- Client relay can work (in theory)
- Client relay might be the best technology before transition to true mesh networks
- We have the tools to study centralized client relay networks
  - Both **simulation** and **analytical study**
  - **Prefer speed over detalisation,** but **not sacrificing accuracy**
- An optimal protocol is an open question...

Thank you for your attention

Questions and comments
are most welcome