A Token-Based MAC For Long-Distance IEEE802.11 Point-To-Point Links

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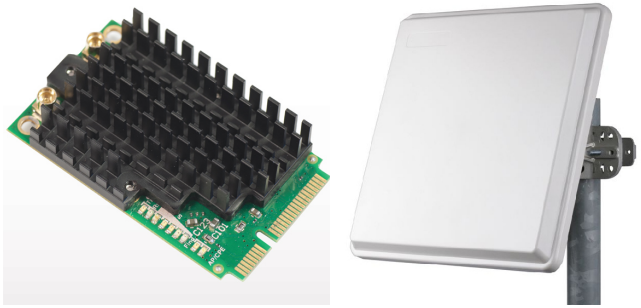
A Different Technology for Broadband in Rural Areas

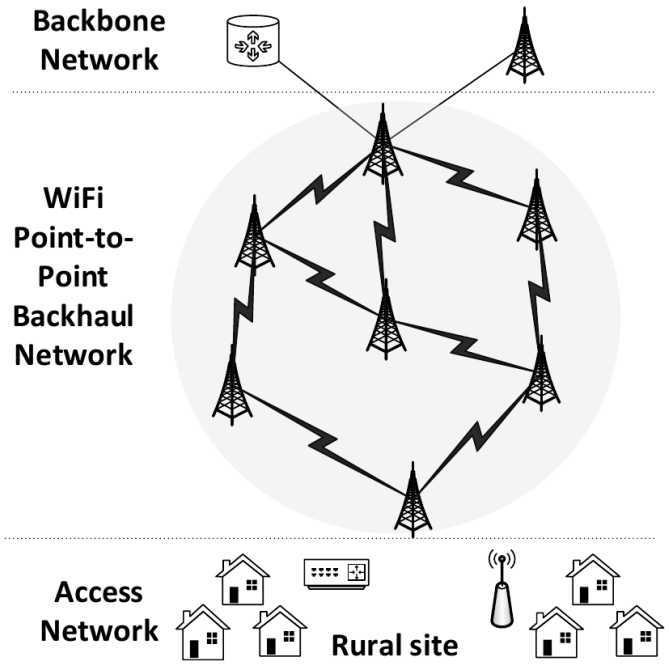
Commercial off-the-shelf (COTS) WiFi/802.11 transmitter and directional antennas

- Inexpensive (low CAPEX)
- Free-to-use band (low OPEX)
- Low energy consumption (low OPEX)
- Well developed and documented

Used in a controlled Multi-Radio Multi-Channel Wireless Mesh Network (WMN)[1]

- Our main research fields:
  - Channel Allocation [1]
  - MAC-layer optimization [2–4]
  - Propagation modeling [5]





[1] Keywords: WiFi-based Long Distance (WiLD) networks [6] and Coordinated Wireless Backhaul Networks (WBNs) [7].

The 802.11 MAC on Long-Distance Links

- 802.11 MAC-layer: CSMA/CA with a binary exponential back-off algorithm called Distributed Coordination Function (DCF)

DCF design assumptions:

- Contiguous stations in a cell
- Spatial restrictions of a few hundred meters

WiLD network topology:

- Point-to-Point links
- Link distances up to several kilometers

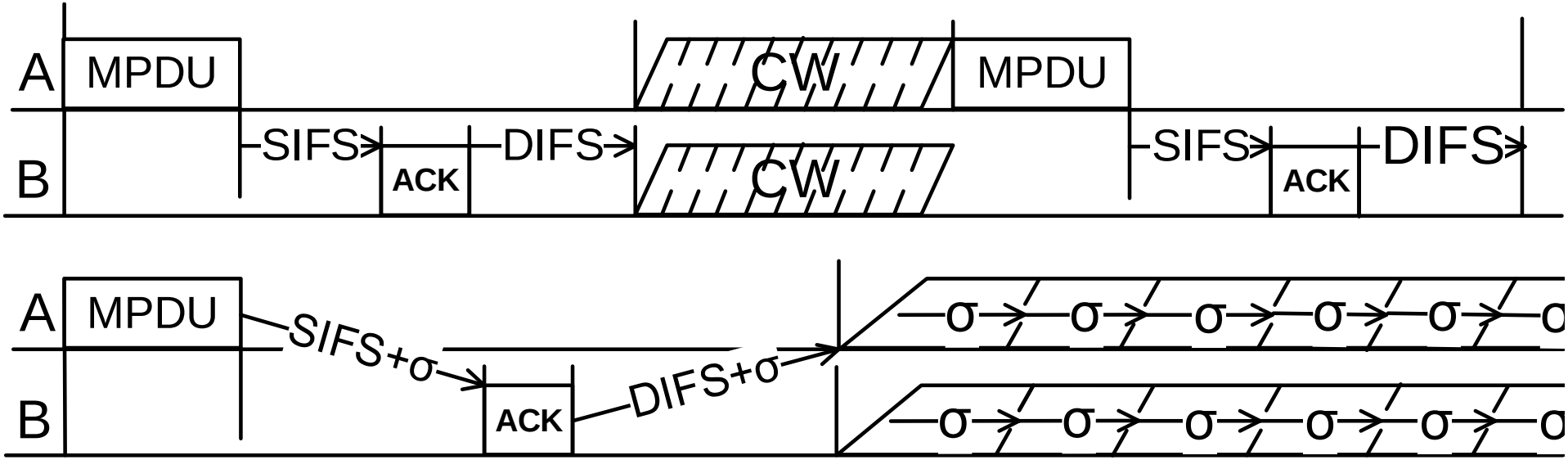
- Two paths in the research community (and in the industry):

A <u>Adapt</u> and optimize the DCF for long-distance links

B <u>Replace</u> the DCF with a new MAC-layer function

A. Adapt and Optimize the DCF for Long-Distance Links

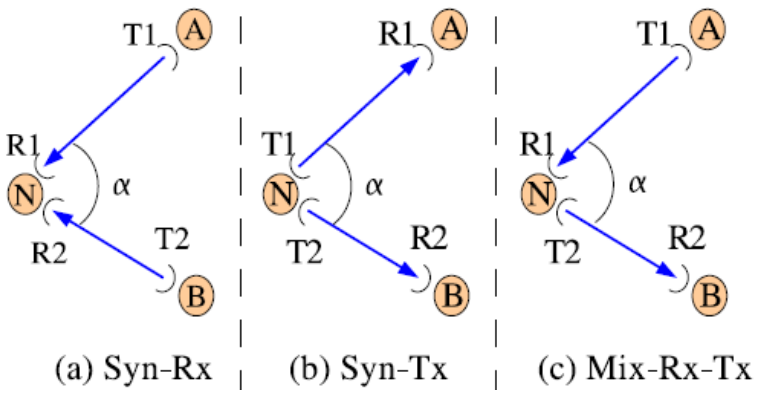
2002 Timings need to be adapted [8]
2007 Increase ACK timeout, Slot time, SIFS and DIFS [6]
2010 Modeling of 802.11a long-distance links [9, 10]
2012 Propagation time factor is now part of the standard [11]
2015 Modeling and optimization of 802.11n links long-distance links [3]



Operation of the DCF with transmission of A to B. On top short distances, on the bottom increased timings on long-distance links.

B. Replace the DCF with a New MAC-layer Function

- Mainly TDMA approaches based on [12]
- Time slots:
  - Fixed or variable
  - Synchronization: tight (GPS) or loose
- Single wireless channel network
- Goal: Provide more spectrum for access



Sync OP of 2P [12].

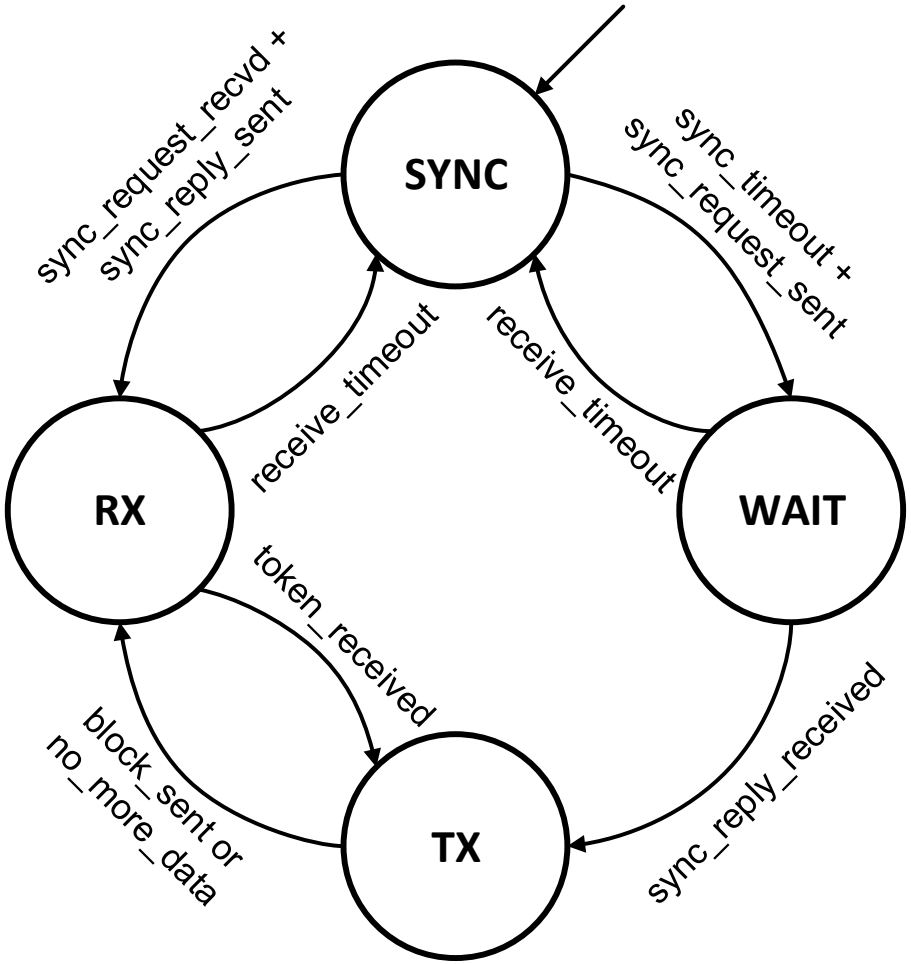
Overview of alternative MAC-layer approaches for WiLD networks, based on [13]

Year	Approach	Channels	Topology	Design	Time	Slots	Link Type	QoS	Testbed
2005	**2P [12]**	Single	Constraint	Distr	Loose	Static	PtP	✗	✓
2007	**WiLDNet [14]**	Single	Constraint	Distr	Loose	Static	PtP	✗	✓
2008	**JazzyMAC [15]**	Single	Arbitrary	Distr	Loose	Dynamic	PtP	✗	✗
2009	**Dhekne[16]**	Single	Arbitrary	Distr.	Tight	Dynamic	PtP	✓	✓
2010	**JaldiMAC [17]**	Single	Arbitrary	Central	Loose	Static	PtMP	✓	✗
2016	**This Work**	Multi	Arbitrary	Distr.	Loose	Static	PtP	✗	✗

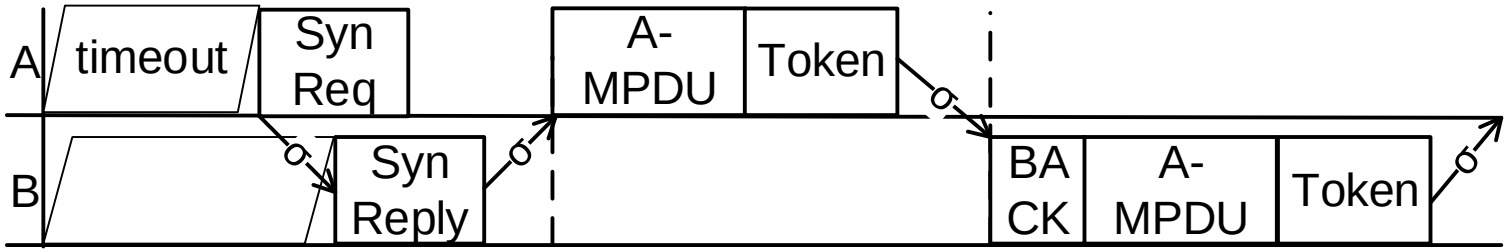
WiLDToken - Motivation, Idea and Assumptions

- Focus on a single long-distance link in a network with non-interfering frequencies assigned (CA algorithm needed)
- Goals compared to an adapted DCF version [5]:
  - Increased throughput,
  - Less delay and jitter,
  - Better fairness and possibility to set a the up- and downlink ratio.
- Our token protocol operation in a nutshell (Station A and B):
  - A holds the token and transmits a specified amount of data.
  - When finished, or no data is present, A passes the token to B.
  - A switches in the receiving state, B transmits data.
- No back-off is needed
- There are no (protocol induced) collisions on the medium

WiLDToken - State Machine and Packet Exchange



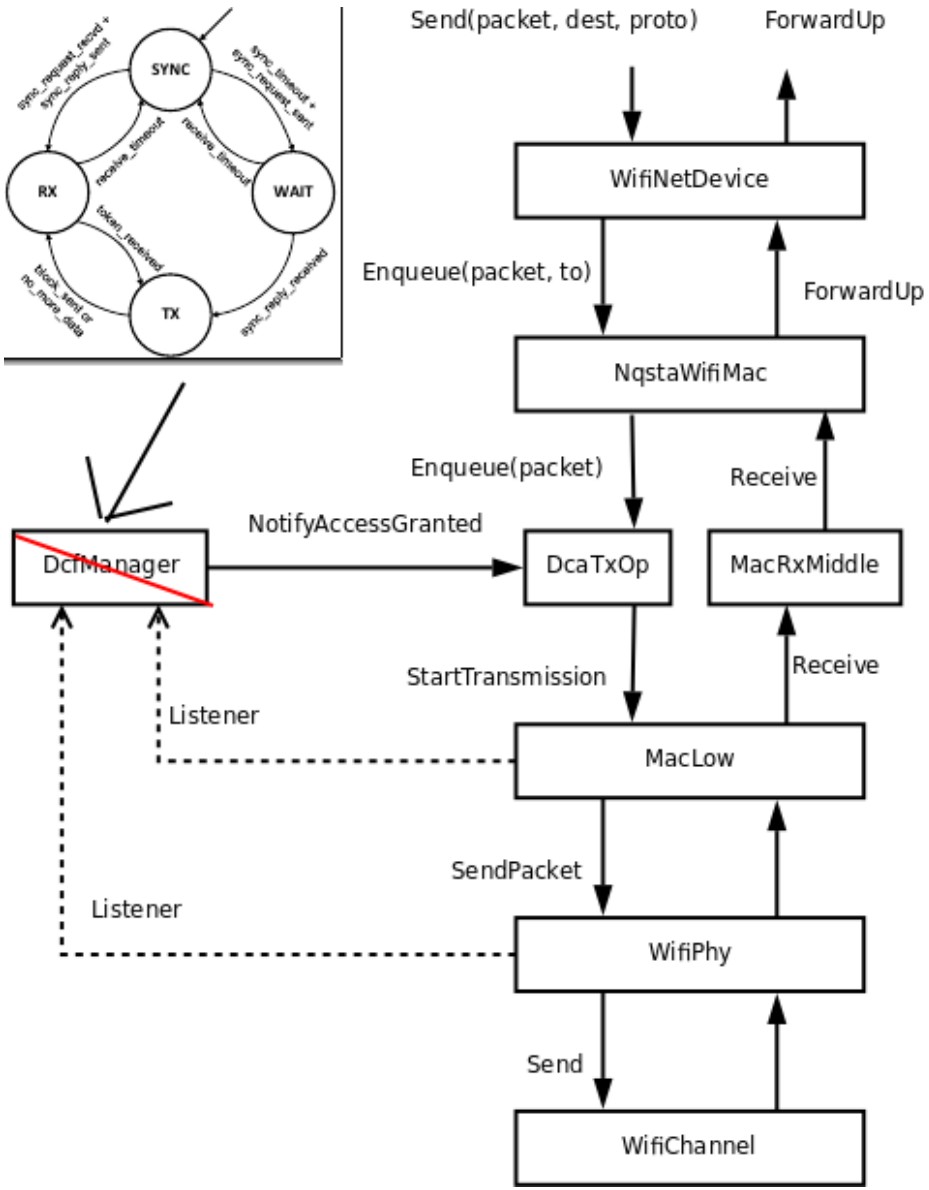
- Data exchange phase (RX and TX states)
- Synchronisation phase (SYNC and WAIT states)
- Send limit (regulatory)
- Sync and Receive Timeout
- Token format: Exploit 802.11 subtype field for sync request, sync reply or token.



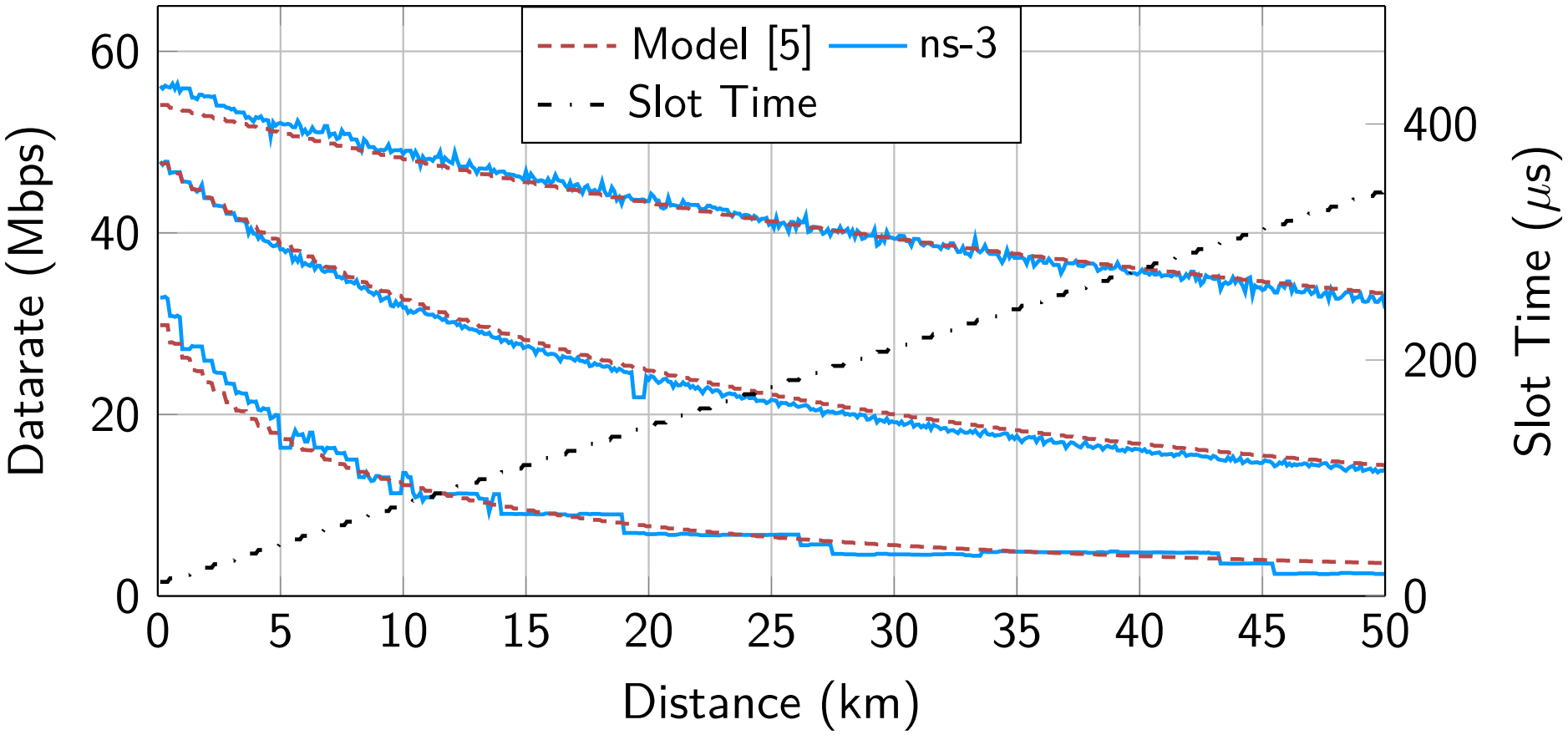
Methodology: WiLD Link Simulation in ns-3

- We use/extend ns-3 (v. 3.24)
- Two implementations:
  - The adapted DCF [3]
  - WiLDToken
- Goal: Re-use as many parts as possible
- Our NS-3 code is online: `http://mc-lab.de/`

- Simulation settings:
- IEEE802.11n ad-hoc mode
- 100 m to 50 km, P2P links, 5.2 GHz
- Omni-antennas with EIRP of 53 dBm
- 20 MHz,MCS 7,SGI -> Phy: 72.2 Mbps
- Bidirectional IP/UDP

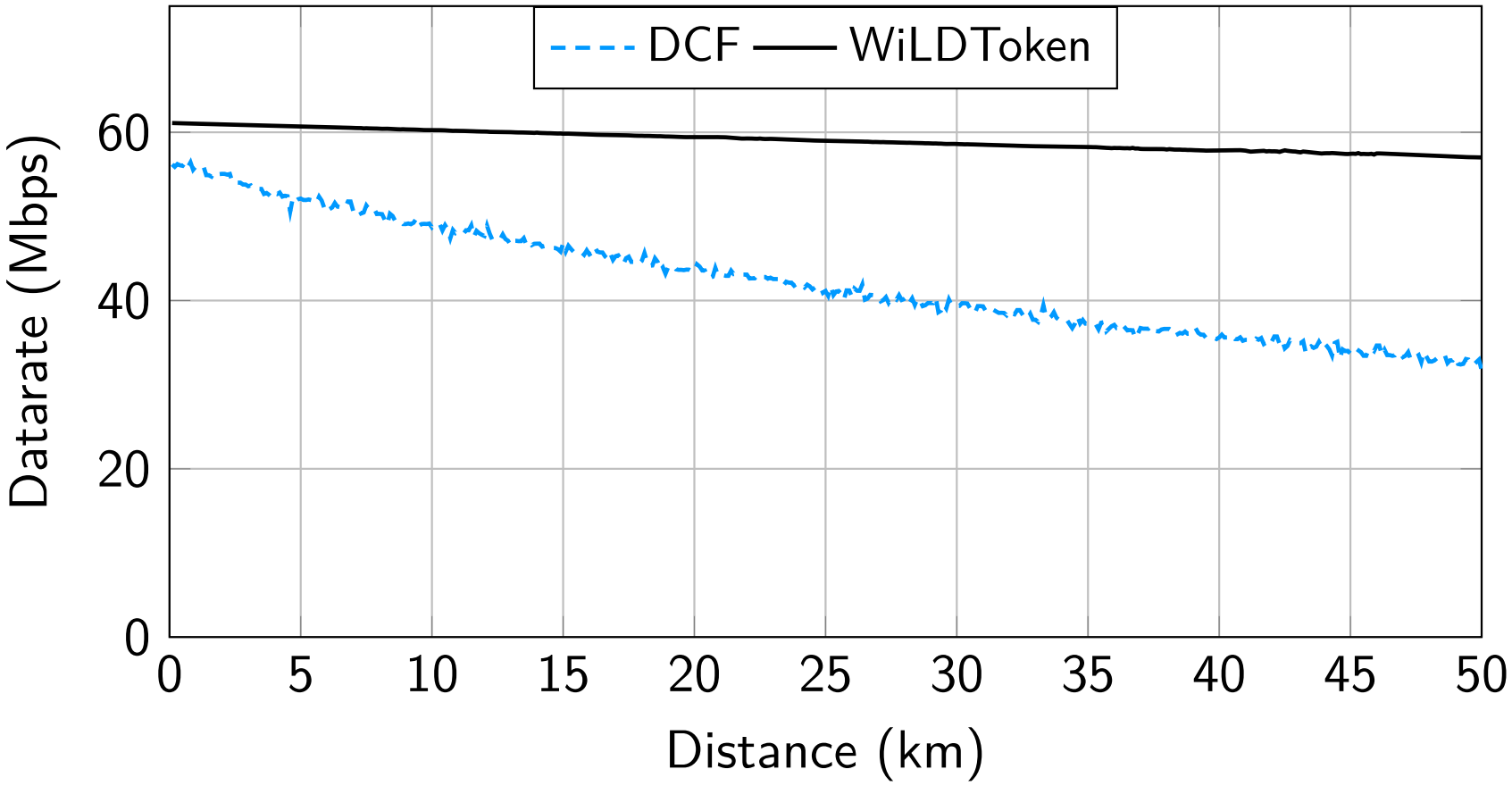


Simulation: Mathematical Model and ns-3 Simulations



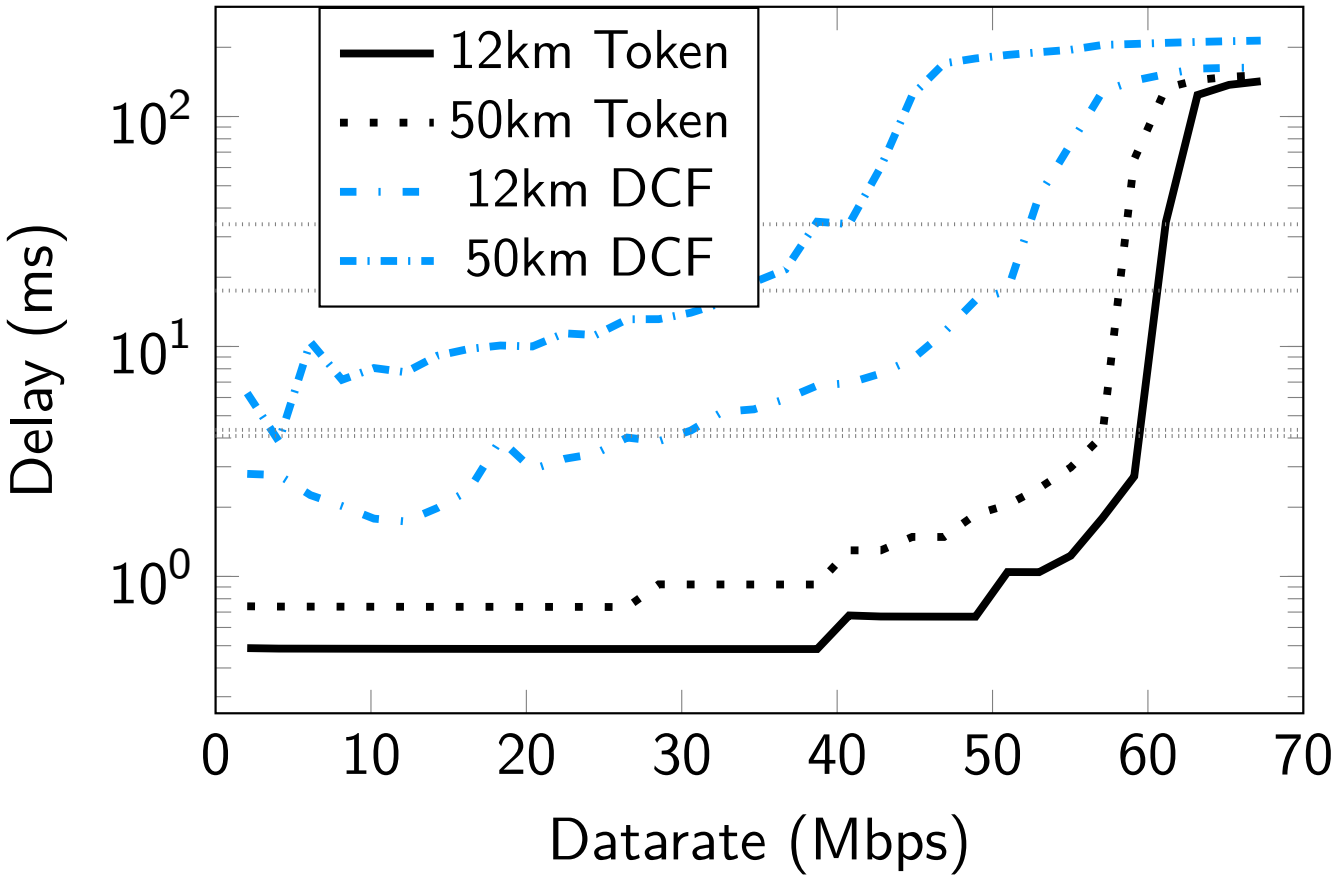
Comparison between mathematical model [5] and ns-3 simulation for an adapted and optimized version of the DCF on long-distance links. Three different values of maximum A-MPDU aggregation: 1023 Byte, 8191 Byte, 65.535 Byte, bounded by 4 ms medium occupancy. MCS7, 20 MHz, Short GI.

Simulation: Performance Gain Compared to the DCF



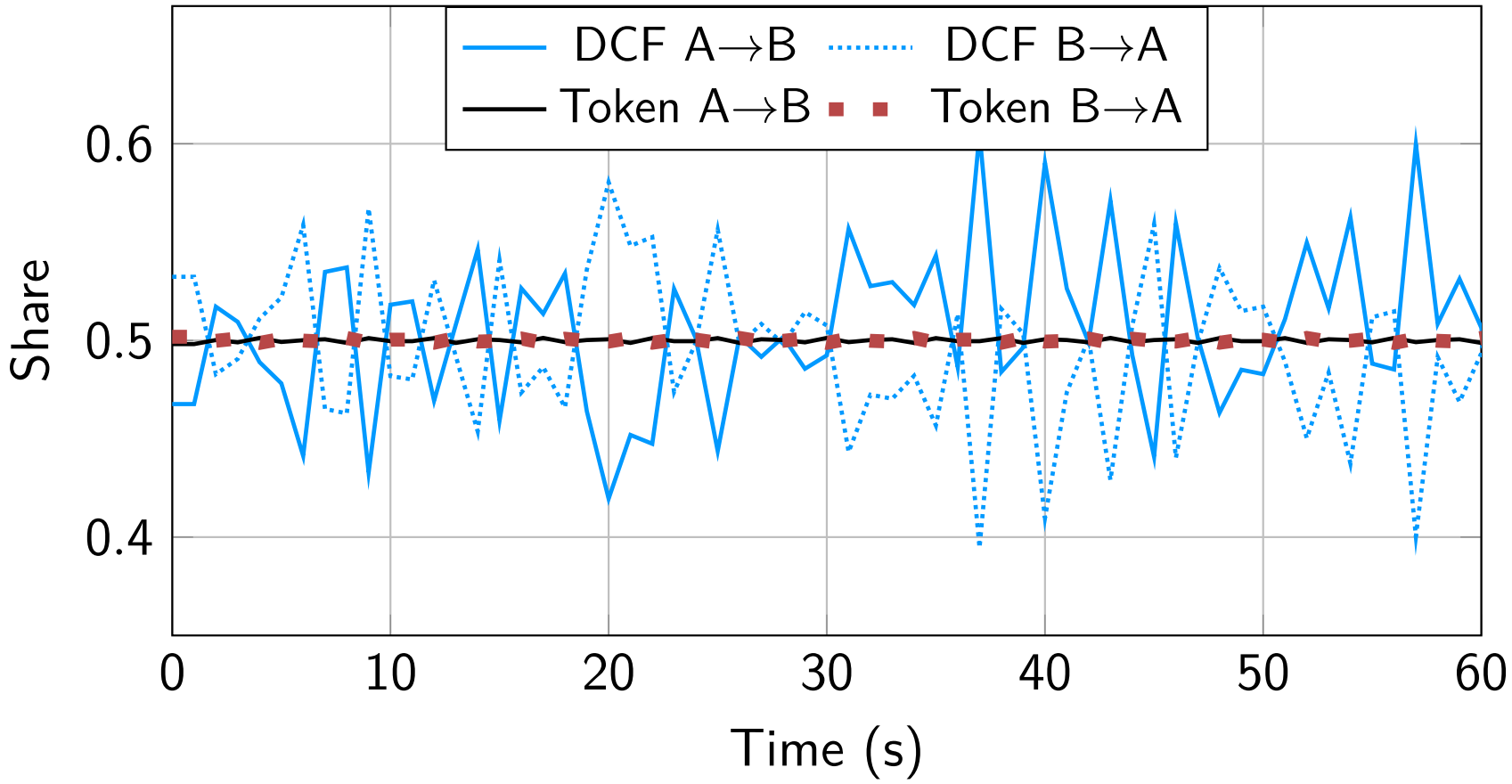
Comparison between ns-3 long-distance DCF simulation and ns-3 WiLDToken simulation. Send limit 4 ms, MCS7, 20 MHz, Short GI.

Simulation: Delay Compared to the DCF



Comparison between DCF ns-3 simulation and WiLDToken. Send limit 4 ms, A-MPDU factor 3, MCS7, 20 MHz, Short GI.

Simulation: Fairness Compared to the DCF



Fairness: Comparison between ns-3 DCF simulation and ns-3 WiLDToken simulation. Send limit 4 ms, MCS7, 20 MHz, Short GI.

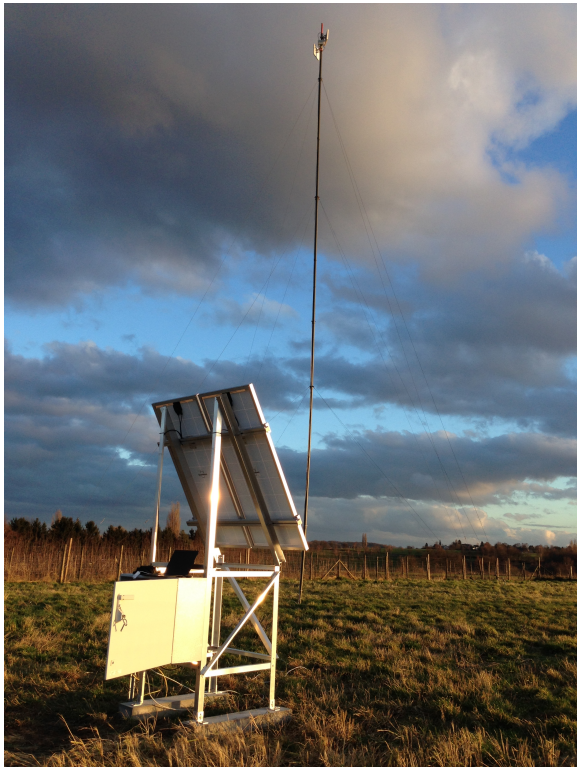
Summary and Future Work

- ✓ A token-based MAC for long-distance links in a MR-MC Wireless Mesh Network (WMN)
- ✓ Initial experiments using ns-3
- ✓ In our scenarios, WiLDToken is superior to the DCF in terms of throughput, delay and fairness

- ? A real-world implementation could lead to additional insights or required adaptations
- ? Traffic class differentiation (already started)
- ? Legal issues and carrier sensing

Thank You!

Are there any questions?



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