
ANALOG VS. NEXT-GENERATION DIGITAL FRONTHAUL: HOW TO MINIMIZE OPTICAL BANDWIDTH UTILIZATION

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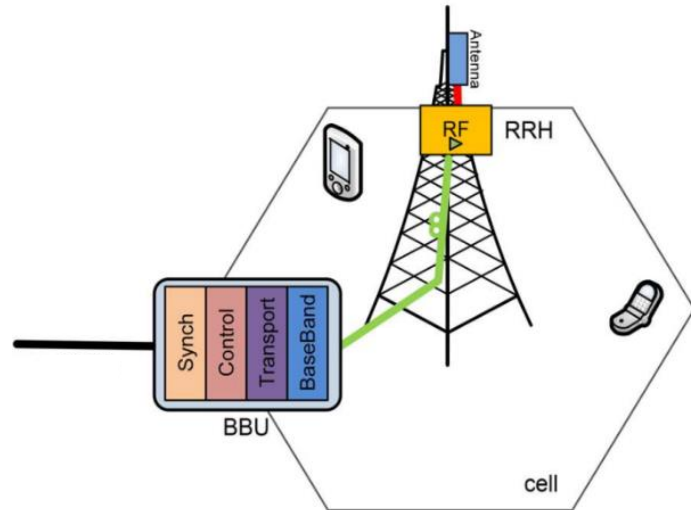


Overview

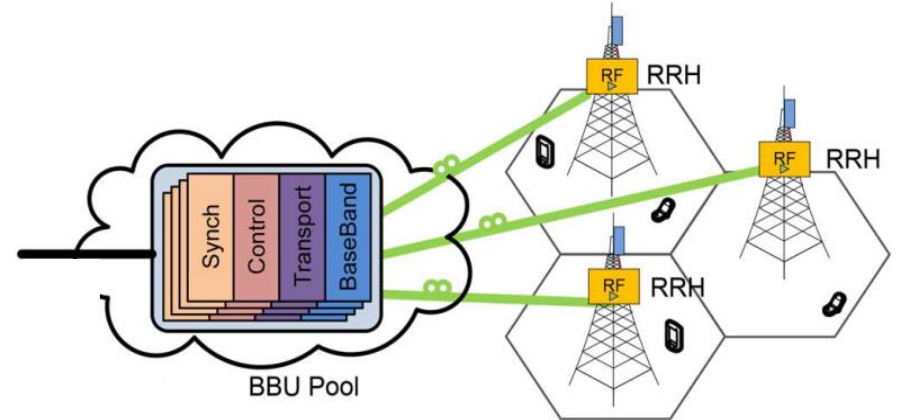
- Introduction
- Fronthaul Concepts
- Simulations
- Experiments
- Conclusions

Introduction

Cloud-Radio Access Network (C-RAN)



Distributed RAN

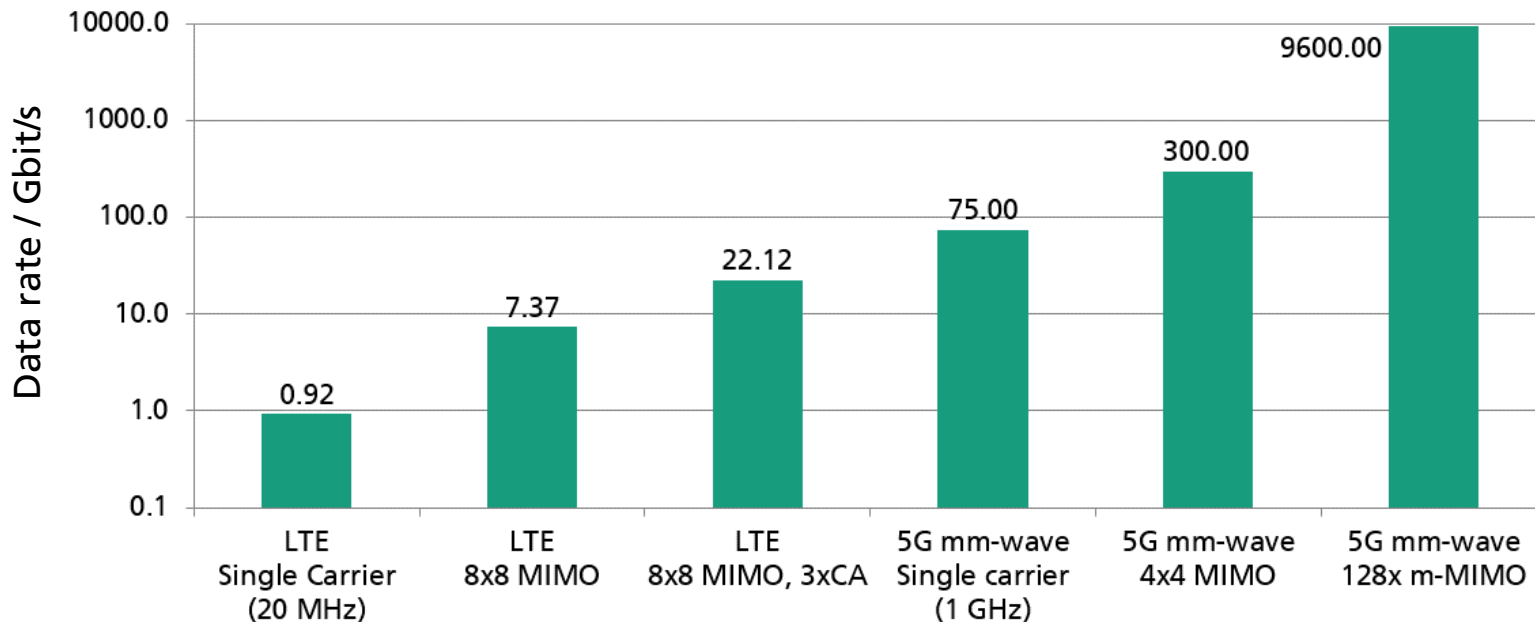


Cloud-RAN (C-RAN)

[1] A. Checko et al. 'Cloud RAN for Mobile Networks—A Technology Overview'. In: *IEEE Communications surveys & tutorials* 17.1 (2015), pp. 405–426.

Introduction

C-RAN fronthaul data rate requirement



→ **New fronthaul solution needed for 5G!**

[4] P. Turnbull et al., "D3.1 iCIRRUS - Verification of Ethernet as transport protocol for fronthaul / midhaul," 2015.

Overview

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Fronthaul Concepts

Approaches for bandwidth reduction

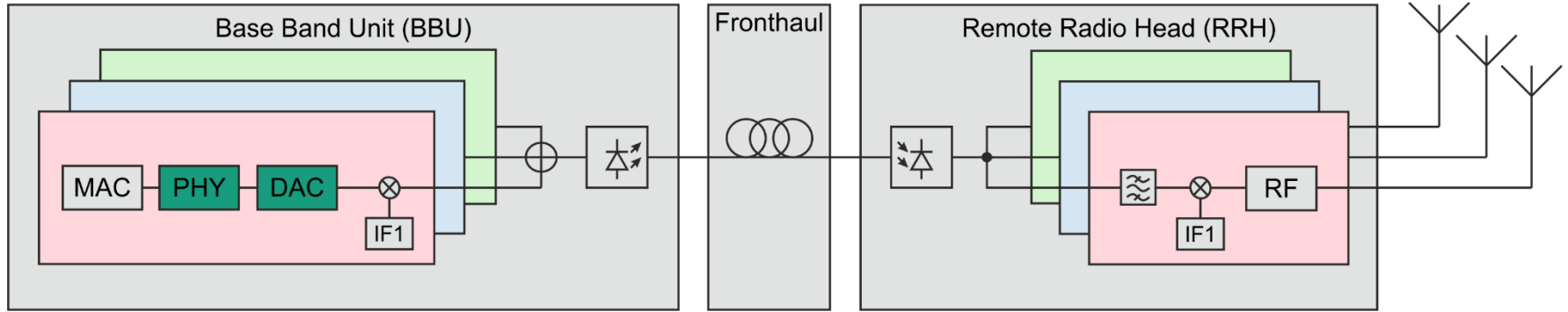
- Analog fronthaul
 - Transport of analog baseband signals over fiber instead of digitized samples
- Next Generation Digital Fronthaul
 - New Functional Split: partial shift of baseband processing functions to RRH
 - Transport of higher-layer data over fronthaul → lower data rate

Aim of this work

Performance comparison between analog and digital fronthaul regarding impact of chromatic dispersion

Fronthaul Concepts

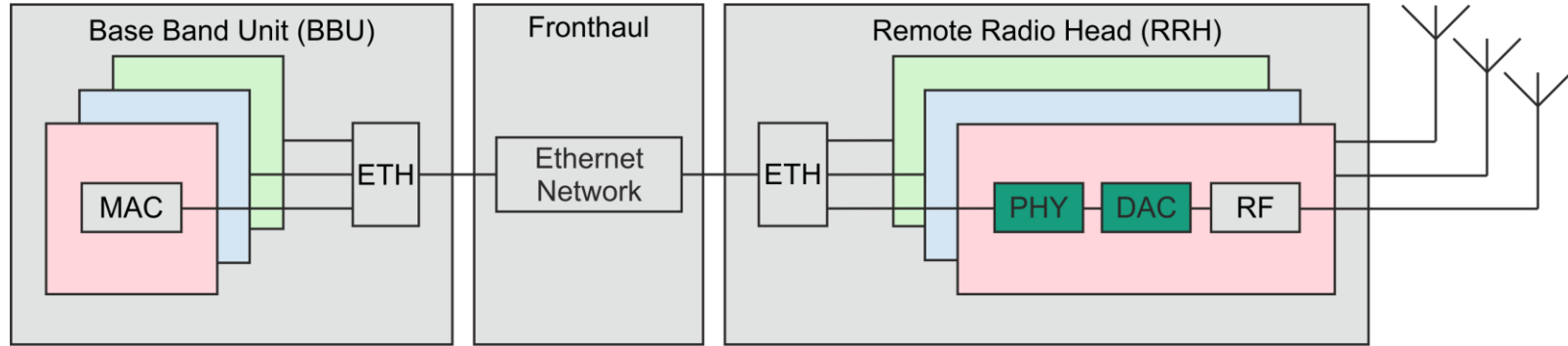
Analog Fronthaul (Downlink)



- Complete baseband processing at BBU, also DAC
- Multiple channels at separate intermediate frequencies (IF), electrical mixing
- Analog electrical signal modulated onto an optical carrier
- Only signal conversion, RF components at RRH

Fronthaul Concepts

Next Generation Digital Fronthaul (Downlink)



- Partial or complete shift of physical layer signal processing (PHY) to RRH
 - Here: split between MAC and PHY – MAC layer (and higher) centralized
- Transport of digital user and control data on the fronthaul (here: Ethernet)
- Data rate decreased by factor 30-50, load dependent

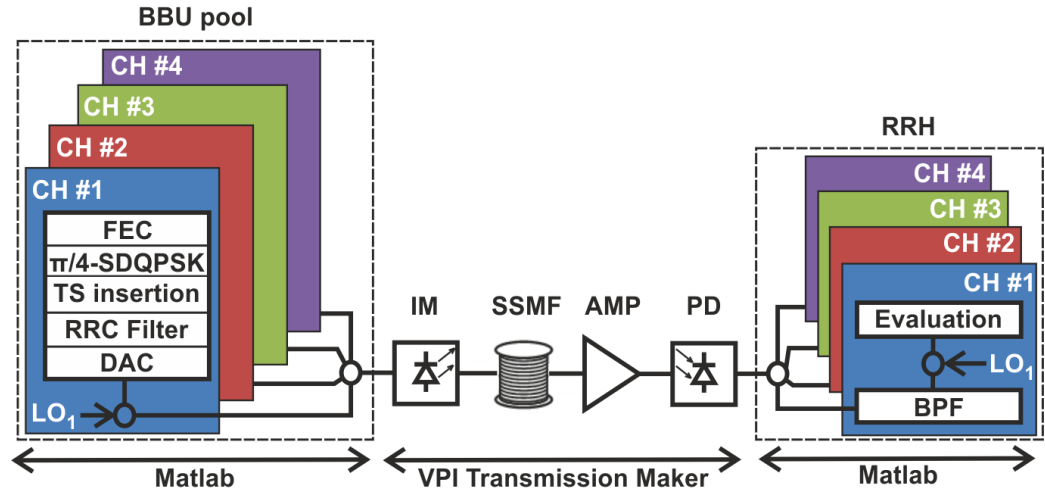
Overview

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- **Simulations**
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Simulations

Setup: Analog Fronthaul

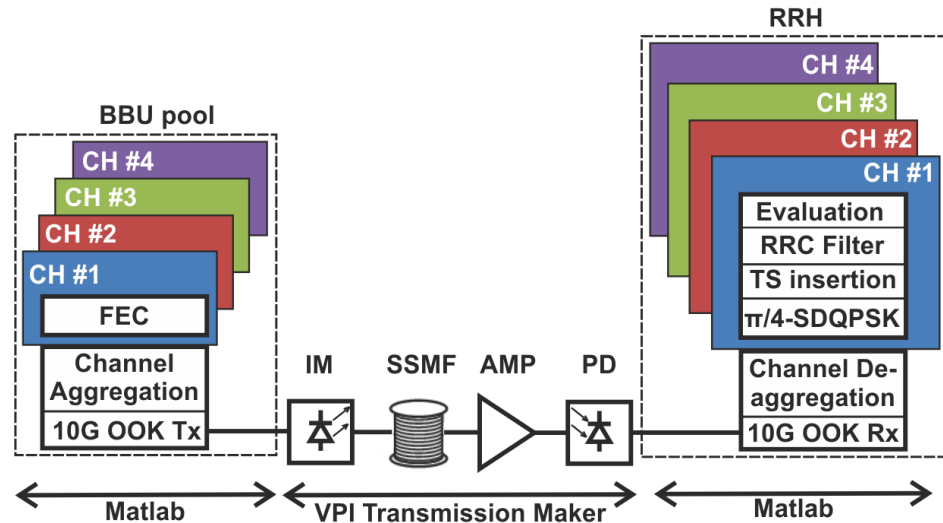
- 4 channels, 2.5 Gbit/s each
- Fronthaul bandwidth:
1.5 GHz/channel
6 GHz overall
- Simulation of different fiber lengths with focus on chromatic dispersion
- Receiver connected back-to-back (no wireless span)



Simulations

Setup: NG Digital Fronthaul

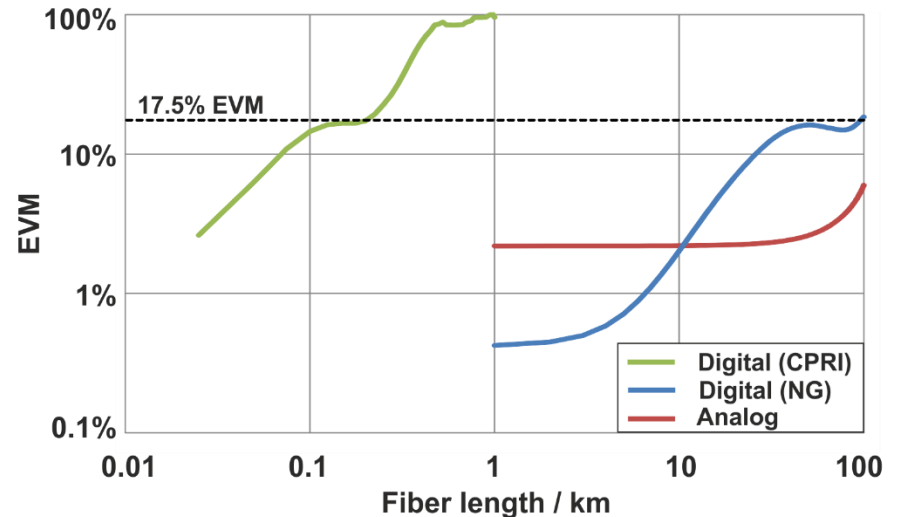
- Fronthaul:
10 Gbit/s On-Off-
Keying (OOK)
- Simulation of different
fiber lengths, comparison
to analog fronthaul
- Receiver connected to RRH
- Optical link identical
to analog fronthaul



Simulation Results: Conventional/NG-Digital/Analog

EVM on a 10 Gbit/s radio signal

- „Conventional“ CPRI solution
 - 200 Gbit/s OOK on FH required (10 bit per I/Q sample)
 - Signal distorted at **<1 km**
- **50 km range:** Performance of both NG Digital and Analog FH good
 - Analog FH more resilient against chromatic dispersion at longer range



Overview

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- Simulations
- **Experiments**
- Conclusions

Experiments

Comparison Analog/Digital Fronthaul

- Fiber length: Limits of both solutions around 50 km
- Generally: **Digital** solution more resilient against **low Rx power**
 - Equal BER at **3-4 dB** below
- At 50 km (limit range): Lower BER for **analog** FH at powers > -8 dBm
 - Reason: noise limitation, less impact of chromatic dispersion (lower signal bandwidth)

Rx Power needed for BER $< 10^{-4}$ (FEC trs.)

Fiber length	Analog	Digital
Back-to-back	-11.5 dBm	-15 dBm
25.5 km	-11 dBm	-14.5 dBm
51 km	-8.5 dBm	-12.5 dBm
76.5 km	Not reached	Not reached

Conclusions

- **Analog and NG-Digital FH: both suitable** for reducing optical fronthaul bandwidth at a range <50 km
- **Next-Generation Digital FH:** better performance at low power levels
 - E.g. low-cost systems without optical amplifier at Rx
- **Analog FH:** performance of wireless system limited by impact on baseband signal
 - Suitable e.g. for indoor systems (room coverage, small cells)
- Deployment to be settled through **practical** and **economic** aspects
 - Mass-production of digital hardware generally more economic
 - Complex access network structure not feasible with analog FH

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WE PUT SCIENCE INTO ACTION.

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